THE DAIRY FARMING HANDBOOK

Compiled by
Dr C.J.C. Muller

Western Cape Government
Agriculture
BETTER TOGETHER.

SA MELKO MILCO

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Dr C.J.C. Muller

Directorate: Animal Sciences
Research and Technology Development Services (RTDS)
Western Cape Department of Agriculture

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SA MELKO MILCO

Tel: +27 21 808 5111
Email: info@elsenburg.com
www.elsenburg.com

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Foreword

Dairy consumption is driven by global population growth and the growth in per capita consumption. A recent analysis by the International Farm Comparison Network (IFCN) shows that global dairy demand should increase by 20 million tons per annum; 40 % of the new demand would be as a result of population growth and 60 % as a result of higher per capita consumption. According to the Organisation for Economic Co-operation and Development/Food and Agriculture Organisation (OECD/FAO) Agricultural Outlook, the global average per capita dairy consumption should increase by about 14% between 2013 and 2023. In response to the rising demand over the past decade and despite a volatile market, dairy production in South Africa has shown an upward trend. In 2014, raw milk production in South Africa reached almost 3 million tons, and in the early part of 2015, milk production reached unprecedented high levels in response to the recovery in the milk to feed price ratios in 2014. In the medium term, milk to feed price ratios are projected to remain favourable under normal weather conditions, inducing an expansion of 28% in milk production over the next decade (Bureau for Food and Agricultural Policy (BFAP) , Agricultural Outlook 2015 – 2024).

The dairy industry in South Africa and in the Western Cape in particular, faces several challenges in the future, such as a volatile economy and the effects of climate change. Climate projections for the region indicate continued warming of 1.5 °C to 3 °C across the entire province by 2050, with some moderation of increases along coastal areas. For these reasons, dairy producers should be climate and production smart to maintain production levels.

The translated and updated Dairy Farming Handbook aims to support dairy farmers with problem-focused information based on scientific research. A wide range of production topics are discussed which can form a foundation for improving the effectiveness of the production processes to ensure financial sustainability of operations. For dairy farming to remain financially viable in spite of the fluctuating farm-gate milk prices and increasing production costs, farmers must increase the efficiency of milk production. This may be done either by increasing production per cow or by decreasing the production cost of milk. The Dairy Farming Handbook therefore focusses on the most important aspects of dairy farming: feeding and nutrition, housing, reproduction management, breeding, and milk production and quality.

We trust that this Handbook, compiled by experts in their particular fields, will be the "roadmap" to sustainable milk production for both commercial and small holder farmers.

Dr Ilse Trautmann
CHIEF DIRECTOR: RESEARCH AND TECHNOLOGY DEVELOPMENT SERVICES

Acknowledgements

The Dairy Farming Handbook includes the original *Melkbeeshandleiding*, which was based on the lecture notes presented annually during a number of two-day short courses on dairy cattle feeding and nutrition, reproduction management and breeding, at Elsenburg and later, also at the Outeniqua Research Farm. The section on Milk production and Quality consists of the original course notes presented to students at the Elsenburg College of Agriculture by **Mr Norman Robertson**, formerly Head of the Dairy Laboratory of the Agricultural Research Council at Elsenburg.

Acknowledgement is also given to a number of former and current colleagues from the Western Cape Department of Agriculture, as well as those who made contributions over time in the form of prepared course notes for hand-outs, presented lectures and practical demonstrations.

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Some chapters have been updated, while new chapters have been added. Some of these chapters, originally published by **Dr Carel Muller** (former Specialist Scientist, Elsenburg Research Farm) in a number of publications (*AgriProbe*, *Afgriland*, *Dairy Mail*, *Elsenburg Joernaal*, *Landbouweekblad* and the *South African Journal of Animal Science*) have been adapted for publication in the Dairy Farming Handbook. Some articles from the Dairy Research Newsletters of the Western Cape Agricultural Research Trust, which were sent to dairy farmers twice a year, have also been included in the Handbook.

New chapters in this edition written by Research Scientists from the Directorate: Research and Technology Development Services (WCDoA) include: **Mrs Marliné Burger** (Animal Sciences) on *Lameness in dairy cows,* **Dr Johan Labuschagne** and **Mr Piet Lombard** (Plant Sciences) on *Establishing forage crops for silage and hay production***, Dr Robin Meeske** (Animal Sciences) on *Ensiling forage crops and surplus pasture*, and **Dr Ansie Scholtz** (Animal Sciences) on *Biosecurity on dairy farms*. **Ms Janke van der Colf** (Plant Sciences) and, **Dr Pieter Swanepoel** and **Dr Philip Botha** (former Researchers, Plant Sciences), from the Outeniqua Research Farm at George updated the chapter on *Establishing and managing cultivated pastures.* **Ms Carinne van Zyl** (former Economist, Agricultural Economics Services) updated the chapter on *Economic factors affecting dairy farming*. **Dr Alfred Kidd** (Stellenbosch Veterinary Clinic) contributed the chapter on *Vaccines and immunization of dairy cattle* for the section on *Health and Biosecurity in dairy herds* and a new chapter on *Milking parlours for modern dairies* contributed by **Mr Rykie Visser** (Agrinet) has been added to the section on *Milk production and Quality*.

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The Dairy Farming Handbook

Foreword I

Acknowledgements II

Contents III

Dairy cattle nutrition and feeding — Section 1

Housing for dairy cattle — Section 2

Reproduction management in dairy herds — Section 3

Dairy cattle breeding — Section 4

Milk production and quality — Section 5

Health and biosecurity — Section 6

Abbreviations and acronyms — Section 7

References — Section 8

SECTION 1

DAIRY CATTLE
NUTRITION and FEEDING

CHAPTER 1

GENERAL INTRODUCTION TO DAIRY FARMING

Introduction

The number of dairy farms in South Africa has, over the past 30 years, decreased, while the number cows in dairy herds has more than doubled. Milking parlours have increased in size and throughput doubled making it easier to milk large numbers of cows on a daily basis. Currently, in rotary parlours with 50 milking clusters, 300 cows per hour can be milked by employing only four to five workers. Together with this, computer programmes are available to collect large numbers of records, such as the milk yield at each milking event, live weight of cows, activity of cows between milking sessions, and the conductivity of milk. All this information can be used to improve the management of dairy cows. However, in spite of all these developments, basic principles in the way cows function and how they are managed, are important aspects of which farmers should always be well aware of.

Components of a dairy herd

Dairy cows are the production units of a dairy herd. Because milk is the main source of income for a dairy farm, herds should consist of mostly lactating cows. Cows have only two production cycles, namely being in milk (lactating) or being dry (non-lactating). At least 82% of all the cows in the herd should be in milk at all times. This proportion increases when cows are longer in milk than the standard 300-day lactation period, while it decreases when cows have long dry periods. When a small proportion of the cows in the herd are in milk, the total milk yield of the herd would be low.

To start a lactation period or milk production cycle, cows must calve down. From this, bull or heifer calves are born. Bull calves are usually culled early in life for veal or beef production, except for breeders raising bull calves to be marketed for natural service or the artificial insemination (AI) industry. Heifers, on the other hand, are reared to eventually replace culled cows from the herd. Cows are culled for a number of reasons, mostly because of mastitis, or not becoming pregnant, or because of low milk yields, injuries, disease, and death. When the cull rate of cows is low, fewer heifers have to be raised to maintain the herd size. The extra heifers born in the herd then creates an additional income source for the dairy farm, as heifers can be sold to other farmers suffering from high cull rates or wanting to expand their herds. The management style in a dairy herd has a major effect on the number of cows that are culled from a dairy farm.

When cows are dry, they should be in the last two months of the reproduction cycle before their next calving down (or due) date. After calving, cows are usually in milk for about 300 days, after which they are dried off to prepare for the next lactation. When it is difficult to get cows to become pregnant, they may be in milk for longer than 300 days. Although cows may be milked for a longer lactation period, they should be dried off at least 60 days, although not less than 50 days, before the next expected calving date.

Heifer growth rates

Other non-producing animals other than dry cows in a dairy herd include heifers in various age groups. Dairy cows start their lives as a heifer calf after which they grow at breed-specific growth rates, i.e. gaining live weight and increasing body size, to calve down for the first time at about two years of age. Heifer calves, at birth, weigh approximately 6 to 7% of the live weight of the mother. As Jersey cows weigh about 380 to 420 kg, their heifer calves would be about 24 to 28 kg at birth. Holstein cows, on the other hand, weigh about

560 to 620 kg which means that their heifer calves would be about 35 to 41 kg at birth. The live weight gain of Jersey and Holstein heifers should be approximately 0.45 - 0.50 and 0.70 - 0.75 kg per day, respectively. The live weight of dairy cows varies to a great extent as it is affected by their age or the lactation number of cows. For this reason, the growth rates of individual heifers would vary considerably. It is therefore important that heifers are weighed on a regular basis, usually monthly, to record their gain in live weight. Heifers reach sexual maturity at about eight to nine months of age, but they are usually only inseminated for the first time at about 12 to 13 months of age when they have reached minimum target live weights. For Jersey heifers this is about 200 to 215 kg, while it is 300 to 325 kg for Holstein heifers.

The lactation curve

After first calving, a heifer becomes a cow and after that, the age of a cow is indicated by the number of times she had calved down, i.e. a first, second, or third lactation (also referred to as parity) cow. Farmers sometimes refer, incorrectly, to a small, not well grown-out first lactation cow, as a first lactation heifer. The daily milk yield of cows follows a distinct pattern throughout the lactation period. After calving, the daily milk yield of cows increases quickly and reaches a peak at about 6 to 8 weeks after calving. After this, the daily milk yield of cows may be maintained at this high level after which it usually slowly declines at about 0.3 to 0.6% per week with advancing stages of lactation, i.e. increasing number of days in milk. The rate at which milk yield drops after peak is an indication of the persistency of milk production. This trait varies among cows, although it is also affected by the feeding programme. The total amount of milk produced during the lactation is therefore a combined effect of peak milk yield and persistency of milk production after peak.

Sire selection

The genetic merit of cows, together with their feeding level and feeding management, affect the peak production and persistency during the lactation period. Low genetic merit cows will, at the same feeding level, always produce less milk than high genetic merit cows. Dairy farmers should keep in mind that the result of the selection of a sire or a group of sires made today will only be observed fully in five to eight years from now. The current dairy herd therefore consists of decisions on sire selection that were made five to 10 years ago. Current low milk yields of some cows could be attributed to low genetic merit bulls that were used in the past. It is therefore important that bulls with above average breeding values for production traits be used in the dairy herd on an ongoing basis.

Dairy cows are ruminants

Dairy cows, being ruminants, have a unique digestive system and can utilise forages, like hays, silages, pastures and straw, as well as concentrated feeds, such as grains (maize, wheat, barley and oats), and protein sources, like fish meal, cottonseed-oil cake meal, soybean meal. Because cows are ruminants, they can utilise feed not generally used by people. The ruminant stomach consists of four compartments, i.e. the reticulum, rumen, omasum and abomasum. These four compartments function as a single unit. The rumen makes up about 80% of the ruminant stomach and has a content of about 160 litres. It is in fact a large fermentation vat containing vast amounts of anaerobic (meaning living in the absence of oxygen) bacteria, protozoa, and other organisms that live in symbiosis with the dairy cow. These organisms in the rumen are responsible for the digestion of feeds in the rumen. It is only in the abomasum that enzymes are produced to digest feeds and semi-digested material that flows from the reticulo-rumen.

Cows must ruminate to maintain a healthy rumen. When cows eat, they chew feed into smaller pieces before swallowing it. Long coarse feed particles create a mat in the top part of the rumen with smaller pieces lower down. Because of regular, rhythmic movements of the rumen, the longer feed articles are pushed into the reticulum from where it is regurgitated back into the mouth where this feed is chewed for a second time. Including sufficient amounts of roughage in the total diet, should ensure that cows ruminate for at least eight to nine hours per day. Saliva is produced during this rumination process, also known as chewing the cud, and mixed with the feed. Saliva contains sodium bicarbonate ($NaHCO_3$), which is a natural buffer neutralising the acidity in the rumen fluid. The rumen mat disappears when the diet contains too little roughage or when the roughage component is too finely ground. This slows down the rumination process, resulting in cows producing less natural buffer causing an increase in the acidity levels of the rumen fluid. This is observed as a decrease in the pH-level of rumen fluid. This may result in a metabolic condition known as acidosis. At pH-levels below 5.5, cellulytic digesting micro-organisms are killed, resulting in less acetic acid being produced. This results in cows producing milk containing less butterfat. Moreover, when the acidity in the rumen reaches very high levels, the movements of the rumen may stop causing rumenstasis. Continuing high acidity levels may even affect the rumen papillae causing abscesses on the rumen wall. To maintain a healthy rumen, the roughage component of the diet should not be less than 35%. When high levels of concentrates are fed during the early part of the lactation, a buffer should be included in the diet to reduce the acidity in the rumen. Alternatively, high levels of concentrates should be fed in smaller amounts at more regular intervals, i.e. more than twice a day. The amount of concentrate cows receive is dependent on the quality of the roughage being fed. Higher quality roughages with regards to crude protein and energy content require less concentrates to sustain high milk yield levels.

Feeding of cows

Cows consume a large amount of feed on a daily basis while also drinking large amounts of water, i.e. about 80 to 120 litres, depending on the weather conditions and feed consumed. Cows drink more water when it is hot, while their water intake is less when high moisture feeds are fed.

All feeds contain moisture and dry matter (DM). Even dry feeds, like hay or straw, contain about eight to 10% moisture. Silages and pastures contain about 65% and 85% moisture, respectively. The DM content of feeds contains the crude protein, energy, minerals, and vitamins that cows will utilise to produce milk. The daily feed intake of Jersey cows is about 14 to 16 kg DM, while Holstein cows consume about 24 to 28 kg DM per day. Higher producing cows usually have higher feed intakes. This increase in feed intake is, however, not linear and is actually determined by rumen capacity.

Feed troughs for dairy cows must be large enough to hold the bulky feed that cows are fed on a daily basis. The feed trough width should not exceed 850 mm, unless cows have to feed from both sides. In that case the feed trough should be at least 1.2 m wide. This will ensure sufficient head space for cows to feed from both sides. It is easier for cows to eat from a feed trough when the feed trough floor is about 10 cm higher than the surface they are standing on. A neck rail should be provided at the front of the feed trough to prevent cows from walking through the feed trough and to reduce the head movement of cows while eating. This is especially required when cows have to consume coarse, unmilled low grade roughages like straw. The neck rail of the feed trough should be about 650 - 700 mm above the throat rail. A lower neck rail reduces the head movement of cows, although it may also cause injuries to cows, especially when they have to reach far forward for feed. The forward horizontal pressure on the neck rail is reduced when it is attached about 15 to 20 cm forward above the throat rail. The upright poles that the throat and neck rail are attached to should be spaced in such a way that sufficient feeding space is available for cows. Holstein and Jersey cows require at least 700 - 750 and 550 - 650 mm per cow, respectively. The uprights must therefore be put up with these linear requirements in mind.

Most types of roughages on their own do not contain sufficient feedstuffs to maintain high milk yield levels or growth. For this reason, concentrated feeds, such as grains and protein sources like cottonseed or soy bean meal, should be fed to cows as well. Concentrates could be mixed and fed separately to cows or they can be mixed together with the available roughage in a total mixed ration (TMR). The amount of concentrates that are fed to cows depends on the daily milk yield level and the quality of the available roughage. On good quality grass-clover pasture 4 - 6 kg per cow per day of a 10 - 12% crude protein (CP) content concentrate would be sufficient for Jersey cows, while for Holstein cows 8 - 12 kg per day of a similar concentrate would be required. Cows being fed roughages, like oat hay or wheat straw, would require a considerably higher level and quality of concentrate than for cows on grass pastures. For this reason, diets containing poor quality roughages are generally more expensive requiring higher milk yields to break-even. Cows are usually fed twice a day, preferable after milking. Total mixed rations for dairy cows should be correctly formulated and mixed to prevent digestive upsets.

The production of milk

Cows produce milk on an ongoing basis until the udder is full. They are usually milked twice a day, i.e. early in the morning and late afternoon. When cows are milked more often during the day, milk production is stimulated as the milk is removed and space is available for more milk to be produced. Low producing cows can be milked once a day, especially when the available feed is limited or of a poor quality. The initiation of the milk let-down process is caused by the hormone oxytocin. The release of oxytocin is prevented by the hormone adrenaline that is produced when cows are under stress or given a fright. For this reason, the milking process should always be conducted in a stress-free environment, as cows can lose their milk by being frightened suddenly.

Before milking, the teats of cows should be washed with running water and afterwards dried with a paper towel. The first milk from the teat is milked by hand onto a sieve to check for mastitis after which the milking cluster is attached to the teats. Cows showing mastitis should be treated immediately after milking. These cows should be identified and when the problem occurs regularly, the reason for this should be identified. Mastitis has a major financial implication as contaminated milk has to be discarded after treatment. Sub-clinical mastitis also has a large negative impact on the milk yield of cows, while reducing the quality of milk in the bulk tank.

In closing

The feeding of cows can be simple, although for profitable milk production, diets should be correctly formulated, mixed and fed. In this manual, some basic information on principles and practices of dairy farming is provided to improve the knowledge and skills of existing and new dairy farmers. The same principles apply whether 30 or 3000 cows are being milked on a dairy farm. Dairy farmers should have some basic knowledge of the way the rumen of cows function. They must be aware of the impact of the environment, genetic merit, and management principles on the production performance of dairy cows. It is important that dairy farmers continually seek new information to apply to their existing operations. World-wide research is ongoing towards improving feeding programmes, estimating genetic merit of dairy cows and bulls, while facilities are being improved to reduce the every-day labour inputs in order to simultaneously improve the welfare of animals and workers.

CHAPTER 2

RUMINANT DIGESTION – HOW THE RUMEN WORKS

Introduction

The modern dairy cow is without a doubt one of nature's most remarkable success stories. Cows have the ability to convert roughages to food suitable for human consumption. They have been doing this for many ages and could truly be called the mother of mankind. Present day dairy cows can produce, on average, 7200 kg of milk over a 10-month lactation period. This amount of milk converts to 225 kg of high quality protein, 254 kg of fat, and about 50 kg of minerals. What is further remarkable is that they can repeat this production process after a 2-month rest period following a parturition process during which a heifer or bull calf is born. This amount of protein is sufficient for the protein requirement of a mature man for 10 years, while providing enough energy for 5 years, and calcium for 30 years. For this production system, cows have a digestive system that can convert feeds not generally consumed by humans. The better the quality of feed, the more efficient cows become. To feed cows correctly, a proper understanding of the function of the digestive system is required.

Cows are ruminants

Cows are ruminants which mean that their digestive systems differ from that of humans as their stomach consists of four parts or compartments operating as a unit. The four parts consist of the rumen, reticulum, omasum and abomasum (Figure 2.1).

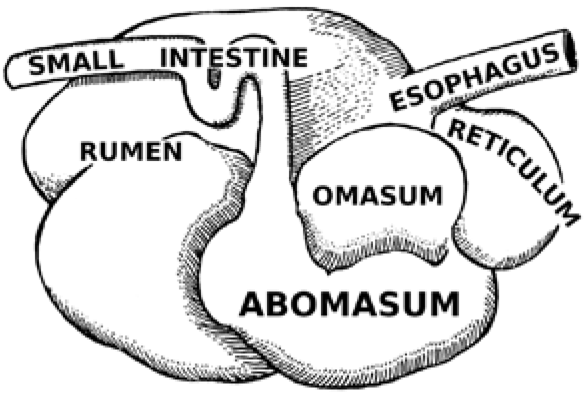


Figure 2.1 A schematic description of the rumen of a dairy cow (De Ondarza, 2000)

1. Reticulum

The reticulum makes up about 5% of the ruminant's stomach. It is a tube-like compartment with the inner wall having a honeycomb appearance. It works in tandem with the rumen and has two functions:

- Contractions of the reticulum wall initiate regurgitating coarse feeds back into the mouth for rumination or chewing the cud.
- It acts as a safety net for catching foreign objects occurring in feeds.

2. Rumen

In mature cows, the rumen makes up about 80% of the total volume of the ruminant stomach which is approximately 160 litres. The rumen is basically a large fermentation vat and contains millions of micro-organisms, like bacteria, protozoa and some fungi. Organisms live in symbiosis with the ruminant and are responsible for the digestion and fermentation processes occurring in the rumen. There is no oxygen in the rumen; therefore, organisms live in an anaerobic environment. Rumen bacteria make up the largest number, i.e. numbering about 2 - 4 x 10^9 per mℓ of rumen fluid with protozoa numbering 1 x 10^6 per mℓ of rumen fluid. Bacteria are also more complex than protozoa. The most important rumen bacteria are those that secrete the cellulose fermenting enzyme, cellulase, for the digestion of cellulose occurring in fibrous material, such as forages. Other organisms are responsible for starch and sugar fermentation and lactic acid fermentation. Both cellulytic bacteria and protozoa are sensitive to changes in the acidity levels in the rumen. At high acidity levels, pH levels below 5.5, large numbers of these cellulytic bacteria and protozoa die, reducing the digesting of forages. This usually happens when cows consume high levels of concentrate, while also consuming finely ground forages. This causes cows to not regurgitate coarse material in the rumen for rumination. By ruminating, cows produce large amounts of saliva to buffer the acidity in the rumen.

In the rumen, micro-organisms have three important tasks, i.e.

a. Organic matter in feeds is broken down to relatively simple chemical compounds, such as ammonia and volatile fatty acids. These volatile fatty acids provide about 50 - 70% of the daily energy requirements of cows. Acetic, propionic, and butyric fatty acids make up about 90% of all the volatile fatty acids in the rumen. Each of these fatty acids is produced by a specific type of rumen bacteria functioning at a specific acidity or pH-level. The fermentation of cellulose, which makes up the largest portion of the fibre fraction of forages, occurs at a pH level of 6.5 to 6.8. This produces acetic acid as an end product which is a precursor for fat in milk. Bacteria that break down starch forming propionic acid are active in a more acidic environment at a pH level of 6.2 - 6.5.

b. Proteolytic bacteria and some of the protozoa break down part of the protein in feeds to amino acids and ammonia. These products are then used by the rumen micro-organisms to produce microbial protein. When these rumen micro-organisms die, they are digested and broken down in the lower digestive tract of the ruminant. This is then used by the ruminant as a protein source.

c. The micro-organisms in the rumen are also capable of synthesizing water soluble B-group vitamins. This makes supplementing these vitamins unnecessary.

3. Omasum

The omasum makes up about 8% of the total ruminant stomach. It consists of a large number of folds, like the leaves of a book. Water is absorbed through these folds while the folds press food into finer particles.

4. Abomasum

The abomasum makes up about 7% of the ruminant stomach. It is a true, glandular stomach, which produces digestive juices and acid acting similar to that of the stomach of a monogastric animal. These juices contain a number of enzymes, like pepsin and rennin, which are used in protein digestion. The abomasum is adapted to digest large amounts of rumen bacteria. For this, the abomasum secretes the enzyme, lysozyme, which efficiently breaks down bacterial cell walls. The acidity level in the abomasum is high and reaches a pH of about 2 - 2.5. This kills all rumen micro-organisms. Little or no digestion of fat, cellulose or starch takes place in the abomasum. Feeds are in the reticulo-rumen for about 60 hours, 8 hours in the omasum, and 3 hours in the abomasum. From here feed moves down into the ileum where it is further broken down enzymatically under the influence of the spleen and liver into smaller particles that can be absorbed into the bloodstream.

Rumen health

The efficiency of rumen fermentation is dependent on the presence and maintenance of a floating mat of coarse feeds (Figure 2.2). This coarse rumen mat has an important function, as it traps the fine feed particles, while also providing shelter for the vast number of micro-organisms in the rumen. When cows eat, feed is chewed into smaller portions while being mixed with saliva. This mixture, or feed bolus, is swallowed with the longer portions of the feed getting trapped in the upper layer of the rumen mat, while the smaller parts sink down into the lower part of the rumen fluid. The rumen contracts rhythmically about 2 - 3 times per minute. The long particles in the feed moves to the back of the rumen and down into the reticulum. The reticulum initiates the regurgitating action, bringing coarse feeds back into the mouth to be chewed again.

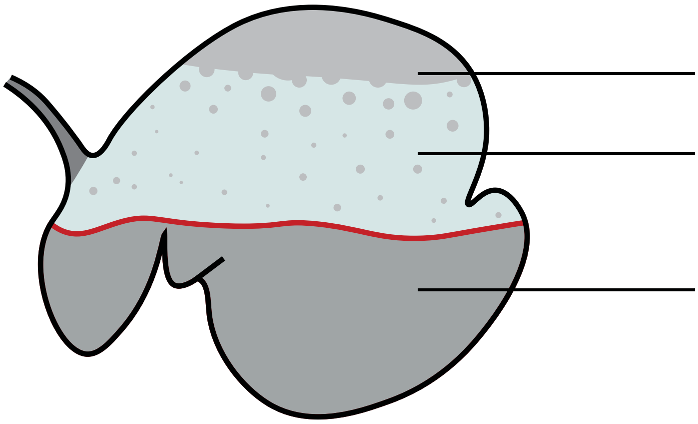


Figure 2.2. The feed distribution of material in the rumen

Normally, cows ruminate for about 8 - 9 hours per day. Saliva is secreted in the mouth during this chewing process and mixed with the feed. Saliva contains sodium bicarbonate ($NaHCO_3$) which is a natural buffer. The acidity level of the rumen fluid is neutralised by the $NaHCO_3$ maintaining the pH at about 6.5. When the diet contains too little crude fibre, like when concentrate levels are high or the roughage is too finely ground (forage particles less than 25 mm in length), the following can happen in the rumen:

- The rumen mat disintegrates and loses its ability to protect the rumen micro-organisms and to catch the fine feed particles. This results in feed particles moving quicker through the rumen, reducing the digestion of feeds.
- The rumination reflex is not stimulated, resulting in not regurgitating feeds to be chewed again and producing less saliva to act as a buffer for the rumen fluid.
- The acidity level of the rumen increases, resulting in a reduction of the pH level and acidosis developing. At a pH of below 5.5, micro-organisms digesting cellulose are killed, resulting in less acetic acid being produced. This will reduce the fat content in milk.
- At a high acidity level, rumen contractions are suppressed and may even stop completely.
- Prolonged high acidity levels in the rumen may damage the rumen wall, especially the rumen papillae, resulting in ulcers in the liver. This is because bacteria normally found in the rumen end up in the bloodstream and affect the liver.

In closing

To keep the rumen of a dairy cow healthy to ensure that it functions normally, the daily diet should include at least 40% roughage. When high levels of concentrates are fed, for example in early lactation, an artificial buffer should be included in the concentrate component of the diet. High levels of concentrate could also be distributed further and fed more than twice a day.

CHAPTER 3

THE DIGESTION OF FEEDS IN DAIRY COWS

Introduction

Digestion of feeds is the starting point of feed utilisation. It involves the breaking down of organic components in feeds to simpler compounds before they can pass through the mucous membranes of the digestive tract into the blood stream and lymph. The breaking-down process is termed 'digestion', while the passage of the digested nutrients through the mucous membranes is called 'absorption'. In dairy cows, like in all ruminants, digestion occurs mechanically, chemically, and microbially. The mechanical process involves the masticating (chewing) and ruminating of feeds, further aided by the muscular contractions of the rumen and alimentary tract. The chemical processes take place through enzymes secreted by cows in the digestive juices, specifically in the abomasum. Microbial digestion is also enzymatic, although this is brought about by the action of the large number of bacteria and protozoa living in the highly specialised environment of the rumen. Rumen bacteria live under anaerobic conditions in symbiosis with the host animal.

Protein digestion

The crude protein (CP) content of feeds is estimated from the total nitrogen (N) content of feeds. Nitrogen consists of true protein, free amino acids, amides, amines, nitrates and other ammonia compounds. All feeds therefore contain some true protein and other protein compounds generally known as non-protein nitrogen (NPN). This is also included in the estimation of the CP content of feeds.

Initially, the protein quality of feeds for dairy cows did not receive much attention, mainly because of its breakdown by rumen micro-organisms to simpler compounds such as ammonia (NH_3), methane (CH_4), volatile fatty acids and carbon dioxide (CO_2). These compounds are used by the rumen bacteria to produce their own protein which is later further digested in the lower digestive tract into amino acids. Today it is recognised that the true protein requirements of high producing dairy cows is much higher than the amount of microbial protein produced by the rumen bacteria. It was also found that all protein sources are not degraded or broken down similarly in the rumen. A portion of the protein source escapes microbial fermentation and flows through the rumen into the abomasum and small intestine where it is digested enzymatically into amino acids. There are two types of protein in feeds, namely:

- Rumen-degradable protein (RDP): This is protein that is degraded in the rumen to simple compounds, like ammonia (NH_3), which is then later re-used for the synthesis of microbial protein, and

- Non-degradable protein (NDP) or bypass protein: This is protein that withstands microbial degradation in the rumen which is then digested enzymatically in the lower digestive tract for use by the dairy cow.

The degradability of protein feeds is demonstrated schematically in Figure 3.1. The degradability of most protein feeds in the rumen varies between about 30 and 100%. For instance, the degradability of the protein in fishmeal is only 30%. The rest of the protein in fishmeal escapes degradation in the rumen and is digested in the abomasum and lower intestine. Fishmeal is for this reason regarded as a good source of bypass protein. On the other hand, the degradability of the protein in groundnut oil cake meal is about 80%; therefore making it a poor source of bypass protein. A non-protein nitrogen source, like urea, is degraded fully in the rumen. Rumen microbes use the degraded protein for the synthesis of microbial protein. The utilisation of this is dependent on the availability of easily available energy in the rumen.

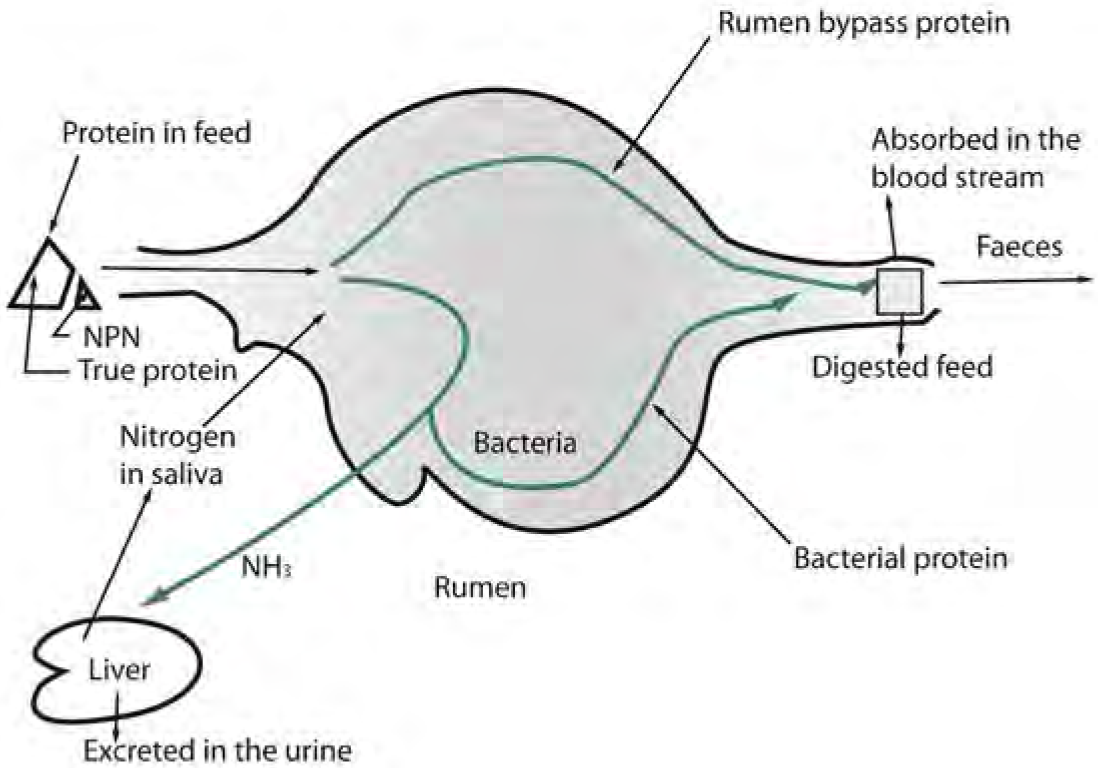


Figure 3.1. A schematic demonstration of protein digestion in the rumen of a dairy cow (Satter & Roffler, 1975)

When feeding feeds containing high levels of RDP, the capacity of the rumen micro-organisms to convert ammonia to microbial protein may be exceeded. This causes a buildup of excess NH_3 in the rumen. This has little direct feeding value and is absorbed from the rumen into the bloodstream and carried to the liver where it is converted to urea. Some urea is returned to the rumen via saliva, while the greater part is excreted in the urine. For this process, energy is required that would otherwise have been used for the production of milk. Ammonia poisoning may occur when the capacity of the liver to convert NH_3 to ammonia is exceeded. Reduced fertility in dairy cows is sometimes attributed to this. The expected milk yield of cows is 8 litres per cow per day when using NPN as the only source of CP. For higher milk yields, a sufficient amount of bypass protein is required in the diet. The CP content in the total diet should contain about 60 - 65% RDP and 35 - 40% of bypass protein.

Digestion of carbohydrates in the rumen

Dairy cows require energy for all their life processes, like the biochemical reaction in cells, for moving around, maintenance requirements, the digestion of feeds, for growth, and the production of milk, fat and protein. The most important function of feeds is therefore to provide energy to cows. For ruminants, the main sources of energy are in roughages, grains, and various grain products. Carbohydrate sources in plants usually consist of two main sources, i.e.

- cell walls (plant fibre), and
- the contents of cells.

Carbohydrates in plants can be described as follows:

Plant carbohydrates

- **Cell contents**
  - **Sugars**
  - **Starch**
- **Cell walls**
  - **Pectin**
  - **Hemi-cellulose**
  - **Cellulose**
  - **Lignin**

Plant cell contents include all the highly fermentable sugars and starches, while plant cell walls contain fibrous carbohydrates, hemi-cellulose, cellulose, and indigestible lignin. The amount of lignin in the cell walls determines to a great extent the efficiency of fibre digestion for the production of energy. The source of plant carbohydrates and the effect of the type of fibre on the digestibility of feeds resulted in the following concepts:

Neutral detergent fibre (NDF): This refers to the cell wall contents of feeds and is an indication of the bulkiness of the feed affecting feed intake.

Acid detergent fibre (ADF): This refers to the digestibility of the fibre in the cell walls of plants and includes the less fermentable fibre components.

The different components can be summed up as follows:

- Acid detergent fibre (ADF) = Cellulose + Lignin
- Neutral detergent fibre (NDF) = Hemi-cellulose + Cellulose + Lignin
- Non-fibre carbohydrates (NFC) = Sugar + Starch + Pectin

General guidelines for total mixed rations for dairy cows include the following:

NDF: 30 - 36% of DM
ADF: 21% of DM
NFC: 30 - 35% of DM

Diets high in non-fibre carbohydrates (NFC) are digested in the rumen to propionic acid. High levels of this stimulate the production and the secretion of insulin stimulating body fat deposition instead of the production of milk. Therefore, diets containing high levels of sugar, starch, and pectin's will result in cows gaining body condition, while not necessarily producing more milk. On the other hand, diets containing high levels of digestible fibre (NDF) produce proportionally more acetic acid in the rumen that stimulates the secretion of growth hormones. In this case, milk production is stimulated at the expense of body condition and live weight.

At higher milk yield levels, it becomes increasingly more difficult for dairy cows to meet their energy requirements. This can be overcome by feeding feeds containing high levels of starch, like grains replacing the roughage or fibre component of the diet. This could, however, create problems for high producing dairy cows, like a low fat percentage in the milk, acidosis, rumen stasis, low feed intakes, and ketosis. It is therefore important to maintain specific concentrate to roughage ratios. A ratio of 65% concentrate to 35% roughage should be regarded as an upper limit.

Including animal fats and some plant oils contained in oil seeds, increase the energy content without reducing the roughage component of diets. This is because the energy content of fats, on the same unit basis, contains 2.25 times more energy than the starch in grains. Including fats in diets has the following advantages:

- iso-energetic diets contain fewer starchy ingredients,
- a relatively high fibre intake can be maintained while the grain content is reduced, and
- the efficiency of energy consumption in dairy cows is increased. This is because fat utilisation is more efficient than utilising fat stored in the body or provided by carbohydrates.

Fats should, however, not be included in the diet at very high levels as this may result in large amounts of free fatty acids in the rumen, which may be toxic for rumen micro-organisms. This can reduce the fermentation in the rumen, specifically affecting fibre digestion because a thin layer of fat may cover the roughage in the rumen. The inclusion level of fats should therefore not exceed 7 to 9% of the diet. Fat in the diet should consist of 3% rumen degradable fat, 3% rumen undegradable (or inert) fat, and 3% fat from other feeds.

In closing

Digestion of feeds is the starting point of feed utilisation. It involves the breaking down of organic components in feeds to simpler compounds before they can pass through the mucous membranes of the digestive tract into the blood stream and lymph. In dairy cows, like in all ruminants, digestion occurs mechanically (chewing), chemically (through enzymes), and microbially (by microbes in the rumen). The degradability of most protein feeds in the rumen varies between about 30% (fish meal) and 100% (urea). Carbohydrates in plants consist of cell walls (plant fibre) and cell contents (sugar and starch). Fat is included in diets to increase the energy content of diets, while maintaining roughage levels. This creates a healthier rumen environment.

CHAPTER 4

ECONOMIC FACTORS AFFECTING DAIRY FARMING

Introduction

Dairy farm management decisions should focus on the profitability of the entire dairy farm. In the long term, the management of a dairy herd functions within specific limitations, such as the farmer's or manager's management skills and abilities, environmental factors (climate, water and soil), market factors (price of inputs and the product price), and the genetic merit of the cows. The aim of dairy farming is to produce the best possible quality and highest quantity of milk at the lowest possible cost. Understanding feeding principles and the feeding management of lactating and dry cows, young calves and replacement heifers, has a major and direct effect on the profitability of a dairy farm. Furthermore, an in-depth knowledge of general herd management, pasture management, animal health, record-keeping, and financial management is also required. Planning, organising, delegating, monitoring, and evaluation skills will further contribute to the success of a dairy farm.

The distribution of the total production cost of milk

The distribution of the most important cost items as a percentage of the total production cost of milk is shown in Figure 4.1. Feed cost of all the different classes of animals making up a dairy herd has always been the largest contributor of the production cost of milk. This usually contributes between 60% and 75% of the total production cost of a dairy herd, mainly depending on the production system being used, i.e. a pasture-based system or a total mixed ration system. It is expected that, in future, the cost of labour and energy will increase, although, because of the continuing increase in total feed costs, only small changes are expected in the distribution of the various cost items. It is therefore important that dairy farmers are well-informed about factors affecting the feed cost of a dairy, as well as the general trends in the different items making up the production cost of a dairy.

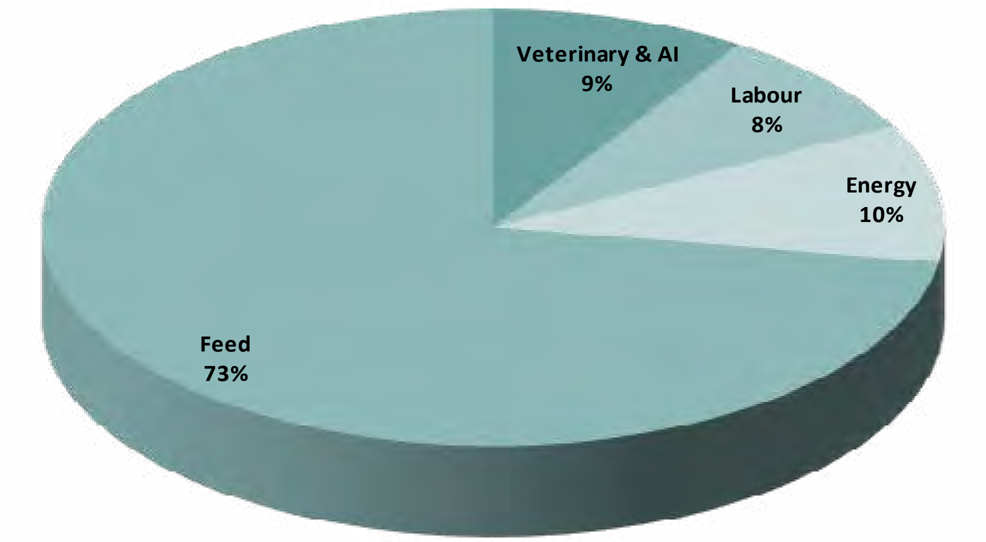


Figure 4.1. The distribution of the total cost of the production of milk

Factors driving dairy farm profitability

It is important to know which factors and how much each of these factors affects the profitability of the dairy farm. This identifies the level of attention regarding time and energy each factor should receive. This is especially important in a changing environment that is focused on achieving the maximum effect on profitability. In Figure 4.2 the major factors categorised as an input or an output of a dairy farm affecting dairy farm profitability are indicated.

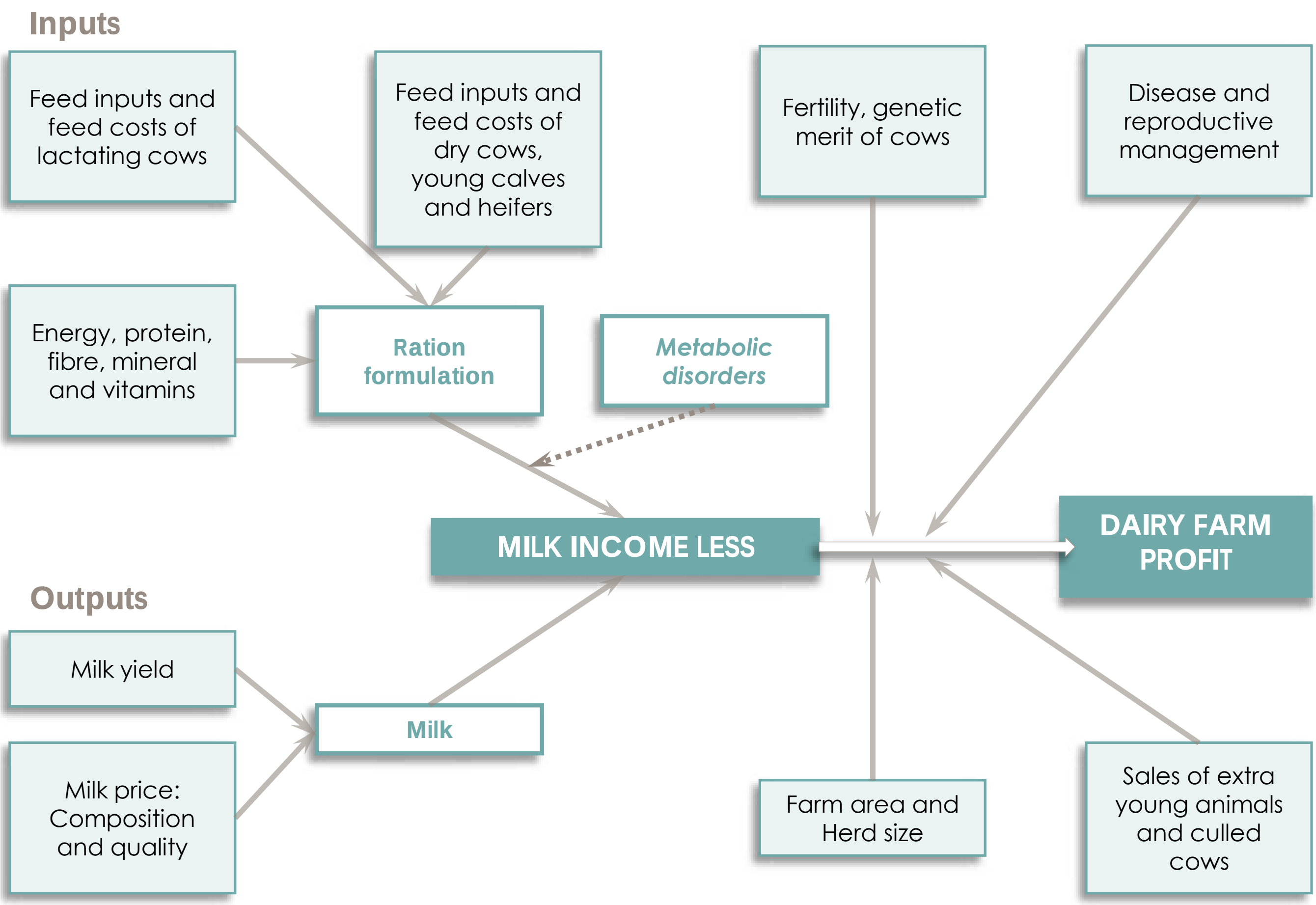


Figure 4.2. Factors affecting the profitability of a dairy farm

Feeding management

Because the feeding cost of a dairy is the largest contributor to the total production cost of milk, the feeding programme has a large effect on dairy farm profitability. It is therefore important to understand the difference between feeding programmes and the cost implications of each of these programmes. Formulating similar diets for lactating cows using oats hay or rye-grass pasture as roughage source would show a 40% difference in total diet cost. Naturally, this would have considerable effect on the break-even point of milk production. The total feed cost refers to all the costs involved regarding the feeding of productive cows and non-productive animals, like the dry cows, young calves, and heifers. Some of the possible feeds used on a dairy farm are indicated in Figure 4.3.

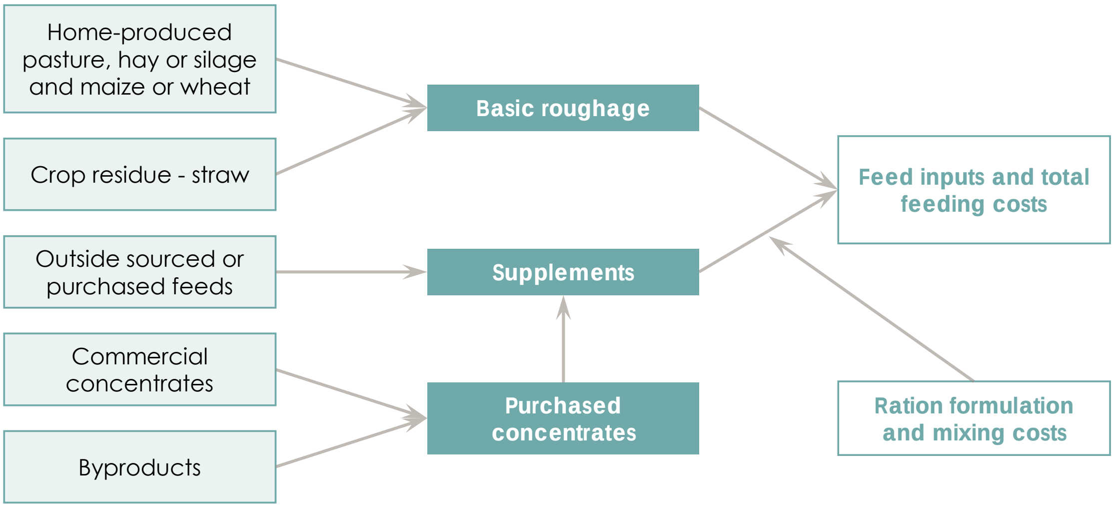


Figure 4.3. Components of feed inputs on a dairy farm

The cost of the diet must be based on a profitable diet formulation, i.e. a diet that satisfies the nutrient requirements of cows in order to achieve the target milk production in a certain time period at a minimum cost.

The effect of roughage quality on milk production

Critical aspects in the feeding management of dairy cows are the quality and availability of roughage, as well as the balance between nutrients. Because cows are ruminants, their diets should be based on feeding as much roughage as possible. However, because roughages alone do not satisfy the nutrient requirements of dairy cows for producing even a moderate milk yield, diets are supplemented with suitable concentrates. High quality roughage helps to maintain a more stable and healthy rumen, while maximising feed and nutrient intake. It also reduces diet cost as less concentrates have to be included for a balanced diet. The quality and physical particle size of the roughage are two factors that directly affect the dry matter intake (DMI) of dairy cows and consequently the level of milk production.

Imbalances in the diet of cows could affect milk production or milk composition negatively, i.e. the fat content of the milk could be low because of an imbalance in the roughage content of the total diet when too much starch (concentrates) is fed or when the fibre has been ground too finely reducing its scratch factor and rumination time. The protein content in the milk is reduced when the diet contains too little energy. Usually in this case, the condition of cows will also deteriorate. In some cases, when the diet has too little by-pass protein, cows often show a low or no peak production early in the lactation period. Reducing the peak production by one litre of milk has a negative effect on the total lactation yield of approximately 180 litres. High protein levels in the diet, especially coming from non-protein nitrogen (NPN), has a negative effect on the milk yield of cows of about two to three litres of milk per day. This is because cows have to use some of the energy in the diet to utilise these protein components. This often happens when cows are on highly fertilised cultivated pastures. Milk fever may occur because of an imbalance in the calcium-to-phosphorus ratio.

There is a common perception among dairy farmers that roughage of a low quality could be corrected by a suitable concentrate supplementation. This is observed in the large amounts of low grade roughages like wheat, barley and triticale straw that are being fed to cows on a regular basis. These roughages are actually waste products from the cereal industry and while filling the rumen of dairy cows, they add very little to the total diet of lactating dairy cows. However, these roughages are being fed because of their availability. Correcting poor quality roughage or a shortage in roughage by increasing the quality and quantity of concentrates is not always a good economical option. The quantity of concentrate fed per cow depends on the roughage quality, milk production target, as well as the concentrate costs. Low grade roughages have a diluting effect on the total diet of cows and should only be included in diets at low levels.

The quality or feeding value of roughages harvested as hay or silage is affected by growth stage. In general, maize silage can be harvested at a wider range of maturity than legume crops, having a less severe effect on DMI and consequently milk yield. On the other hand, lucerne harvested at an increasing growth stage towards maturity (the full flower stage) results in an increase in the crude fibre content with a reduction in the digestibility of the fibre, generally reducing the feeding quality of lucerne hay.

In Table 4.1 the effect of increasing growth stage of lucerne hay on the milk yield of Holstein cows being fed different levels of concentrates is shown. The milk yield of cows increased at higher concentrate levels regardless of harvesting stage, while the milk yield was reduced by increasing growth stage from before flowering to full flowering.

Table 4.1. The effect of growth stage of lucerne hay and concentrate level on the daily 4% fat corrected milk yield (FCM) of Holstein cows (Beauchemin, 1991)

	Concentrate content in total diet (%)			
	20	37	54	71
Harvesting stage	4% FCM kg/day			
Before flowering	29	40	42	41
Early flowering	32	33	37	36
Mid flowering	27	29	31	30
Full flowering	26	27	29	31

Feeding more concentrates to cows to compensate for the lower feed quality of more mature lucerne hay, affected gross margins (Table 4.2). Although the milk yield of cows increased with increasing levels of concentrates, the gross margin of milk production was reduced for both concentrate feeding level and advancing growth stage. Growth stage had the larger negative effect on gross margins in comparison to concentrate feeding levels. The highest gross margins were shown at the 20 and 37% concentrate feeding level and earliest harvesting growth stage (before flower stage). This indicates that poor quality roughage cannot be corrected or substituted by increasing the amount of concentrates in the diet. It is therefore suggested that the additional investment in optimising roughage quality is worthwhile as it reduces supplement costs while increasing the gross margin of milk income over feed cost.

Table 4.2. The effect of growth stage of lucerne hay and concentrate level on the gross margin of milk income over feed cost based on the 4% fat corrected milk yield of Holstein cows

	Concentrate content in total diet (%)			
	20	37	54	71
Harvesting stage	Milk income less feed cost (R/cow/day)			
Before flowering	15.0	15.2	14.0	12.0
Early flowering	10.4	9.6	10.4	7.4
Mid flowering	8.6	8.0	7.9	6.2
Full flowering	7.5	7.6	8.0	8.8

Availability of roughage

Dairy cows have a daily nutrient requirement of energy and protein, minerals and trace elements. As discussed, a minimum quantity of fibre is also required for optimum ruminal activity and health. Despite the superior genetic potential of a cow, the performance could be substantially poorer than expected, essentially driven by the weakest link in the nutrient chain. The nutrient requirements of dairy cows vary with stage of production (days-in-milk) and gestation. Generally, the lactation period is divided into early lactation, peak DMI, mid- and late lactation period and the dry period. Feeding according to specific feeding requirements can partially provide an indication of the optimum milk production, reproduction, and health of dairy cows.

An imbalanced nutrient supply and intake often result in specific consequences, such as low butterfat or protein content, low or no peak in production, reproduction problems, and metabolic disorders in the different stages of production and gestation. These possible consequences have mostly severe economic implications for the dairy farm.

Herd management

Successful dairy farming includes the effective management of all stages of heifer growth and production. Pro-active herd management starts with record-keeping, analysis of individual animal data, while monitoring the overall herd performance for profitability. Herd management focuses on the management of productive (lactating cows) and non-productive (calves, heifers and dry cows) stock for the optimal, overall physical and economic performance. Feeding and managing non-productive stock is a major cost on dairy farms; therefore, the number of non-productive days, as well as the number of animals in this category, must be minimised.

Rearing calves and replacement heifers is a substantial cost for the dairy farm, with their feed costs amounting to about 15 to 20% of the total feed costs of a dairy herd. The costs of rearing calves and replacement heifers should be estimated in terms of the cost per kilogram of weight gain and the total cost of rearing calves to targeted live weights at specific ages. The mortality cost of heifers leaving the herd at various ages should also be included as a cost factor in the rearing of replacement heifers.

Although young calves and heifers do not directly contribute to the farm income, their feeding should not be neglected by limiting their daily allowance by giving them a poor quality diet in an effort to reduce rearing costs. When bulls of high genetic merit are being used to inseminate cows, heifers born from these matings usually have a high genetic merit. By feeding a low quality diet, rearing costs actually increase because of a longer feeding period for heifers to reach sexual maturity and the correct live weight and size at first calving. A study has shown that Holstein-Friesian heifers calving down at 363 kg produce 1992 kg less milk over their first three lactations than similar heifers calving down at 450 kg. The cost of rearing heifers to reach a live weight that is 87 kg heavier would have been less than the extra income derived from the higher milk yield. Because heifers are growing at a slower rate, the number of heifers in the herd also increases, which further increases the total feeding cost of all the heifers. For instance, in a dairy herd of 100 cows, the number of heifers in the herd would increase from 89 to 133 when age at first calving increases from 24 to 36 months of age. It is important to find ways to reduce feed cost of heifers, though without affecting the growth and development of calves and replacement heifers as they have an important role in the dairy's future.

Reproductive management of heifers starts with them being reared to reach the correct live weight and size at first insemination. Slow-growing heifers reach the correct live weight at a later age, resulting in heifers being older when they calve down for the first time. This results in a higher feeding cost. An earlier age at first calving results in a higher turnover ratio, increasing the economic efficiency of the dairy herd because, fewer replacement heifers are required to meet the internal replacement rate.

Research has shown that cows only require a dry period of 40 to 50 days, and that well grown-out heifers can be very productive when they valve down at about 22 to 24 months of age, provided that they have reached a live weight of at least 90% of their mature live weights. A dry day period longer than 60 days and an age at first calving beyond 24 months of age should be regarded as non-productive with the potential of decreasing farm profit.

The milk yield potential of any dairy herd is firstly set by its genetic merit. Feeding the total herd as well as individual cows should take place given the full extent of their genetic merit. Therefore, management, and specifically feed management, is seen as the leading factor in milk production. To feed cows their specific nutrient requirements, group feeding and individual feeding, according to production potential, is proven to be beneficial, in terms of milk production, as well as cost-effective rations that could result in better milk income and less feed costs margins.

Furthermore, grouping cows according to production level or age would optimise their physical and economic performance. Feeding transition cows separately, or by separating the first lactation cows from mature cows, should be considered according to the individual dairy farm.

Feeding a balanced diet is required for all stages of growth and production. Allowing for specific cow behaviour may result in an increased feed intake and milk production, while reducing metabolic disorders.

Herd management also needs to consider the optimal time to cull heifers and cows. To cull heifers early, at a young age, will save on rearing cost, though overall production cost increases because fewer heifers reach first calving. Mortality cost of heifers is a factor that has to be included in the rearing cost of heifers. Milk yield in first lactation cows may be used as a selection criterion. Early identification of poor performing first lactation cows will reduce the cost of getting them pregnant to be culled later. Greater heifer inventories and strong beef prices may put more pressure on the decision to cull cows. Successful culling strategies are based on economic principles and accurate production records have to be used. Culling is generally categorised as economic culls (voluntary culling) or biological culls (involuntary culling). If culls are mainly categorised as biological, the decision to cull is nearly made for the producer. When cows are categorised as economic culls, it allows for more management control over which animals stay or leave the herd. However, cull decisions should be made on cows in order not to trade-off profitability.

The most difficult task is to optimise performance of all productive and non-productive cows given the limited time and resources. By fine tuning the management of the herd, along with continuously implementing basic principles, the milk production, reproduction, and health of dairy cows can be significantly improved.

Milk income

Both correct feeding and herd management would result in a higher milk yield, which would contribute to a higher increased milk income for a dairy farm. Milk income is further influenced by the unit price increase from a better milk composition, i.e. higher fat and protein percentages. This may, however, depend on the dairy processors preference based on their individual production purpose. Reduced or complete control of bacterial contaminations or improving milk quality can also increase the unit price of milk.

Dairy farm profitability measures

Although feed management, herd management, and milk income are categorised as the major factors affecting profitability, it is important to focus on suitable strategies to increase profits. This includes strategies such as:

- minimising costs,
- minimising assets per production unit to reduce fixed costs,
- marketing milk to receive the best unit price and therefore increase income, and
- increasing production to maximise income.

By understanding the factors affecting profitability and the linkages between these factors, the level of profitability can be estimated.

Milk income minus feed costs is one measure of the profitability of feeding management. This quantifies the margin above feed cost available to cover all other costs to eventually leave a profit (Figure 3). However, milk production is determined by a combination of biological, environmental, and economic factors; therefore, milk production does not react directly to changes in absolute prices. Milk production decisions should rather be based on relative prices.

The milk-to-feed price ratio is measured for the profitability of feed management based on the relative prices. The price of maize and soybeans is used as a proxy for feed price, a derived weighted feed price of 70% maize and 30% soybeans.

The milk-to-feed price ratio gives an indication on how much is spent on feed in relation to the income received from the milk produced. When the milk price increases relative to the feed price, milk production may increase. On the other hand, an unfavourable milk-to-feed price ratio is when the milk unit price decreases in relation to the feed price. In this situation farmers tend to produce less milk. In Figure 4.4 the volatility of the milk-to-feed price ratio over a number of years in South Africa is shown.

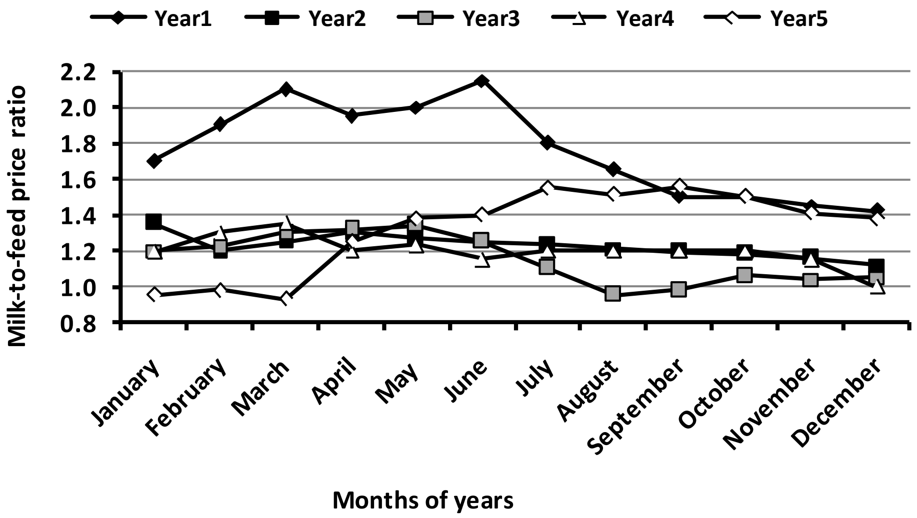


Figure 4.4. The volatility of the milk-to-feed price ratio in South Africa over a five year period

Although efficiency of a dairy herd may be estimated in a broader sense, feed efficiency is mainly considered as feeds become more expensive, having a continuous leading share in the costs of a dairy herd. It is therefore more important to make maximum use of feed; therefore, feed efficiency is used as a measure for relative profitability of a dairy business. Feed efficiency measures how well a cow actually converts the feed ration consumed into milk production; it is expressed as the litres produced per kg DMI.

Financial planning

Successful dairy managers are able to budget the feed costs of the dairy to match income during the different phases of the production season. They also invest wisely in improving their dairy production systems. However, most dairy farmers would rather be among their cows than working on budgets, profitability measures, and cost ratios. Many farmers, including dairy farmers, do not make enough use of budgeting or at least some production cost measurements tools. Because of the relative poor income-to-cost ratio, cash flow planning and budgeting are becoming very important aspects of the sustainability of a dairy. Advance financial planning may help to avoid short-term shortages of cash.

A budget is a financial tool that is used to plan future income and expenses of a business. Every dairy farmer is in the business for profit; the profit is the balance between the expenses and the income.

The usefulness of a budget largely depends on its correctness and realism of the information and assumptions considered. In order to compile such a budget, own knowledge and experience, historical records, and benchmarking records should be used to make accurate estimations in terms of the income, the expenses, and the cash flow position of the business.

Although various types of budgets exist, an enterprise budget and a cash-flow plan are crucial for a farming business.

An enterprise budget is a projection of the income and expenses of producing a product (an enterprise) based on a set of assumptions. Enterprise budgets can be organised and presented in several different formats, but they typically contain three sections: (i) income; (ii) direct variable costs or operating expenses, and (iii) fixed costs. If dairy is the only enterprise, income can be generated from milk and culling or selling of excess stock. The expenses could be expected for labour, purchased feed, establishing self-produced pastures (including fertilisers, irrigation, and/or seed) veterinary costs (medicine, AI and/or services), water, electricity, chemicals, transport, fuel and repairs, depreciation, taxes, insurance, interests, and licences. An enterprise budget can be calculated up to various levels, where the gross margin level is commonly used to compare the performance of enterprises that have similar requirements for capital and labour. A gross margin refers to the total income derived from an enterprise less the variable costs incurred in the enterprise. An enterprise budget can further be calculated to the net farm income level or profit level.

As some expenses are difficult to allocate to a specific enterprise, it is classified as overhead costs and usually associated with buildings, record keeping, budgeting, rent, interest and taxes that are applicable to more than one enterprise on a farm. Overhead costs can include both variable and fixed costs. The term overhead costs will normally rather be included in a whole farm budget, a combined effort of all enterprises on the farm, than an enterprise budget. If a budget is compiled for a single enterprise, these costs should still be considered, but it would be necessary to allocate it even if an arbitrary (but consistent) method of allocation must be used.

A cash flow plan is a recorded projection of the amount and timing of all cash inflows and cash outflows expected to occur throughout the planning period. Cash flow budgeting looks only at money movement, not at net farm income or profitability. The cash flow plan will point out potential problems in meeting financial obligations and give an indication when cash will available for new investments.

All dairy producers need to know the drivers of profitability and how their costs compare to other dairy producers in the area. In general, higher profit farms tend to do a little better in most areas of cost control and income. Even small differences in each area can add up to a big difference in overall profitability.

Financial management programmes

A number of financial management programmes are available for farmers to use. The basic principles of such programmes are to enable the management of enterprise costs and incomes. This should be done on at least a monthly basis to enable the early detection of unusual costs. In some cases, these programmes are used to compare the financial situation of farmers within study groups. Generally, milk income is about 95% of all the dairy income while the feeding cost of all the animals in the dairy is about 65 to 75% with veterinary, semen and other medical cost being about 10% and labour and other overhead cost being about 25%. From this information, gross margins above feed costs can be determined while also estimating specified costs. By keeping this information up to date, cost and income trends could be estimated which would enable the financial management of the operation.

In closing

For financial survival, dairy farmers should apply some basic principles. These include the following:

- improve technical knowledge of the operation, which includes basic principles on feeding, etc.,
- run the dairy farm according to business principles,
- be adaptable in management using the correct and recent technical knowledge,
- plan daily activities better,
- make better use of workers while also providing training when required,
- set targets and record it for everyone involved with the dairy to see,
- be positive and have a long term vision for the dairy farm,
- look for answers regarding problems encountered in the daily running of the farm, and
- market products before it is being produced, which includes enterprise budgeting.

CHAPTER 5

CLASSIFICATION AND NUTRITIONAL PROPERTIES OF FEEDS

Introduction

The feeding cost of lactating cows is the largest single cost in the operation of a dairy. The key to maximising dairy farm profitability is to maintain the correct nutrient levels while managing feed costs. A correct feeding programme allows cows to produce larger quantities of milk of a high quality. To establish or to manage the feeding programme of a dairy herd, two aspects are important, i.e. (i) the nutrient requirements of animals, and (ii) the feeding qualities of available feeds. For this reason, the most important characteristics of some feeds are discussed here. This information, together with the chemical composition of feeds, should be used as guidelines in diet formulation. In practice, on farm level, ignorance about the feeding qualities of feeds often results in the under- and overfeeding of cows, resulting in poor production performances, as well as poor economic results.

Types of feed

1. Hay

Hay is whole crop plant material that has been harvested and sundried before baling. In the Western Cape, hay is mainly made from oats, barley, triticale, and to a smaller extent serradella, vetch, and lupines. In the summer rainfall areas, hay is made from lucerne, various grass types, like *Eragrostis curvula* and *E. teff,* and in some cases *sorghum* hay. Other crops like ground nuts could also be harvested as hay. There are some aspects about hay that are important, i.e.

- Legume hays have higher crude protein (CP) and calcium (Ca) levels than cereal and grass hays.
- Time of harvesting whole forage crops affects the chemical composition and feeding quality of roughages.
- Losses in leave material during harvesting reduces the quality of hay, specifically lucerne hay, as up to 10% of harvested material can be lost during baling. Leaves contain the highest CP and energy levels of the whole crop.
- The way hay is being fed affects its intake while increasing wastage of hay. Although lower quality roughages should be milled to improve its voluntary intake, high quality roughage does not require milling.
- Hay made from cereal crops should include the whole plant with early developed grains.

(a) Legume hay

Lucerne is the most well-known legume hay. It has a high palatability that improves the quality of most diets when included as a feed source. Lucerne hay contains medium to high (12 - 18%) levels of CP, depending on the growth stage when harvested, although it is poor in energy. It combines well with roughages like maize silage, maize grain and molasses as these feeds increase the energy content of the mixture. If correctly designed feed troughs are used, then lucerne hay can be fed unmilled. There are no limitations on its inclusion level in diets, although dry cows should not receive large quantities of lucerne hay specifically during the steam-up period as this may lead to milk fever when cows calve down. This is mainly because of the high Ca content of lucerne hay.

Although pea hay is also a legume hay, its quality is lower than that of lucerne hay, because the seed has been harvested before baling, while it has also reached a more mature growth stage. When baled at a later growth stage, pea straw is of poor quality and should be milled before being fed to animals.

(b) Cereal and grass hay

Cereal and grass hays have lower CP (less than 12%) and Ca levels than legume hays. The growth stage at harvesting has a large effect on the chemical composition and feeding value of hay. Tef and ryegrass hay have a finer texture and can be fed unmilled in correctly designed feed troughs. The inclusion levels of these hays in diets for lactating cows should be limited, because of their lower feeding quality with regards to CP and energy.

2. Straw

This is the stem and leaves residues of cereal crops after the grain has been harvested. Wheat, barley, triticale, and oat straws are the most common cereal straws, especially in the Western Cape Province. These straws have low levels of CP (less than 5%), while also lacking energy and minerals, while containing high levels of ADF because of the maturity of crops at harvesting. Oat straw has possibly the highest quality followed by barley and wheat straw. Maize and grain sorghum straws have similar feeding values to wheat straw. Straws have to be milled to ensure a high feed intake. The low feeding value of most straws limits their inclusion levels in diets. It could be fed to replacement heifers as long as sufficient protein and energy supplementation is provided.

In the past, cereal straws were upgraded by treating it with ammonia gas in an oven or in a stack covered with plastic sheeting. Ammoniation improves the energy and protein content as the process breaks the lignin bonds in the cell walls, releasing some of the energy that is available in the hemi-cellulose portion of the fibre. At the same time, the ammonia gas increases the CP content of the straw, although it is of a highly degradable form. The inclusion level of ammoniated wheat straw for dairy cows should not exceed 40% of the total diet, especially for high producing dairy cows. It is also important to supplement most macro- and micro-elements, as well as Vitamins A and E, when feeding ammonia wheat straw as a roughage source to dairy cows.

3. Cultivated pastures

Cultivated pasture is generally the cheapest roughage source for dairy cows. The cost of ryegrass pasture may vary from R1200 to R1800 per ton dry matter (DM), while lucerne hay may cost R1800 to R2500 per ton while having a lower CP and energy levels. Factors affecting the milk yield from cultivated pastures are mainly their energy and DM contents. For this reason, using lucerne hay in place of ryegrass pasture increases the feeding cost of dairy cows which results in a higher break-even point of milk production. The CP content of pastures is high, usually in excess of the nutrient requirements of dairy cows, i.e. a Jersey cow consuming 12 kg DM ryegrass pasture per day takes in 2460 g CP per day. This is sufficient for 28 litres of milk per day, while the energy intake at the same time can only support milk production at 12 - 13 litres per cows per day. Kikuyu pasture has a low Ca availability, while other pastures have high levels of potassium which increases the risk of milk fever in dairy cows at calving down.

In Table 5.1 the chemical composition of different cultivated pastures collected over a three year period at the Outeniqua Research Farm is shown. The CP levels range from 18 - 23% on a DM basis. Kikuyu has a lower energy level and higher NDF and ADF levels, which makes this a more bulky pasture type in comparison to ryegrass and ryegrass/clover mixtures. Lucerne and ryegrass/clover pastures have higher levels of Ca than kikuyu and ryegrass. Selenium and zinc levels are low in the pastures, as shown in Table 5.1.

Table 5.1. The mean chemical composition of kikuyu, ryegrass, ryegrass/clover and lucerne pastures (TDN = Total digestible nutrients; ADF = Acid detergent fibre; NDF = Neutral detergent fibre)

Chemical ingredients	Grass type (Values on a DM basis)			
	Kikuyu	Ryegrass	Ryegrass/clover	Lucerne
Dry matter (%)	17.4	13.7	15.2	19.3
Crude protein (%)	18.5	22.0	22.6	23.4
TDN (%)	58.6	67.9	66.1	63.2
ADF (%)	30.0	27.5	28.8	30.2
NDF (%)	63.5	48.5	46.5	40.9
Ash (%)	9.7	9.8	10.2	8.2
Calcium (Ca%)	0.43	0.67	0.88	1.19
Phosphorus (P%)	0.33	0.36	0.40	0.33
Magnesium (Mg%)	0.36	0.36	0.44	0.37
Sodium (Na%)	0.28	0.89	0.65	0.31
Potassium (K%)	3.04	3.39	3.01	2.36
Copper (Cu pm)	8.08	6.86	8.13	8.00
Zinc (Zn pm)	43.9	42.9	44.4	42.1
Manganese (Mn pm)	79.8	60.5	63.4	43.4
Iron (Fe pm)	196	194	360	149
Selenium (Se pm)	0.07	0.04	0.08	0.03

4. Silage crops

Ensiling roughages is a cheap way of storing roughages as often no structures are required. Maize silage is the main roughage source for dairy cows in the summer rainfall areas. Good quality silage can also be made from most grass types and legume crops like lucerne and lupines. Because forage crops are ensiled at an earlier growth stage than hay and are not dried before ensiling, silage has a higher moisture content of about 65%. This makes silage bulky, reducing the possibility of transporting it over large distances. Depending on its DM content 2 - 3 kg of silage is equivalent to one kg of hay on an "as is" basis. The feeding value of silages from the same crop is often higher than that of hay, as harvesting is done at an earlier growth stage. Silage is excellent feed for young animals older than 9 months of age. There is no limitation to its inclusion level in dairy cattle diets, although for high producing cows it should probably not be fed more than 30% of the diet. Silage with mold should not be used as the fungi could contain poisonous compounds.

5. Concentrated feeds and mineral sources

As cows are ruminants, their basic diet should consist of roughages. However, roughages are in most cases deficient in energy, protein and minerals, especially when feeding high performing cows. The deficiencies in roughages are supplemented in the diet by using concentrated feeds like grains, seeds and mineral sources. Cows should never be fed concentrated feeds as the only feed source as the digestives system of ruminants is not capable of digesting such feeds. A number of concentrated feeds and mineral sources are listed alphabetically below and the symbols E, P and M for energy, protein and mineral, respectively are used to describe the use of each feed (From MacGregor, 1980):

Barley (E): This cereal grain can be used to replace maize grain when the price difference is favourable. It has about 95% of the energy value of maize grain, because the fibre content is higher. The chemical composition of barley can vary considerably depending on its source and growing conditions. Like all cereal grains, the value of barley is reduced when grains are small. Barley is very palatable and can be used in large quantities. The energy content of barley is slightly below that of wheat while the CP content is between that of wheat and maize. When the quality is good, it can replace up to 70% of maize grain in diets.

Blood meal (P): This is a good protein source as it is highly undegradable in the rumen. Palatability may be a problem, especially when it is fed in combination with carcass meal. It can, on its own, be included up to 8% in the concentrate mixture. Blood meal containing small black particles with a distinct burned smell should not be used as this indicates overheating which would have reduced the quality of the product.

Bone meal (M): This is boiled (steamed), dried and milled animal bones from abattoirs. It is used mainly as calcium (Ca) and phosphorus (P) sources. Because it also contains small amounts of grease, gelatin and meat fibre, it has a low crude protein (CP) value and is generally a good source of trace elements.

Brewers' grains from barley (P): This is the residue from brewing Lager beer and is usually a mixture of barley, maize and brewers' yeast. The product is very palatable and is safe to use even on its own. It is a medium-protein and high fibre feed. The protein has a low solubility value and is degraded slowly in the rumen. Dairy cows can be fed up to 16 - 18 kg of wet brewers' grain per cow per day. The limiting factor of brewers' grains is the moisture content. In a total mixed ration, it can be included up 25% on a DM basis.

Brewers' grains from sorghum (P): This is the by-product from brewing sorghum beer. It contains higher levels of energy and protein than brewers' grain from barley. The product is very palatable and is safe to use. The limiting factor of brewers' grains is the moisture content. In a total mixed ration it can be included up 25% on a DM basis.

Carcass meal (P): The protein content in carcass meal is high and is highly undegradable in the rumen. Palatability can be a problem, especially when it is fed together with blood meal. The chemical composition of carcass meal varies considerably, while the fat content can be high. The inclusion level in concentrate mixture should not be more than 8%. When blood meal is also used, the inclusion level should be lower, i.e. less than 5%. The use of carcass meal in ruminant feeding has been banned because of the possibility of mad-cow disease. Only carcass meal from poultry may be used in ruminant feeding.

Cottonseed oil cake meal (P): Cottonseed oil cake meal, or cottonseed meal, has a high protein and energy content. It is a good source of rumen bypass protein. It is the by-product after the oil in whole cottonseed has been extracted and the hulls have been removed. Two different processing methods are used to extract oil, i.e. expeller and a solvent processes which results in different amounts of oil remaining in the meal and this affects their energy values. Although cottonseed meal contains small amounts of gossypol, a toxic compound found in whole cottonseed, the levels are too low to affect dairy cows even when high levels are fed. The heating process during oil extraction seems to change the toxic compound making it a useful protein source for young ruminants. The phosphorus content of cottonseed oil cake meal is high. The maximum inclusion level in the total mixed ration is about 20%.

Cottonseed, whole (P & E): Whole cottonseed is high in protein, fat, fibre and energy. Whole cottonseed (also called fuzzy seed), with the lint still attached, is difficult to grind which makes it more bulky. De-linted whole cottonseed has a smooth black appearance and tends to have a higher CP and fat content than the fuzzy seed. Feeding whole cottonseed to lactating cows increases their milk yield and milk fat content. It can be fed at 1.8 - 3.0 kg per cow per day while the maximum inclusion level of whole cottonseed is 20% in total mixed rations. No grinding is required before feeding it to cows. It contains gossypol which may be toxic to young animals and should therefore not be fed to animals younger than six months of age.

Di-calcium phosphate (DiCaP) (M): This product is a mixture of dicalcium and phosphate providing Ca and P at a ratio of 1.5:1. It is used to balance the Ca and P contents of mixtures. The maximum inclusion level is 2% in total mixed rations.

Fat (E): The energy value of animal fats is highly concentrated being about 2.5 times that of ground maize grain. Several kinds of fat products are available. Unsaturated fats (in liquid form at room temperature) is not recommended to be used in animal feeding as it affects the rumen microbes reducing fibre digestion, as well as the fat and protein percentage in the milk of cows. The more saturated fats, such as tallow and animal/vegetable blends, have given the best results when fed to dairy cows. Palatability may be problem when inclusion levels are high, i.e. above 2%. Solid or so-called prilled fats are inert in the rumen and may be included in diets up to 0.5 kg per cow per day. These fats do not affect the activity of the rumen population and should improve the fat and protein percentage in milk because of higher energy content and no effect on fibre digestion. The Ca and Mg levels in the diet should be about 1.0 and 0.35%, respectively, when fat is fed at this level as fats tend to reduce the absorption of these minerals.

Feed lime (M): Feed lime is used as a source of calcium and is finely ground limestone (calcium carbonate). It contains at least 36% Ca. It also contains small amounts of magnesium (less than 0.5%). Other sources of unslaked lime and agricultural lime should not be used in diets as they may contain harmful impurities.

Fish meal (P): This is the best protein source for dairy cows as the protein has a high rumen bypass value, i.e. not being degraded in the rumen. The protein in fish meal is a rich source of essential amino acids like lysine and methionine. The palatability may be a problem for animals not accustomed to it and the inclusion levels should be low when feeding it for the first time. The inclusion level should be increased over a two week period. Inclusion levels of 2 - 5% produce good results when high quality protein sources are required.

Grain sorghum (E): The energy content of grain sorghum is slightly lower than that of maize. Two types are available, i.e. bird-resistant (bitter) and sweet sorghum. Bird-resistant sorghum is dark-red in colour and contains higher levels of tannins. This requires a higher CP level in the diet when sorghum grains are included at high levels. Sweet sorghum has a light pink colour. Grain sorghum must be coarsely ground before it can be included in the diet. It is better to use a roller mill to break the grains, because it becomes very powdery when put through a hammer mill. Maximum inclusion levels are similar to that of maize grain and could replace it, although is it recommended that maize should still be included at 30% of the diet. Sorghum is grown in areas that are too dry for maize production.

High protein concentrates (HPC's) (P): These are commercial mixtures containing a number of protein sources including urea. Some minerals and salt are usually also included in such mixtures. When comparing different mixtures, their CP content and protein source should be considered especially when urea is included in the mixture. This may also affect the mixture's palatability. Inclusion levels in total mixed rations are seldom higher than 20 - 25%.

Lupin seed (P & E): Lupin is an annual, cool season grain legume. Lupin varieties that have alkaloid levels of about 0.5 to 2.0% on a dry matter of the seeds are called bitter lupines. These levels of alkaloids are both toxic and unpalatable for livestock. Lupin varieties with low levels of alkaloids (less than 0.03%) are called sweet lupines and are safe for feeding to animals. Lupin seed is relatively high in CP, as well as energy. However, its amino acid content of methionine and cystine is lower than that of other vegetable protein sources. The CP content of lupin seed is affected by cultivar, climate, and soil conditions. Rumen degradability is higher than that of soybean meal protein. Because it is highly degradable in the rumen, it should not be the major source of protein in the diet, especially when fed together with urea or anhydrous ammonia. Sweet lupins can be fed to dairy cows up to 1.8 kg per cow per day or at a maximum inclusion level of 15% in concentrate mixtures. It should be rolled or ground before feeding.

Magnesium oxide (MgO) (M): Magnesium oxide is a mineral that contains about 50 - 58% magnesium (Mg) depending on its source. It has two common uses in animal feeding, namely to supplement Mg in the diet or as a feed additive to support the fat content in milk. MgO is also used to supplement Mg to cows on lush pasture. For this purpose it should be fed between 25 to 115 g per cow per day. It is a common practice to feed about 55 g per cow per day. Magnesium oxide is not very palatable and it may be several days before cows become accustomed to it. A mixture of ⅓ MgO and ⅔ bicarbonate of soda ($NaHCO_3$) may be used as a buffer, i.e. an anti-acid supplement. This is typically used in diets containing high levels of concentrates and finely ground roughages causing the rumen to become too acidic.

Maize bran (E): Maize bran is a by-product from white maize. Its CP content is low, while the energy content is medium. It is often used to fill-up diets and to reduce the compactness of mixtures. The inclusion level is usually determined by its price.

Maize cob meal (E): Maize cob meal is ground maize cobs with the kernels included. Sometimes it may also contain cob leaves. Because maize cob meal is harvested at a more mature stage, its fibre content is high from the cob and leaves. This reduces the energy content of maize cob meal to medium levels, while its CP content is low. It is generally very palatable and acidosis does not occur often, even when the inclusion level in the diet is high. The inclusion level should, however, not be more than 70% of the total diet. Without cob leaves, the energy content is higher, although still less than that of maize grain. It is a good supplement for low to medium producing cows and for younger animals.

Maize germ meal (E & P): This product is not readily available and is often confused for hominy chop. Maize germ meal has a high fat content and a CP content of about 10%. The energy level in maize germ meal is similar to that of maize grain, because of the higher fat content. A high inclusion level in the diet reduces the fat percentage in milk. Because of the high fat levels, it is not stored for a long period as it would become rancid.

Maize gluten meal (P): Gluten meal is a by-product of the starch industry. Maize gluten feed is a mixture of gluten meal and maize bran which can be included in diets for dairy cows as protein supplements. Maize gluten meal, used as Gluten 20 and Gluten 60 (Prime gluten), contains 20 and 60% CP, respectively, and has no inclusion level limitations. Gluten feed should not consist more than 15 - 30% of the diet, because of a lower protein and energy content than gluten meal. The protein in Gluten 20 is degraded relatively fast in the rumen having a low bypass protein value, while Gluten 60 is degraded slowly in the rumen having a high rumen bypass value. Gluten feed can be fed up to 5.5 kg per cow per day.

Maize grain (E): Maize grain is the most common energy source in dairy cattle diets. It is high in energy and low in protein, fibre and minerals. Maize grain is a palatable feed and may be included in the diet as the main source of energy. Both yellow and white maize can be used in animal feeding as their chemical composition varies little. The best results are obtained from finely milled or rolled maize grain. The energy content of second grade maize grain is lower than that of first grade maize grain because of a larger proportion of impurities from the stalks and cobs. There are no limitations on the inclusion level in diets, although because of the high starch content, it is best not to provide more than 6 - 7 kg per day for Holsteins and 4 - 5 kg per day for Jerseys, especially when concentrates are fed twice a day.

Mineral pre-mixes (M): There are a number of mineral pre-mixes available. Such pre-mixes are formulated to supplement specific minerals in areas where a deficiency has been established. Recommendations to their use should be followed carefully. An animal nutritionist should be consulted when a deficiency of a specific mineral is suspected. Inclusion levels of specific minerals are important as interactions among minerals occur which may affect the production response of cows.

Molasses (E): Cane molasses is a by-product of the manufacturing process of sugar from sugar cane. It is very palatable and can be used to improve the palatability of diets for dairy cows and thereby reducing the dustiness of dry total mixed rations. It is available in liquid form containing about 25% moisture. Because it has a thick and sticky consistency, it is difficult to mix into diets, unless it is diluted with water or heated. It has a medium energy level (72% TDN on a DM basis) and is a good source of potassium (K). Molasses is also available as a powder (Calory3000). The powder is fine and free-running containing the same chemical composition as molasses syrup. Being a powder it is easier to use than molasses syrup. Molasses meal is a mixture of bagasse (fibre) and molasses syrup. Because of the fibre, the energy content of molasses meal is lower than that of molasses syrup. It is, however, easier to include in diets while still having the same binding and palatability advantages. The maximum inclusion level in diets is 15%.

Mono-calcium phosphate (M): Mono-calcium phosphate is used to supplement Ca and P in the diet at a ratio of 0.9 to 1 for Ca and P.

Oats grain (E): The fibre content of oats grain is higher than the other cereal grains resulting in its energy content being lower. It must be ground or rolled before using it to separate the fibre. It is very palatable and could replace maize grain in heifer diets. Oats grain can be included in calf diets, because they chew their feed more thoroughly than cows. The inclusion level of oats grain in concentrates should be limited, because of its lower energy content, i.e. not more than 33% of the concentrate mixture. It has about 90% of the feeding value of barley grain because of its fibre content.

Peanut oil cake meal (P): Peanut oil cake meal or peanut meal is the product remaining after the extraction of most of the oil from peanut kernels and skins removed. It is used as a protein supplement, although it provides less energy than soybean meal. Rumen degradability of the protein is high. It is a very palatable feed, although it may contain aflatoxin. The maximum inclusion level is about 15% in total mixed rations.

Peanuts (E & P): Whole peanuts contain about 40% oil and should be used within 2 - 3 days after grinding it. Diarrhea may occur at high inclusion levels, while the fat and protein content of milk may be reduced because of the fat in peanuts. For this reason, the inclusion level should be 8% in total mixed rations and 5% in concentrates. When it is used with the hulls included, sand on the hulls could increase the wear on the hammer mill used for grinding the peanuts. The hulls would also reduce the feeding value of whole peanuts because of the increased fibre content. Peanut skins contain about 14% crude fibre and are generally a high-fat (26%), palatable feed for dairy cows. However, peanut hulls contain a high percentage (16%) of tannin, which acts in the digestive system by binding protein and making it unavailable for digestion or absorption. As the amount of tannins in the diet increases, more undigested protein is excreted, thereby increasing protein wastage. For this reason, peanut skins are not recommended as a feed for lactating cows.

Soybean oil cake meal (P): Soybean oil cake meal or soybean meal is the product remaining after oil has been extracted from the beans. The oil may be removed by solvent extraction or by an expeller process in which the beans are heated and pressed. The CP content of the solvent extracted and expeller process soybean meal differ slightly, i.e. 44 - 48% vs. 42% on an "as is" basis, respectively. Soybean meal is a palatable feed and may be used as the major protein source in diets for dairy cows. Rumen degradability of protein is high and to prevent palatability problems the inclusion level should not exceed 20% in total mixed rations.

Soybeans (E & P): Soybean meal is a high-protein, high-fat, and high-energy feed. The high energy content is because of the high fat content (17 - 20% on an "as is" basis). Raw soybeans should be ground before feeding. After grinding, raw soybeans should, however, not be stored for more than a week before feeding as they become rancid because of their high fat content. Soybeans do not need to be heated or roasted before feeding, unless urea is included in the diet. Soybeans contain urease, an enzyme which converts urea to ammonia, causing palatability problems. Urease is destroyed by heating when soybeans are roasted. Soybeans can also be used without being ground. Urease can also suppress protein digestion in young calves. For this reason, raw soybeans are not commonly used in diets for young calves and diets for lactating cows already containing urea. To prevent the palatability problem in diets containing soybeans, the inclusion level should not exceed 15%. The CP in soybeans is highly degradable in the rumen, resulting in a low rumen-bypass value. The protein inhibiting components and urease activity in soybeans is de-activated when soybeans are roasted or the oil has been extracted. This reduces the rumen degradability and improves the protein quality. The palatability of roasted soybeans is acceptable, although it may reduce the milk fat and protein content in milk. Diarrhea may occur when the inclusion levels in the diet exceeds 20%.

Sunflower hulls: Sunflower hulls are the outer covering of sunflower seeds and the hulls are a by-product of the oil extraction process from sunflower seeds. Sunflower hulls are high in crude fibre (45%) and low in energy and should be considered as a roughage source. The CP content of sunflower hulls is about 5%. They are often used in concentrate mixtures when the total mixed ration requires additional fibre.

Sunflower oil cake meal (P): Sunflower oil cake meal or sunflower meal is the by-product that remains after being dehulled and oil extracted from the seeds. The quality of sunflower meal varies, depending on the amount of hulls remaining in the meal. As the amount of hulls increases, the CP and energy levels of the sunflower meal decrease. Sunflower meal is less palatable than soybean meal and may be used as the major protein source in diets for lactating cows. Its higher fibre and lower energy content, relative to soybean meal, may limit its inclusion level in diets for high producing dairy cows. There are generally two kinds available depending on the fibre and CP contents, i.e. standard at 28% CP containing more fibre content and another high protein meal at about 38 - 42% CP and 11 - 16% crude fibre. The CP in both products is degraded in the rumen, which results in low rumen-bypass protein values. It is not always available and the inclusion level is about 20% in total mixed rations.

Sunflower seed meal (E): Sunflower seed has a high energy potential because of its high fat content (more than 30%). However, the CP content of sunflower seed is low, about 16 - 19% on an "as is" basis. Although sunflower is palatable, its inclusion level is about 15% in a concentrate mixture and about 8% in a total mixed ration. The daily amount should not be more than 1.8 kg per cow. Studies in the USA have shown that sunflower seed do not need to be rolled or processed before using is; however, if it is ground, it should be used within 2 - 3 days as it could become rancid because of the high fat content. Too high inclusion levels could reduce the fat and protein percentages in milk while also causing diarrhea.

Triticale (E): This is cereal crop resulting from the combination of wheat and rye grain. The energy and CP content of triticale is similar to that of wheat grain. It can be fed at the same level as wheat.

Urea (P): This is a synthetic compound with a high level of nitrogen. It is therefore not a true protein source but a concentrated source of nitrogen. Microbes in the rumen use this nitrogen as building blocks for microbial protein. It should not be included at levels higher than 1% of a total mixed ration or 0.5% of a concentrate mixture. In the rumen, urea is degraded very quickly to ammonia and is poisonous when fed at too high levels. Cows should not consume more than 110 g of urea per day. Diets containing urea should also contain at least 40% maize or wheat grain to provide sufficient energy for the rumen micro-organisms to produce microbial protein. It is usually not recommended to use concentrates containing urea when cows are on cultivated pastures as this combination could exceed the safe levels of urea in the diet.

Wheat (E): The energy value of wheat grain is slightly lower than that of maize grain, although its CP content is higher, 12 vs. 8.5%, respectively. Several varieties of wheat is being grown resulting in a large variation in its CP content, i.e. varying from 9 - 15% and the TDN from 74 - 82%. Wheat is a palatable grain and should be fed coarsely ground or crushed for best results. It should not be fed whole or finely ground. This makes it dusty, thereby limiting its palatability. Wheat contains about 60% starch and is therefore digested faster than maize grain. This could result in acidosis, especially when large amounts of wheat are fed to cows. The inclusion level of wheat in diets should be increased slowly up to a maximum of 70% of the amount of maize being fed. When low levels of concentrates are fed, the inclusion level of wheat in concentrates can be higher even to the point of replacing maize grain.

Wheat bran (E): Although wheat bran has a higher CP content than wheat, i.e. 15 vs. 12%, its energy content is lower. It is highly palatable with a low Ca content. The fibre content of wheat bran is higher than that of wheat, i.e. 11 vs. 2.5%. Because of its lower energy content, it can be included up to 25% in a grain mixture, 15% in a total mixed ration, or fed at a rate of 3 to 3.5 kg per cow per day. The phosphorus content is high. It is used mostly to increase the fibre content of concentrates reducing its density.

Wheat bran (fine - "Pollards") (E): This is mainly wheat bran with a small amount of wheat grain included. Its energy content is higher than that of wheat bran.

In closing

A large number of feeds can be used in dairy cattle feeding. The daily diet usually consists of a combination of feeds. Diets should contain minimum fibre levels while increasing energy and protein levels could be manipulated by specific feeds.

CHAPTER 6

THE CHEMICAL COMPOSITION OF FEEDS

Introduction

The chemical composition of feeds used in dairy cattle feeding programmes is recorded in feeding tables in a number of textbooks. The aim of this chapter is not to give a complete and only source of information on the chemical composition of feeds, but rather to demonstrate principles with regards to diet formulation and the feeding requirements of dairy cows, replacement heifers, and young calves. Included is a list of the chemical composition of locally available feeds from *Dierevoeding* (1977) by Prof. F.J. van der Merwe, previously from the University of Stellenbosch. This list can be supplemented with feeding tables from other South African publications, such as the "Manual on the nutritive value and chemical composition of commonly used South African feeds" by R.M. Bredon, P.G. Stewart and T.J. Dugmore, published in June 1987 by the previously known Natal Region of the Department of Agriculture and Water Supply. Also available are publications from overseas journals and books.

Feed companies mixing commercial feeds have their own data bases regarding the chemical composition of feeds as each new batch of feed is analysed to enable the correct formulation of concentrate mixtures. The chemical composition of feeds differs quite substantially between batches which are sourced from different parts of the country and in most cases from overseas. Regular analyses of feeds will ensure correct formulation as commercial mixtures and feeds have to comply with strict legal requirements. At most, feeding tables provide guidelines to the chemical composition of feeds requiring that feeds should be analysed on a regular basis even for home use.

Dry matter content of feeds

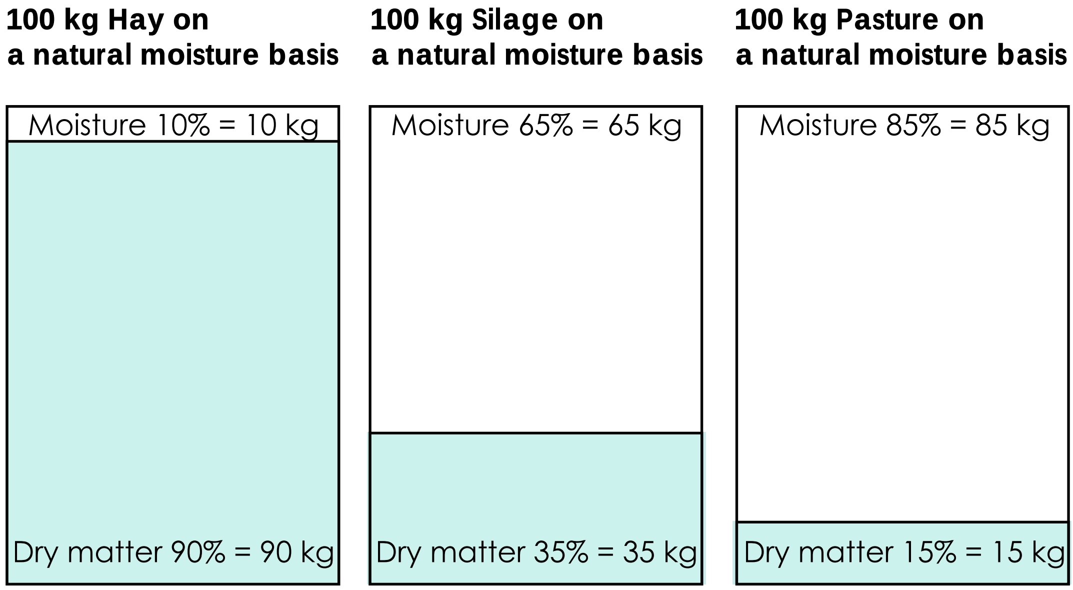
The dry matter (DM) content of feeds often causes confusion in diet formulation. All feeds contain some moisture including those feeds that are seemingly dry. Dry hay and grains usually contain about 8 - 12% moisture. Such feeds are described as "air dry". The moisture content of dry feeds depends largely on the moisture content of the air and the moisture attracting ability of the specific feed. On the other hand, silages and pasture contain a large quantity of moisture, i.e. 65 and 85%, respectively. This means that 100 kg of pasture contains 15 kg DM and 85 kg moisture.

The real DM content of feeds is determined by drying an "air dry" or "as is" feed sample in an oven up to a constant weight. The difference between the weight of the feed sample before and after drying gives an indication of the amount of moisture that is lost. From this, the DM content of feeds is estimated. For example, a feed sample weighing 100 grams on an "as is" or natural basis weighs 40 grams after drying. The weight loss, i.e. 60 grams, is mainly moisture. The rest of the feed sample, i.e. 100 – 60 grams = 40 grams, is the DM content of the feed containing the nutrients like CP, CF, Ca, P, etc. To estimate the DM content of the feed, the following equation can be used:

DM content = (100 – 60)/100 x 100% = 40%

Feeds can be described as follows:

- As fed, wet, or on fresh basis, air dry or "as is". The DM content of feeds may vary from about 8 to 92%. The moisture content of hays and grains is usually about 8 to 15%.
- Oven-dried or moisture-free or on a dry basis - in this case where feeds dried in an oven to a constant weight.
- Hay equivalent (HE) – in this case usually roughages are compared on a similar DM content as standard hay, i.e. about 88 to 92% DM content. This makes comparing hay, silage and pasture possible as their DM content varies from 90 to 15%. The relationship between moisture and DM in different roughages is illustrated as follows:



The following examples can be used to demonstrate the need to compare feeds on a DM basis:

The CP content of wheat straw, at a moisture content of 10% (DM content of 90%), maize silage, at a moisture content of 65% (DM content of 35%), and wheat (5 months growth) pasture, at a moisture content of 85% (DM content of 15%) is 3% or 30 g per kg feed "as is" or on a natural basis. On a DM basis, these feeds each contain the following CP contents:

Wheat straw	: 3/(100-10) x 100 =	3.3% CP of 33.3 g CP/kg DM;
Maize silage	: 3/(100-65) x 100 =	8.6% CP of 85.7 g CP/kg DM; and
Wheat (5 months' growth)	: 3/(100-85) x 100 =	20.0% CP of 200.0 g CP/kg DM

The chemical composition of commonly used South African feeds

The chemical composition of a number of South African feeds from *Dierevoeding* by Prof. F.J. van der Merwe (1977) is presented in Table 6.1. This list of feeds is divided into dry and green roughages, silages and concentrated feeds. The nutrient components that are presented together with the dry matter (DM) content of feeds include the following: crude protein (CP), total digestible nutrients (TDN), crude fibre (CF), calcium (Ca), and phosphorus (P). Average quality South African lucerne hay has a DM content of 90%, containing 150 g CP, 500 g TDN, 315 g CF, 10 g Ca, and 2 g P per kg of feed on an "as is" basis.

Table 6.1. The chemical composition on a natural basis or "as is" of a number of commonly used South African feeds (DM = dry matter, CP = crude protein, TDN = total digestible nutrients, CF = crude fibre, Ca = calcium, and P = phosphorus)

Feeds	DM (%)	CP (g/kg)	TDN (%)	CF (g/kg)	Ca (g/kg)	P (g/kg)
Dry roughages						
Barley hay	90	70	52	255	2.5	2.2
Barley straw	92	40	40	350	2.8	1.0
Blue buffalo grass hay *(Cenchrus cilliaris)*	90	65	50	-	3.2	1.3
Clover hay	90	210	62	195	15.0	3.0
Columbus grass hay	90	90	53	285	4.3	2.0
Cow pea hay	90	140	56	250	13.0	1.8
Elephant grass hay *(Pennisetum purpureum)*	90	90	48	315	4.0	1.6
Eragrostis curvula hay (early)	90	80	56	-	2.5	1.2
Eragrostis curvula hay (late)	90	50	50	445	2.0	1.0
Foxtail millet grass (Boermanna) hay (*Setaria italica)*	90	80	54	350	3.4	1.4
Ground nut hay (good)	90	100	59	210	15.0	1.5
Ground nut hay (poor)	90	60	54	280	14.0	1.1
Lucerne hay (¾-full flowering)	90	140	50	300	9.3	1.8
Lucerne hay (1/10-½ flowering)	90	150	52	285	11.2	2.1
Lucerne hay (average SA quality)	90	150	50	314	10.0	2.0
Lucerne hay (post flowering)	90	130	48	315	12.1	1.5
Lucerne hay (pre-flowering)	90	180	54	235	18.9	2.7
Lupin hay	90	90	53	300	5.5	1.8
Maize hay	90	100	58	-	2.5	1.9
Maize husks, stacked without heads	90	50	50	340	2.6	0.9
Maize, head leaves	90	30	54	-	1.8	1.0
Maize, stacked with heads	90	60	54	-	-	-
Nylsvlei grass hay *(Acroceras macrum)*	90	70	56	-	2.6	0.3
Oats hay (average)	90	50	55	290	1.8	2.0
Oats hay (early)	90	60	58	260	2.0	1.8
Oats hay (late)	92	40	55	315	1.5	2.5
Oats straw	92	30	44	335	2.5	1,0
Panicum hay *(Panicum spp.)*	90	70	54	-	3.0	1.4
Pea hay	90	150	55	240	12.0	2.5
Pearl millet hay *(Pennisetum typhoideum)*	90	75	51	-	3.2	1.2
Rhodes grass hay *(Chloris gayana)*	90	60	53	-	2.5	1.5
Soy bean hay (*Glycine max*)	90	100	57	-	9.8	2.0
Sudan grass hay (*Sorghum sudanense*)	90	90	52	-	3.5	1.6
Sweet grass hay (*Panicum laevifolium*)	90	60	50	-	2.5	1.3
Tef grass hay (*Eragrostis tef*)	90	80	52	320	3.3	1.3
Veld grass hay (poor quality)	90	40	38	330	2.5	0.4
Veld grass hay (well fertilized)	90	60	50	275	3.0	1.2
Wheat straw	92	30	38	360	1.6	0.8
Green roughages						
Barley, April	18	41	14	-	0.6	0.4
Barley, May	22	32	17	57.5	0.5	0.3
Barley, June	23	24	16	-	0.5	0.3
Clover	15	36	10	32.0	2.3	0.5
Columbus grass, 45-65 cm high	25	36	15	67.5	1.2	0.4
Kikuyu 12 cm high	20	37	13	55.0	0.4	0.4
Lucerne, pre-flowering	20	44	12	47.0	4.0	0.7
Lucerne, early bloom	23	46	15	59.5	5.0	0.7
Lucerne, after flowering	30	37	15	122.0	4.0	0.6
Oats, May	20	33	15	-	0.5	0.4
Oats, June	25	24	19	52	0.5	0.5
Oats, August	30	27	20	-	0.5	0.5
Feeds						
Pearl millet, 40 cm high	15	26	13	31.5	1.0	0.5
Pearl millet, 120 cm high	18	11	12	57.0	1.0	0.5
Sudan grass, 60 cm high	19	29	15	44.5	1.0	0.5
Sudan grass, 120 cm high	24	19	13	77.0	0.8	0.4
Veld grass, Highveld 5 December	35	37	22	106.5	1.5	1.4

Feeds	DM (%)	CP (g/kg)	TDN (%)	CF (g/kg)	Ca (g/kg)	P (g/kg)
Dry roughages						
Veld grass, Highveld 29 December	40	26	26	147.0	1.7	0.8
Veld grass, Highveld 15 February	50	23	29	196.0	2.3	0.3
Veld grass, Highveld 23 March	50	23	27	205.0	2.3	0.4
Veld grass, Highveld 16 April	50	18	25	197.0	1.7	0.3
Wheat, early	30	54	24	46.5	0.6	0.5
Wheat, 5 months	35	30	26	65.5	0.6	0.6
Silages						
Babala silage	25	25	16.0	-	1.4	0.7
Lucerne silage	25	37	15.0	76.5	4.0	0.8
Maize silage	27	30	18.0	81.0	1.0	0.6
Oats silage	25	19	13.2	80.0	0.8	0.7
Oats/lupine silage	25	30	15.0	83.0	1.5	0.5
Potato silage	25	18	15.5	-	0.6	0.5
Concentrates						
Acorns, ripe, dry	88	45	60.0	29.0	-	-
Apple pomace, dry	90	46	65.0	150.0	1.0	0.9
Apple pomace, fresh	10	5	7.0	-	0.1	0.9
Barley, seed and meal	90	90	78.0	61.0	0.6	3.3
Blood meal	92	850	60.0	20.0	3.0	2.5
Brewers grains, dry	90	190	67.0	210.0	2.0	4.5
Brewers grains, wet	25	51	19.0	59.0	0.5	1.4
Carcass meal	93	550	65	14.0	80.0	40.0
Citrus meal	94	50	74	110.0	10.0	1.2
Cotton seed hulls	90	40	47	-	1.3	0.6
Cotton seed meal	92	230	86	-	1.4	6.8
Cottonseed oil cake meal (expeller process)	92	420	80	99.5	2.0	10.0
Cottonseed oil cake meal (solvent process)	94	470	75	131.5	2.5	12.0
Cray fish meal	92	440	28	135.1	152.5	16.5
Fish meal, average	92	600	71	4.5	47.0	26.0
Fish meal, sardine	94	635	72	1.0	44.0	26.0
Fish meal, white	90	640	70	3.5	68.5	37.0
Groundnut oil cake meal (expeller process)	94	445	80.0	94.0	1.8	5.0
Groundnut oil cake meal (solvent process)	94	500	76.0	80.0	1.8	6.5
Linseed oil cake meal (expeller process)	90	320	75	-	4.0	8.0
Linseed oil cake meal (solvent process)	90	340	70	-	3.5	7.5
Lupin seed, blue	90	280	78	124.0	2.1	2.8
Lupin seed, white	90	370	85	100.0	3.0	4.5
Lupin seed, yellow	90	380	82	146.5	2.5	4.6
Maize bran	90	86	70	92.0	0.3	2.7
Maize germ meal (expeller process)	90	100	82	70.0	0.4	5.0
Maize germ meal (solvent process)	94	115	65	60.0	0.4	5.0
Maize gluten meal	92	260	75	80.0	1.3	6.4
Maize head meal	90	75	75	110.0	0.3	1.6
Maize, maize meal	89	85	82	22.0	0.2	2.0
Molasses syrup (for cattle)	75	30	60	-	8.9	0.8
Molasses syrup (for sheep)	75	30	55	-	8.9	0.8
Oats	90	95	67	112.5	1.5	5.0
Potatoes, dry	90	81	71	-	0.5	2.5
Potatoes, fresh	20	18	16	-	0.1	0.5
Skimmed milk powder	92	340	79	-	12.0	10.0
Sorghum ears	90	90	65	90.0	0.2	2.8
Sorghum grain	90	100	80	14.0	0.3	3.5
Sunflower oil cake meal (expeller process)	92	400	74	198.5	4.0	10.0
Sunflower oil cake meal (solvent process)	94	450	70	138.0	4.0	8.0
Triticale	90	140	78	-	0.5	4.5
Wheat	90	120	80	25.0	0.4	4.0
Wheat bran	92	140	62	101.0	1.3	9.0
Wheat bran, fine (pollards)	92	150	65	70.0	0.7	8.0
Wheat germ meal	93	250	82	19.5	1.0	10.0

In closing

A number of feeding tables on the chemical composition of feeds are available in the literature. Presented here, is a table of the chemical composition of feeds commonly used in South Africa. In some tables the chemical composition values of feeds may be presented on a DM or an air dry ("as is") basis. All feeds contain some moisture, including those feeds that seem dry. The quality of feeds with regards to their CP or energy contents should be compared on a DM basis. In most cases, it is accepted that when a diet is balanced for macro-components, it is also balanced for most of the micro-components, like trace elements and vitamins. A mineral pre-mix mixture may be included in the diet in areas with known trace element deficiencies or in dairy herds producing at high milk yield levels (> 35 ℓ per day).

CHAPTER 7

HOME-MIXING OF DAIRY CATTLE DIETS

Introduction

Home-grinding and -mixing of diets for dairy cattle has specific advantages for dairy farmers. Farms producing their own roughages and part of the grain component could save at least 20% on the cost of commercial feeds by milling or grinding grains and mixing specific mixtures on the farm. The lower cost is due to the saving on the overhead cost of producing commercial feeds. To produce high quality diets on the farm requires the application of a number of basic principles. This is to ensure that home-formulated and -mixed diets are similar in quality to commercial mixtures. For this reason, as a first step, farmers should invest in a scale with a weighing accuracy of 1 kg to ensure that individual feeds are weighed correctly before mixing. Farmers, who are not prepared for this capital outlay, should not consider home-mixing of feeds as production will be affected negatively because of incorrect diets. The final home-mixed diet (or mixture) should at all times be as close as possible to the formulated diet. A survey that was conducted at Elsenburg among dairy farmers doing home-mixing showed that many diets were incorrectly formulated, i.e. not appropriate for the group of animals to be fed, usually containing too high or too low protein or fibre levels. The implication of this is that although home-mixtures may be cheaper than commercial mixtures, this advantage will be eroded because of poor production responses by dairy cows.

To formulate diets correctly, good background knowledge of feeds to be used is required. In addition to this, some knowledge is required on the nutrient requirements of animals. It is to be expected that dry or lactating dairy cows should not receive the same diet. Similarly, replacement heifers in different age groups should also not be fed the same diet. Usually the same concentrate mixture can be fed to cows differing in age (lactation number) and milk yield, although, by feeding different amounts per day, specific nutrient requirements of cows are met. Farmers considering home-mixing should keep in mind that milling and mixing of feeds on the farm is an additional farm operation which requires good management to prevent it becoming a cost factor to the whole operation. Someone with the required knowledge of the feeding value of feeds and nutrient requirements of cows should be responsible for the formulating and mixing of diets. Such a person must also ensure that feeds are bought on time and that a complete inventory of feeds is kept up to date. It is therefore incorrect not to include a specific feed when it is not available or to "fix" the mixture by including a lower quality feed at the same amount. For this reason, a complete inventory of feeds must be kept while feeds must be acquired at least once a week to ensure sufficient amounts of feeds are available for an ongoing mixing of feeds.

Inclusion levels of specific feeds

Feeds are usually included at specific levels in diets. This is to prevent digestive problems in cows, while keeping the cost of diets at a minimum level. In Table 7.1 the maximum inclusion levels of some feeds are presented. Inclusion levels are not absolute values, being conservative and should be used as guidelines to prevent digestive problems. It should be kept in mind that the quantity of feeds in mixtures is more important than the proportion of feeds. Farmers should also make use of other sources of information for specific feeds.

Table 7.1. The inclusion level of different feeds in concentrates and total mixed rations (TMR) for dairy cows (Adapted from MacGregor, 1989)

Feeds	Inclusion level (%)		Intake (kg/day)
	Concentrate	TMR	
Animal fat	2 - 3*	3 - 4	0.5 - 1.0
Barley grain	75	40-50	7.0 - 9.0
Blood meal	5	2 - 3	1.0 - 2.0
Brewers' grain (wet)	-	15 - 25	2.5 - 4.5
Canola (full fat milled)	12	8	1.6
Carcass meal	10	4.5	0.5 - 1.0
Cotton seed (milled)	20 - 25	10 - 12	2.0 - 4.0
Cotton seed (whole)	5 - 10*	10 - 15	2.5 - 3.5
Fish meal	10	4 - 6	1.0 - 2.0
Glutenfeed (25% CP)	40 - 60	25 - 40	5.5 - 7.5
Lucerne hay	5 - 10	25 - 50	-
Maize grain	50 - 60	25 - 40	-
Maize grain with milled heads	15 - 25	15 - 25	2.7 - 4.5
Molasses	5 - 10	3 - 5	0.5 - 1.5
Oats grain	50 - 75	25 - 30	4.5 - 75
Prime gluten (60% CP)	15	15 - 30	-
Soy bean oil cake meal (44% CP)	15	15 - 30	-
Sunflower oil cake meal (28% CP)	20 - 30	10 - 15	2.0 - 4.0
Urea	1 - 2	0.5 - 1.0	0.1 - 0.2
Wheat bran	25 - 35	15 - 25	2.7 - 4.0
Wheat grain	25 - 50	20 - 25	4.5 - 6.5

*The total daily intake of whole cotton seed, soy beans and animal fats should not exceed 3 - 4% of the diet

Farm-produced roughages

Roughages produced on the farm should be the basis of formulating diets for dairy cows. Because of the winter rainfall pattern of the Western Cape area, mostly cereal and winter growing crops are produced here. Other crops include vetch, lupines, and serradella, usually grown in rotation systems with cereal grain production, i.e. wheat, barley, and canola. The winter rainfall pattern limits the production of better quality, both in quantity and chemical composition, hay or silage crops such as lucerne or maize silage. Because dairies in this area have increased in size because of economic pressures, roughages like lucerne hay produced in other parts of the country are sourced and transported to the Western Cape. However, because of the bulkiness and quality (in terms of concentrates), transporting roughages over large distances should be avoided as this increases the cost of milk production.

The cost of the total diet of a dairy is reduced when most roughages of the highest quality are produced on the farm, i.e. as close as possible to animals to be fed. Silage bunkers should be put up as close as possible to open camps or housing systems to reduce the cost of transporting silage. The reason for this is that silage contains approximately 65% moisture, which has to be transported to the feed troughs. It is also difficult to transport silage over long distances, like between different farms unless it is ensiled as large round bales. Although bales are covered by six layers of plastic to avoid the ensiled material being exposed to the air which cause mold forming, the plastic wrapping is often damaged during the handling and transportation of the bales. As sealing the damaged plastic wrappings is difficult, it is best to feed the silage as soon as possible, i.e. within 10 - 20 days, to avoid feeding moldy silage. If required to move bales, it should be done once a week.

The most common roughages produced in the Western Cape are oats and triticale preserved as hay or silage. Other roughages include lupine silage, while vetch is also used in rotation programmes for wheat production. These crops are also combined in mixtures usually in an effort to increase the crude protein content of the roughage. Because cereal crops are produced in this area, large quantities of crop residues like wheat, barley and oat straw are available to be used in feeding dairy cattle. In some areas, usually along rivers and reservoirs, it is possible to irrigate crops, pastures, such as ryegrass and kikuyu, are established for grazing either by dairy cows or heifers. Lucerne hay and maize silage are increasingly being produced in some areas where irrigation is available.

In Table 7.2 the chemical composition of a number of ensiled cereal crops are presented. Silage samples were collected from a number of dairy farmers in the Piketberg-Eendekuil area of the Swartland (Muller *et al*., 2000).

Table 7.2. The mean (standard deviation = SD) chemical composition (% of DM) of different silage crops produced in the Piketberg-Eendekuil area of the Swartland (Crude protein = CP, Acid detergent fibre = ADF, Neutral detergent fibre = NDF, Total digestable nutrients = TDN, Calcium = Ca, and Phoshorus = P)

Parameters		Oats	Triticale	Sweet lupines	Barley wheat	Mixtures		
						Oats/ Triticale	Oats/ Barley wheat	Oats/ vetch
Number of samples		34	19	12	9	12	25	12
pH		4.06	3.99	3.98	4.03	4.17	3.98	3.85
CP (%)	Ave (SD)	7.6 (1.8)	9.5 (0.9)	13.5 (1.7)	9.3 (0.05)	8.6 (1.0)	9.2 (1.5)	12.1 (0.6)
	Range	4.7 - 11.3	8.1 - 11.6	11.6 - 16.3	8.4 - 9.9	8.4 - 9.7	5.7 - 13.4	11.3 - 13.3
ADF (%)	Ave (SD)	38.1 (4.8)	38.8 (2.1)	46.3 (3.3)	40.2 (1.5)	37.9 (2.4)	40.0 (2.4)	37.7 (2.4)
	Range	30.8 - 45.7	35.3 - 43.7	39.3 - 51.1	37.9 - 42.5	34.5 - 42.7	34.9 - 44.2	35.0 - 43.4
NDF (%)	Ave (SD)	59.7 (5.3)	60.4 (2.3)	56.4 (2.8)	63.6 (1.7)	61.8 (2.2)	62.3 (2.4)	52.8 (1.7)
	Range	50.0 - 69.2	56.6 - 63.8	51.8 - 62.2	61.4 - 67.5	58.1 - 66.4	58.0 - 66.9	50.9 - 55.7
TDN (%)	Ave (SD)	69.1 (4.6)	62.6 (4.9)	62.7 (3.4)	61.7 (2.1)	66.3 (1.2)	63.1 (4.2)	69.6 (0.9)
	Range	58.5 - 75.7	54.9 - 71.3	55.3 - 67.5	58.8 - 66.2	64.6 - 68.4	56.1 - 70.2	68.2 - 72.1
Ca (%)	Ave (SD)	0.18 (0.04)	0.19 (0.04)	0.68 (0.07)	0.23 (0.02)	0.31 (0.02)	0.24 (0.06)	0.49 (0.11)
	Range	0.16 - 0.18	0.14 - 0.28	0.57 - 0.80	0.18 - 0.26	0.28 - 0.34	0.18 - 0.38	0.36 - 0.77
P (%)	Ave(SD)	0.19 (0.02)	0.25 (0.04)	0.29 (0.03)	0.20 (0.03)	0.23 (0.01)	0.20 (0.03)	0.21 (0.02)
	Range	0.18 - 0.20	0.17 - 0.32	0.25 - 0.35	0.17 - 0.24	0.20 - 0.25	0.16 - 0.30	0.18 - 0.23

The range and standard deviation for the different component crops indicate the large variation in the chemical composition of the different silage crops. The CP content of oat silage is on average 7.6% (on a DM basis), while it varies from 4.7 to 11.3%. The coefficient of variance (CV) indicates the variation in the chemical composition of feeds. The CV for oats, triticale, sweet lupines, barley wheat, mixtures of oats and triticale, oats and barley wheat, and oats and vetch was 24, 10, 13, 1, 12, 16 and 1%, respectively. This is to be expected as silage samples were collected from different farms, the large variation in chemical composition is probably related to difference in soil, rainfall and crop growth stage at time of ensiling. With increasing maturity in forage crops, the fibre content increases, while the CP content decreases. Because of the decrease in digestibility with maturity, due to more lignin forming in plant cell walls, the total digestible nutrients (TDN) content of crops also decreases as plants grow towards maturity.

The effect of the chemical composition of specific roughages can be demonstrated by formulating least-cost diets. The cost of total mixed rations using the maximum values of the chemical composition for oats, triticale, sweet lupine, barley wheat, and a mixture of oats and triticale silage resulted in a saving of 23, 24, 23, 13 and 9%, respectively, vs. the cost when using the minimum values. Similarly, by using sweet lupine silage rather than oat silage, total diet cost is reduced by about 10% because of the higher CP content of the sweet lupine silage in comparison to oat silage.

Pasture vs. hay

Variations of two milk production systems are being used in the Western Cape Province, i.e. a fully or partially pasture-based or a zero-grazing total mixed ration (TMR) system. Because the Southern Cape has a year-round rainfall pattern, milder summer conditions and water available for irrigation from major rivers and mountain run-off streams, pastures can be established for utilisation by dairy cows. The Swartland area has a clear winter rainfall pattern with most rain occurring in the winter, from May to September, resulting in farmers having to use winter cereal crops or lucerne hay imported from other provinces as roughage sources. In this area, it is difficult to cultivate pastures because of limited water for irrigation, while high summer temperatures and the prevailing south-easterly winds reduce pasture production.

Roughage source has a major effect on the composition of total diets for dairy cows. Examples of four such diets are shown in Table 7.3. While all total diets provide the same amount of CP and energy, the roughage component of the diets vary from 35 to 73% for lucerne hay and ryegrass pasture, respectively.

Table 7.3. Total diets containing lucerne hay, oat hay, kikuyu and rye-grass pasture as roughage sources providing similar amounts of protein and energy (Hay equivalent = HE, Cotton seed oil cake meal = CSOCM, and Total digestible nutrients = TDN)

	Roughage source			
Feeds	Lucerne hay	Oat hay	Kikuyu pasture	Ryegrass pasture
Roughage (kg HE)	355	370	475	730
Maize meal (kg)	250	250	200	100
Wheat grain (kg)	215	100	140	100
Wheaten bran (kg)	100	100	100	50
CSOCM (kg)	58	146	65	-
Urea (kg)	5	10	-	-
Salt (kg)	10	10	5	10
Bone meal (kg)	2	4	5	-
Feed lime (kg)	5	10	10	10
Chemical composition				
Crude protein (%)	15.0	15.0	15.0	18.5
TDN (%)	66.0	66.4	66.0	68.5
Crude fibre (%)	14.0	14.1	15.0	18.5
Calcium (%)	0.66	0.60	0.61	0.85
Phosphorus (%)	0.38	0.46	0.40	0.37

The composition of diets differs because of the varying CP and energy levels in the different roughages. Although lucerne hay has a higher CP content in comparison to oat hay, its energy content is lower. The higher CP and energy contents of kikuyu and ryegrass pastures reduces the concentrate portions of these diets. This has a direct effect on the total diet cost, reducing it by 29% and 46%, respectively in comparison to a total mixed ration containing lucerne hay. This means that by using kikuyu and ryegrass pastures as roughage sources, the break-even milk yield level of dairy cows would be reduced. The ratio of the feed costs of TMRs containing oat hay, kikuyu pasture and ryegrass pasture would be 0.88, 0.71 and 0.56, respectively in comparison to a TMR containing lucerne hay. The break-even milk yield level of Jersey cows consuming 15 kg/cow/day at a milk price of R4.50 would be 17, 15, 12 and 9 litres of milk per day for TMRs containing lucerne hay, oat hay, kikuyu pasture and ryegrass pasture, respectively.

Nutrient requirements of dairy cattle

To formulate a diet for dairy cattle, their feeding requirements should be known. This information is available in a number of feeding tables for dairy cows. The most common system being used in South Africa is the nutrient requirements tables of the National Research Council of the USA as provided in the manual: Nutrient Requirements of Dairy Cattle. Different countries have developed their own nutrient requirement tables for dairy cattle.

In Table 7.4 the chemical composition of total mixed rations for different types of dairy cattle is demonstrated. The aim is mainly to indicate the difference in diets for different classes of dairy cattle. Producers formulating their own diets could use this table as a general guideline. Newer information on the nutrient requirements of dairy cattle is available in the 2001 issue of the NRC. This contains more information than is provided here. It is recommended that farmers should use a trained animal nutritionist to formulate diets using the latest information on the nutrient requirements of cows and suitable computer programmes and –models.

Table 7.4. The chemical composition (values on a DM-basis) of total mixed rations for dairy cattle (NRC, 1989)

Live weight (kg)	Fat (%)	Dairy cow diets							Heifers				
		Milk yield (kg/day)											
400 500 600 700 800	5.0 4.5 4.0 3.5 3.5	7 8 10 12 13	13 17 20 24 27	20 25 30 36 40	26 33 40 48 53	33 41 50 60 67	Early lactation cows	Dry cows	Calf starter meal	3-6 months	6-12 months	>12 months	Bulls
TDN (%)		63	67	71	75	75	73	56	80	69	66	61	55
CP (%)		12	15	16	17	18	19	12	18	16	12	12	10
UIP (%),		4.4	5.2	5.7	5.9	6.2	7.0	-	-	8.2	4.4	2.1	-
DIP (%)		7.8	8.7	9.6	10.3	10.4	9.7	-	-	4.6	6.4	7.2	-
CF (%)		17	17	17	15	15	17	22	-	13	15	15	15
ADF (%)		21	21	21	19	19	21	27	-	16	19	19	19
NDF (%)		28	28	28	25	25	28	35	-	23	25	25	25
C (%)		0.43	0.51	0.58	0.64	0.66	0.77	0.39	0.60	0.52	0.41	0.29	0.30
P (%)		0.28	0.33	0.37	0.41	0.41	0.48	0.24	0.40	0.31	0.30	0.23	0.19
Mg (%)		0.20	0.20	0.20	0.25	0.25	0.25	0.16	0.10	0.16	0.16	0.16	0.16
K (%)		0.90	0.90	0.90	1.00	1.00	1.00	0.65	0.65	0.65	0.65	0.65	0.65
Na (%)		0.18	0.18	0.18	0.18	0.18	0.18	0.10	0.10	0.10	0.10	0.10	0.10

TDN = Total digestible nutrients, CP = crude protein, UIP = Rumen undegradable protein, DIP = Rumen degradable protein, CF = Crude fibre, ADF = Acid detergent fibre, and NDF = Neutral detergent fibre

Table 7.4 shows that the composition of the total diets varies according to the nutrient requirements of animals, i.e. whether cows are dry or lactating, as well as the milk yield and fat percentage of the milk of cows. It is well accepted that diets formulated and fed as close as possible to the nutrient requirement of dairy cattle, improves the economic efficiency of the feeding programme of the herd. There is also a number of different feed formulation programmes to derive least-cost rations for dairy cattle.

Voluntary feed intake

Dry matter (DM) intake is fundamentally important in the nutrition of animals as this determines the amount of nutrients available for health and production. It is further important to prevent the under- or overfeeding of nutrients, promoting efficient nutrient use. Underfeeding results in restricting production or growth, while over-feeding increases the feed cost and excessive excretion of nutrients into the environment. A number of factors affect the voluntary feed intake of animals. In some cases, rumen-fill is regarded as the main factor affecting MM intake. This means that the space inside the reticulo-rumen determines the amount of feed cows can consume. For this reason, production will be restricted when poor quality roughages are fed as this fills up the rumen very quickly, while digestion is slower. Even though much research has been conducted in this regard, a high accuracy of the prediction of DM intake has been difficult to achieve because of the large number of factors affecting feed intake.

Although the feed intake of dairy cows is about 3 - 4% of live weight, this may vary according to breed, milk yield, milk composition, stage of lactation, etc. Research at Elsenburg has shown that the feed intake of first lactation Holstein and Jersey cows consume 3.4 and 4.0%, respectively of live weight of a TMR. This means that although the amount of feed Jersey cows consume is less than that of Holsteins, their proportional feed intake is higher. Research in Ireland has shown similar results.

The following equation can be used to estimate DM intake of lactating cows:

DM intake (kg/day) = [1.8% x Live weight (kg)] + [0.33 x 4% Fat corrected milk yield/day] (McCullough, 1989)

At the University of Wisconsin the following equations were suggested:

Early lactation: DM intake = [0.0641 x LW (kg)] + [0.1713 x Milk yield (kg/day)] + [4.534 x Fat yield (kg/day)]

Mid-late lactation: Early lactation DM intake x 1.07

Presently the equation for predicting the DM intake of lactating Holstein cows is as follows (NRC, 2001):

DM intake (kg/day) = (0.372 x FCM) + (0.0968 x $BW^{0.75}$) x (1 – $e^{(-0.192 \times (WOL + 3.67))}$)

where FCM = 4% fat corrected milk (kg/day), BW = body weight, WOL = week of lactation.

The DM intake of lactating cows is affected by ambient temperatures outside the thermal neutral zone, i.e. decreasing at ambient temperatures higher than 25 - 27°C, while providing shade increases feed intake during summer. Cows consume more feed at night because of a longer feeding period and cooler conditions as ambient temperatures are usually well below 24°C from 18:00 in the evening. The feed intake of cows under intensive feeding conditions is affected less than is the case for cows on pasture. This is because the palatability of TMRs can be manipulated to improve feed intake, i.e. adding water, molasses or byproducts like brewers' grains while protection can be provided against the heat and rain. Diets containing higher roughage levels show a greater and more rapid reduction in feed intake with increasing temperatures. This is exacerbated by poorer quality roughage.

Basic feed formulation

Diets are usually formulated to determine whether the current diet is correct or to estimate a diet for a specific group of animals. When cows perform poorly on a specific diet, an alternative diet has to be estimated. In the second case, a diet is estimated for a new group of animals that have to be fed to reach market live weight at a specific age. However, to formulate diets, regardless of animal type, information on their nutrient requirements with regards to crude protein (CP), total digestible nutrient (TDN), crude fibre (CF), calcium (Ca), and phosphorus (P) requirements of animals must be available. This is to determine the content of each specific ingredient in the diet. Such information can be obtained from Table 7.4 or similar sources in the literature. Table 7.4 indicates that a Holstein cow with a live weight of 600 kg producing 30 kg of milk per day containing 4.0% fat would require a total daily diet containing 16% CP and 71% TDN on a DM basis. A Jersey cow with a live weight of 400 kg producing 20 kg of milk per day at 5.0% would require a similar daily diet.

Using the so-called Pearson's square, it is possible to determine the ratio between two feeds to result in a specific mixture or diet. As an example the ratio between maize meal and cottonseed-oil cake meal (CSOCM) is estimated for a mixture containing 15% CP:

Feeds	CP content (%)	Required CP content (%)	Subtract across (High – low)	Ratio (%)
Maize meal	9		42 – 15 = 27	27/33 = 82
		15		
CSOCM	42		15 – 9 = 6	6/33 = 18
Total			27 + 6 = 33	82 + 18 = 100

This means combining 82% maize meal and 18% CSOCM provides a mixture of 15% CP. The same principle can be applied to estimate the amount of maize meal that Jersey cows require on ryegrass pasture for a total diet content of 68% TDN (on a HE basis):

Feeds	TDN content (%)	Required CP content (%)	Subtract across (High – low)	Ratio (%)
Maize meal	82		68 – 66 = 2	2/16 = 12.5
		68		
Ryegrass	66		82 – 68 = 14	14/16 = 87.5
Total			2 + 14 = 16	12.5 + 87.5 = 100

This means that at a daily feed intake of 16 kg per day, Jersey cows require 2 kg of maize meal to increase the energy content of the total diet to 68% TDN. Furthermore, by back-calculation, it is possible to estimate the CP content of a concentrate mixture to provide a total diet containing 15% CP together with 35% oat hay at a CP content of 5%:

Concentrate CP content = ((100 x 15% CP) - (35 x 5% CP))/65 = 20.4%

Although the chemical composition of feeds is presented as percentage values, the ingredients in the DM content of feeds can also be expressed in grams per kilogram, i.e. 15% CP in lucerne hay is equal to 150 gm CP per 1000 g (or 1 kg) of lucerne hay.

To estimate the CP and energy content of specific diets, the following procedure can be used (Table 7.5):

- List all feeds in the total diet together with the chemical composition of each feed. This may include values for CP, energy (TDN), crude fibre, calcium, and phosphorus depending on the information on the diet that is required.
- Multiply the amount of each feed in the diet with its CP or energy content.
- Add the CP and energy values of all the feeds.
- Divide the total CP or energy values by the total of all the feeds in the mixture to determine the chemical composition of the total diet.

Table 7.5. Estimating the chemical composition of a total mixed ration containing different feeds (CP = Crude protein, TDN = Total digestible nutrients, CSOCM = Cottonseed oil cake meal)

Feeds included in total diet	Diet composition (kg)	CP (g/kg)	TDN (g/kg)	CP in diet (kg)	TDN in diet (kg)
Lucerne hay	350	150	500	52.5	175.0
Barley	250	90	780	22.5	195.0
Wheaten bran	130	140	620	18.2	80.6
Gluten feed	100	260	750	26.0	75.0
Maize meal	100	85	820	8.5	82.0
CSOCM	55	420	800	23.1	44.0
Salt	10	-	-	0	0
Feed lime	5	-	-	0	0
Total	1000			150.8	651.6

The total diet shown above contains 15.1% CP and 65.1% TDN on an "as is" basis.

In closing

Although the feed cost of home-milling and -mixing feeds could reduce the feeding cost of dairy cows, this advantage could be eroded when feed formulation and feed sourcing is not done correctly. Home-mixing is another operation on the farm which could result in a work overload. Diets should be formulated according to the nutrient requirements of animals. Overfeeding cows in terms of protein and energy would reduce profit margins.

CHAPTER 8

REARING REPLACEMENT HEIFERS FROM BIRTH TO THREE MONTHS OF AGE

Introduction

In a dairy herd cows calve down on an ongoing basis to start a new lactation period. Cows are milked for about 300 days after which they are dried up for at least 50 to 60 days before the next expected calving date to recover and build-up reserves for the next lactation period. Heifer and bull calves are born from this. Bull calves are usually sold soon after birth, while heifer calves are raised to eventually replace cows leaving the herd. On many dairy farms, the average mortality rate among dairy heifers is high during the first two to three months of age, as much as 25%. In comparison to this, calf mortality in beef herds is low, about 1 to 2%. A possible reason for the difference is related to the different environmental conditions that beef and dairy heifers are born into. Beef heifers are born outside in a relatively clean environment away from other cows while the calf stays with the dam until weaning at six to seven months of age. Dairy heifers are often born in intensive housing conditions while they are removed from the dam soon after birth as the cows have to be milked for milk sales. However, with appropriate housing and good management the mortality rate of dairy calves after birth can be low. Although calves may succumb because of a number of common calf diseases, the reason for their deaths is often related to the reduction of their natural resistance because of stress factors like malnutrition, i.e. not receiving sufficient colostrum soon after birth, low quality milk replacers, being fed high poor quality roughage, and poor hygienic housing conditions.

Housing young calves

The survival and health of dairy calves start with the calving down process and intake of sufficient amounts of colostrum from the mother soon after birth, i.e. within six hours after birth. Dairy cows should calve down in a clean and germ-free environment. The calving down area could simply be a large open enclosure with pasture or a dry soil surface. The area should be exposed to direct sunlight as much as possible. It should not be an area where cows congregate on a regular basis. The ground surface of the calving down area should therefore not be small, wet and/or dirty. The calving down area should also be in close proximity to the dairy to ensure easy access for workers and supervision of the calving down process. Under intensive conditions, cows should have access to a suitable calving down area or individual maternity stalls. The floor of such stalls should be concreted while being rough to prevent cows from slipping. The slope of the floor should be at least 1 to 2% to allow drainage of urine and water for washing down stall walls and the floor. Walls should be plastered so that they can be washed down after each birth process. Electric lighting should be provided with hot and cold running water for washing hands. Generally, the stalls should be easy to clean and disinfect. Besides providing a clean calving down area, well-designed and correctly built maternity pens have the following advantages:

- enable the observation of cows before, during and after birth process;
- enable providing help to cows with calving (dystocia) problems;
- enable providing help to calves to drink a sufficient amount of colostrum;
- provide protection against unfavourable weather conditions;
- prevent the spreading of diseases like contagious abortions because the maternity stalls can be disinfected; and
- enable the washing of the teats and udder of cows that have calved down preventing calves being contaminated with feces.

It is generally recommended that calves be kept in small individual pens up until at least two to three months of age. The pens should have walls approximately 1.0 m high, 1.0 m wide and 1.8 m long. The pens should have concrete floors sloping from the back to the front to allow for drainage of urine, and there should be solid partitions between calves to prevent cross-suckling by calves which may lead to a spreading of diseases. Wet bedding should be removed on a daily basis and replaced with dry bedding. A shed for housing calves in pens should be open to the east or north-east to allow direct sunlight into the building. There should be a row of windows high up in the back wall to allow for ventilation of air inside the building. Important principles for an intensive housing system for dairy calves include the following:

- it should provide good ventilation while protecting calves against cold drafts of air;
- the building should be dry inside while preventing large inside temperature fluctuations; and
- it should be regularly disinfected (preferably by direct sunlight).

Alternatively, calves could be put into individual, portable stalls with the same dimensions as indicated above. These pens, which should partly be covered by roofing to provide shade and protect calves against rain, are usually cheaper and easier to manage. They should also have solid partions between stalls. They should preferably be placed on a slope so that they can be moved up the slope to prevent a build-up of pathogens in the soil.

Feeding

First four days

As soon as possible after birth, i.e. within three to six hours, calves should consume at least 1.5 to 2 litres of colostrum milked from the mother. Holstein calves should drink (or be fed) at least two litres colostrum, while Jersey calves should drink at least 1.5 litres. If the calf is too weak to drink, some colostrum could be milked out by hand and fed to the calf with a teat. The teat and milk container should be clean and properly disinfected before use. Alternatively, a stomach tube could be used to get colostrum into the stomach (abomasum) of the calf. This should, however, only be attempted by a suitably trained and qualified person. The reason for feeding colostrum at this stage is because it contains immunoglobulins (antibodies) that, when absorbed, provide a passive immunity or protection against diseases the dam was exposed to. However, the ability of the calf's digestive tract to absorb these antibodies quickly diminishes after birth and after 24 hours, no further absorption takes place. Another reason why colostrum should be consumed as soon as possible after calving is because the concentration of the antibodies in the milk decreases quickly after birth. About 12 hours after calving, colostrum contains only about 35% of the original number of antibodies.

After 24 hours, the calf is removed from the mother and put into an individual pen. This is to protect the calf from drinking too much milk and getting contaminated by bacteria in the maternity pen. Once the calf is in her pen, she is fed either whole milk or a suitable milk replacer. Colostrum feeding may continue up to four days of age or while the mother is still producing it as it provides some local protection in the abomasum. The daily milk feeding can be done either from a bucket or by using an artificial teat.

Feeding colostrum to calves

Because colostrum has no actual sale value, it can be used successfully for rearing small calves. Modern dairy cows produce large amounts of colostrum, more than what the young calf can consume in the first four days of its life. Many dairy farmers also sell bull calves soon after birth, giving the opportunity for more colostrum to become available for feeding heifer calves. All the excess colostrum can be fed to young calves during the first few weeks of their lives. The composition of colostrum at birth and time after calving in comparison to whole milk is presented in Table 8.1.

Table 8.1. The composition of colostrum and whole milk of dairy cows

Ingredients	Colostrum			Whole milk at 14 days
	At birth	After 12 hours	After 24 hours	
Total solids (%)	24.0	18.0	14.0	13.0
Fat (%)	6.7	5.4	4.0	4.0
Non-fat solids (%)	16.7	12.0	10.0	8.8
Total protein (%)	14.0	8.4	5.0	3.0
Lactose (%)	2.7	4.0	4.4	5.0
Minerals (%)	1.11	0.9	0.8	0.7

The total solid content of colostrum at birth is almost double that of whole milk because of higher fat and protein contents. The lactose content of colostrum is about half of that of whole milk. This is apparently the reason why colostrum does not cause diarrhea in small calves. Because colostrum contains such a large amount of solids, it can be diluted with water before feeding to older calves. The dilution will depend on whether the colostrum was from day one, day two, or longer after calving. Colostrum collected on the first two days after calving can be diluted in the ratio of two parts colostrum to one part water. This can be fed at the same level as whole milk. Diluted colostrum should, however, not be fed to day-old calves.

Colostrum can also be preserved as follows:

a. Freezing – it can be stored for up to six months in this way;
b. Fermenting – this must be stored at 4°C in a cool room;
c. Alternatively, after fermenting, 1% propionic acid or 0.7% acetic acid can be added, stirred well and stored in a cool place. Colostrum treated like this can be stored for a few months, as long as the ambient temperature does not exceed 21°C.

Before feeding, water should be added as indicated above. Fresh and fermented colostrum should preferably not be combined before feeding. Plastic containers are suitable for keeping fermented colostrum. When no colostrum is available, one whipped egg may be mixed with 300 mℓ water, which is then mixed with one teaspoon of castor oil in 600 mℓ whole milk, can be fed to calves at body temperature (39°C) three times a day. Water should be added before feeding to calves.

Post colostrum feeding to weaning

Calves should be weaned from milk onto dry feed as soon as possible as this reduces their feeding cost while feeding management is easier. However, at birth the digestive tract of a calf is similar to that of a monogastric (single-stomach) animal because the rumen is still undeveloped. Milk goes through the oesophageal groove straight to the fourth stomach, or abomasum, where the digestion of milk takes place. At this stage, calves are unable to digest roughages or to utilise any non-protein products such as urea. For early weaning, the rumen of calves should be developed. This is done by feeding calves dry feed from about seven days of age. They have to be trained to eat such feeds as they do not have the example of their mothers teaching them how and what to consume. The crude protein content of such a concentrate feed or calf starter meal should be about 18%.

To do this successfully, the following should be done:

a. Give calves, in two feedings per day, a daily amount of whole milk or milk substitute at 10% of the calf's body weight. Holstein calves weighing 40 kg at birth should get 2 ℓ of milk in the morning and 2 ℓ of milk in the afternoon. The quantity of milk is not increased as the calf grows older. This will further stimulate the calf to increase its dry feed intake as its nutritional requirements increase with age.

b. Provide a tasty calf starter meal from about seven days of age. This could be provided in a container that is put in the same place where the calf gets its milk twice a day. After drinking the milk, the calf should be introduced to eat the meal by rubbing some of it onto its mouth.

c. Provide initially only a small quantity of fresh meal every day. The calf starter meal should not remain in the feed trough for long periods of time as it usually becomes mouldy because it contains a large quantity of starch. Feeds that have become mouldy and hard are unpalatable and unhealthy. Calves will eat little of such meal.

d. Provide fresh drinking water, on a daily basis, in clean containers. Keep the water away from the calves for one hour before and after milk feeding. This is to prevent calves from overdrinking as this could cause stomach upsets.

e. As soon as calves consume about 0.7 kg of the calf starter meal per day, usually at about five to six weeks of age, she can be weaned from milk. After weaning, the intake of dry feed increases rapidly.

f. From about one month of age, a small amount (about half a kilogram) of good quality lucerne hay can be fed to calves on a daily basis. This will increase the dry feed intake further while stimulating the development of the rumen. After weaning and up to three months of age, calves should receive the calf starter meal on an *ad lib*-basis, while 0.5 kg of lucerne hay is also provided daily. Clean, fresh drinking water should be provided daily as well. At this stage, no low grade roughages should be fed to calves as this will slow down their growth rate.

In closing

The level of management is the most important factor affecting the survival of intensively reared young calves.

Management should focus on the housing, feeding and the health of calves. It usually pays to have someone with keen observation skills to inspect all the calves each day with the aim of identifying problems early. The following aspects of calf rearing should also be attended to:

- Identify calves by attaching a durable plastic tag in each ear. Tags should contain all relevant information on the identity of the calf. Registered Jersey calves should be tattooed as required by the breed society.
- Surplus teats in heifers should be removed as soon as possible. Clean the wound and close with a stitch. Consult a veterinarian in this regard.
- At four to six weeks of age, calves can be dehorned by cauterising the horn buds. Consult a veterinarian in this regard.
- Calves should be inoculated against Anaplasmosis and Brucellosis at four to five months of age. These inoculations can be done simultaneously.

CHAPTER 9

REARING HEIFERS FROM THREE MONTHS OF AGE TO FIRST CALVING

Introduction

Most dairy farmers rear all the heifers born in the herd to first calving as they are required to replace cows that, over time, are culled from the herd. This is preferred to the custom of purchasing heifers from other producers for the following reasons:

- Breeding a high producing dairy herd requires the selection of animals according to their production performance. For this reason, information on the pedigree and production records of such animals is very important. Information on dams and sires of purchased heifers is sometimes unavailable; consequently, their genetic merit would be unknown.
- Purchased animals may carry infectious diseases, like brucellosis (contagious abortion) and bovine tuberculosis, with them.
- The purchase price of heifers is often higher than own rearing cost, while also not in relation to their eventual production performance.
- Heifers are not always available to buy when required in a herd. For home-grown heifers, forward planning is easier, because the number of first lactation cows entering the herd is known well in advance.
- Heifers reared locally are usually adapted to a particular farm's environment and management.

Feeding programme

Feeding is the single most important factor affecting the growth rate of heifers. Reaching minimum live weights at a specific age is important in heifer rearing as this is an indication of their physiological and skeletal development. For heifers, both over- and underfeeding is detrimental. As the nutritional requirements of heifers increase as they become older, their feeding programme (and diets) should be adjusted according to their age. Grouping heifers within specific age groups makes feeding management easier as a specific diet can be formulated according to the nutrient requirements of the heifers within the age group. The amount of feed being fed per day can also be adjusted according to the age group. Feeding tables that are generally being used to formulate diets provide information on the expected daily dry matter intake, protein, energy, and mineral requirements for heifers according to their live weight and expected growth rate. Provision is also being made for large and small breeds, usually being Holsteins and Jerseys. Because the availability of feeds varies among farms, specific diets for heifer rearing are not provided here. At best, general guidelines are provided. Feeding of heifers is generally done according to the following age groups:

- 3 to 6 months of age,
- 6 to 12 months of age,
- 12 months to late gestation, and
- the last 3 months before calving.

Three to six months of age

Heifers in this age group may be put in small groups inside suitably sized pens within a shed or outside in open camps. Preferably, groups should consist of heifers of similar age. The age difference between heifers within a group should not be more than two months. At this stage, the rumen is not yet fully developed and therefore during this stage, the heifers should receive a high quality growth meal (or pellets) and good quality roughage in the form of pasture or legume hay. Feeding young heifers in this age group low quality feeds, such as straw or chaff, or keeping them on stubble fields or fallow lands containing little plant material without giving them extra feed will be extremely detrimental to their skeletal development and growth rate. When pasture is not available, the best option would be to formulate and mix a suitable total mixed ration which is then fed *ad libitum* on a daily basis. Alternatively, high quality roughage, such as lucerne hay, grass-legume hay, or grass-clover pasture, can be fed together with calf growth meal at a rate of approximately 1.5 to 2.0 kg per heifer per day.

Six to twelve months of age

At this stage, the rumen is fully developed and heifers are able to utilise roughage effectively. High quality roughage, such as cultivated pasture, silage, and/or hay, should be the most important feed source. Also at this stage, poor quality roughages and inadequate or a low feed intake are the most important reasons for poor growth and malnutrition. If no high quality roughage is available, the best option would be to provide a total mixed ration formulated to satisfy the nutritional requirement of heifers.

From twelve months of age to first calving

Depending on the type, quantity and quality of roughage available, any of the following feeding programmes can be followed at this stage:

Programme 1: using good quality hay

Provide good quality legume hay (lucerne) or cultivated pasture, plus one kg of maize meal (or small grains) per day until first service. Concentrate feeding is then stopped until three months before expected calving dates after which heifers should again get one kg of dairy meal per day.

Programme 2: using medium quality hay

Provide hay of a medium quality (containing about 6% of crude protein on a DM basis) plus two kg per day of concentrate containing 16% crude protein until first service. After conception, heifers could be fed one kg of growth meal per day in addition to the medium quality hay. From about three months before their expected calving dates, heifers can be fed two kg of a growth meal per day in addition to the medium quality hay.

The additional concentrates being fed during the last three months before calving are extremely important as the nutritional requirement of the heifer increases drastically because foetal and placental growth takes place during this time. As heifers at this stage tend to increase their body condition, the amount of concentrates should be limited.

An early age at first calving

Heifers should start their productive lives as early as possible, as this is the only way to save on their rearing cost. However, many dairy farmers believe that replacement heifers should be fed at a low level to prevent fat accumulation in the udder. There is a general perception that heifers being fed supplementary feeding in the form of concentrates do not grow in size, but rather gain weight because of fat accumulation. Although this is indeed the case for older heifers that have already reached target live weights and which are fed diets containing high levels of concentrates, this does not apply to younger heifers which are in a growing phase. Comparing heifers which are at the same age, faster growing heifers tend to have more body fat, although comparing heifers at the same live weight, there is little difference between them with regard to body fat. One should, however, guard against an excessively high growth rate, as this could cause fatty deposits in the udder. If this occurs before puberty, milk production will be adversely affected. In Table 9.1 a summary of the expected growth rate and target live weights of heifers of various dairy breeds is provided.

Table 9.1. The expected growth rates and target live weights of heifers from different dairy breeds at specific development stages i.e. at conception (15 months of age) and at first calving (24 months of age)

	Breeds			
Parameters	Holstein	Jersey	Ayrshire	Guernsey
Birth weight (kg)	40	25	32	30
ADG* 0 to 12 months of age (kg/day)	0.60 - 0.70	0.40 - 0.45	0.50 - 0.575	0.45 - 0.50
ADG* 12 to 24 months of age (kg/day)	0.70 - 0.75	0.50 - 0.55	0.60 - 0.65	0.55 - 0.60
Live weight at 15 months of age (kg)	320 - 365	215 - 240	270 - 300	245 - 265
Live weight at 24 months of age (kg)	515 - 570	355 - 390	435 - 480	390 - 435

*ADG: average daily gain

Research has shown that the size of the pelvic opening in heifers calving down at a live weight of 584 kg, while differing in age at first calving, is similar. In this study, two groups of heifers were fed different diets to reach similar live weights at first calving although at different ages, i.e. 22.4 and 24.6 months of age. Heifers calving down earlier were on a higher feeding level. Following first calving, all cows were treated the same. During first lactation, the milk yields of cows that differed in growth rate as heifers were similar. However, their production per day of life differed, being 10.0 vs. 9.3 kg for the heifers calving down at 22.4 and 24.6 months of age, respectively. The reproduction performance of cows during first lactation was also the same regardless of age at first calving. The main benefits for an earlier age at first calving was a reduction in the feeding cost of heifers and a higher milk yield per day of life. Both these factors affect the lifetime performance and efficiency of dairy cows.

Feed is converted to body weight more efficiently when animals are on a higher growth rate. This is because a smaller portion of the feed is being used for maintenance requirements, while a larger portion is used for growth (live weight gain). Heifers have to grow as quickly as possible in order to reach sexual maturity to be serviced for the first time. Therefore, for heifers, live weight at first service (and conception) should be reached at the earliest possible age. However, if heifers conceive at an early age while not having reached expected live weights, their milk yield during first lactation will be affected negatively. Moreover, the possibility of calving problems (dystocia) may occur. It is for this reason that it is recommended that heifers should preferably not calve down earlier than 22 months of age. Research indicated that heifers, which had calved after 22 months of age, produced an additional 73 ℓ of fat-corrected milk per month during their first lactation.

Recent research (Muller & De Waal, 2016) based on almost 400 000 Holstein cows in the National Milk Recording Scheme showed that age at first calving had a positive effect on the lifetime (number of days from birth to cull date) and a negative effect on the productive lifetime (number of days in milk in all lactations) of dairy cows (Figure 9.1a). The productive lifetime of cows initially increased, reaching a peak at 29 months of age, after which it decreased. This means that the productive lifetime of heifers calving down after 29 months of age was shorter than that of heifers calving down earlier. The lifetime milk production of cows increased from 20 to 25 months of age after which production decreased. The lifetime and productive lifetime efficiency of dairy cows initially increased up to age at first calving of 24 to 25 months of age after which both traits decreased (Figure 9.1b). Results showed that the lifetime and productive lifetime efficiencies of cows calving down for the first time at 27 and 30 months of age, respectively, was less than that of heifers who had calved down earlier at 21 months of age. This means that heifers should calve down earlier (before 24 months of age) rather than later at 30 months of age.

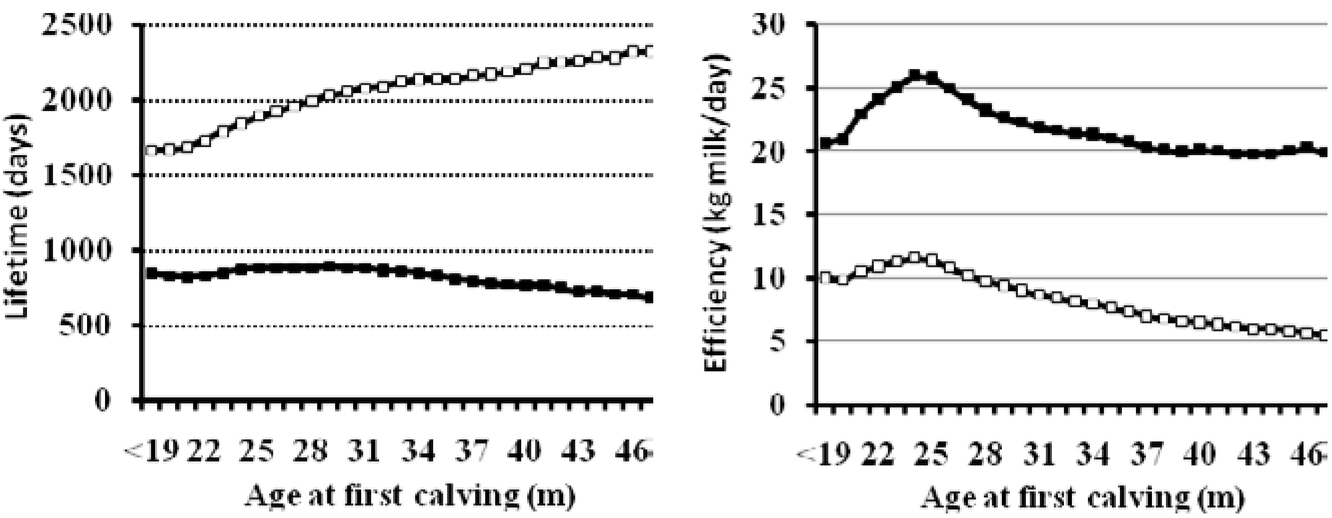


Figure 9.1. The effect of age at first calving of heifers on (a) the lifetime (□) and productive lifetime (■) and (b) the lifetime (□) en productive lifetime efficiency (■) of Holstein cows

The size and body condition of heifers at first calving have a significant effect on their production during their first three lactation periods (Table 9.2). From these results, it can be concluded that heavier heifers at first calving produce more milk during their first three lactation periods. There are mainly two reasons for this, namely, (i) heavier heifers have more body fat reserves to supply their energy needs during the first three months of the first lactation, and (ii) because heifers are closer to their mature live weights, less feed is being used during first lactation for growth towards mature live weight. Usually in early lactation, cows do not consume enough feed for the natural increase in milk yield towards peak production. For this reason they require a sufficient amount of body reserves to enable them to produce high levels of milk, generally described as milking off their backs. The benefit of a higher live weight at first calving lasts up to third lactation.

Table 9.2. The effect of heifer live weight at first calving on milk production during the first three lactations

Lactation number	Extra number of litres of milk produced per lactation for each 1 kg of higher live weight at first calving		
	Per kg	Per 50 kg	Cumulative total
1	8,7	435	435
2	7,6	380	815
3	6,6	330	1145

The reason heifers that are growing too quickly produce less milk during first lactation, is that fatty tissue rather than udder tissue is deposited in the udder. This may occur before or during puberty. The composition of the udder tissue of Holstein heifers that were fed at different feeding levels is shown in Table 9.3. The results show that heifers growing at a slow rate during the first year of life (0.58 kg/day) and a high live weight gain (0.84 kg/day) during gestation, had the largest udders and more milk secreting tissue (parenchyma) than heifers growing at different rates. A high growth rate in heifers, at about 1.0 kg per day during the first 12 months of age although having heavier udders, resulted in the lowest milk secreting tissue in their udders. On the other hand, heifers, at a low growth rate during gestation, also produced less milk-secreting tissue. Therefore, it is generally recommended that the live weight of Holstein and Jersey heifers should, before being served, not be higher than 0.75 kg/day and 0.45 kg/day, respectively.

Table 9.3. The composition of the udder tissue of Holstein heifers fed at different feeding levels and slaughtered at 250 days of gestation

Parameters	Feeding level		
	LL	LH	HL
Weight of udder (kg)	6.4	9.0	6.8
Milk secreting tissue (kg)	4.0	5.4	3.2
Milk secreting tissue (%)	63.7	61.0	49.6
Udder as % of live weight	1.53	1.82	1.39
Live weight gain up to 12 months of age (kg)	0.58	0.58	1.03
Live weight gain during gestation (kg)	0.68	0.84	0.58

LL: Low live weight gain during the first year and gestation
LH: Low live weight gain during the first year and high live weight gain during gestation
HL: High live weight gain during the first year and low weight gain during gestation

It should be noted that a combination of live weight, condition score and live weight gain (growth rate) is critical when rearing heifers to reach their full genetic potential. It is therefore essential that heifers are weighed regularly in order to monitor their growth. Various methods are available for weighing heifers. A scale should preferably be used, as the available weigh bands are not very accurate. It is also difficult to estimate live weight of heifers with the naked eye.

Heifers should preferably be weighed at least once a month. Their body weight should be recorded and compared to an ideal growth curve in order to make adjustments in the feeding programme if necessary. In Table 9.4 the suggested girth (chest) circumference, live weight and shoulder height of heifers of various dairy breeds at specific ages are presented.

Table 9.4. The suggested girth circumference, live weight and shoulder height of replacement heifers growing at the lowest live weight gain for different dairy breeds

Age (months)	Holstein			Ayrshire/Guernsey			Jersey		
	Girth (mm)	Live weight (kg)	Shoulder height (mm)	Girth (mm)	Live weight (kg)	Shoulder height (mm)	Girth (mm)	Live weight (kg)	Shoulder height (mm)
Birth	735	40	635	-	32/30	685	-	25	660
1	810	58	785	660	47/44	760	-	37	685
2	915	77	865	810	62/57	815	785	49	760
4	1 120	113	990	1 105	93/85	915	965	74	865
6	1 270	150	1 065	1 145	123/112	990	1 120	98	965
8	1 400	186	1 120	1 270	154/140	1 040	1 220	122	1 015
10	1 500	223	1 170	1 400	184/167	1 090	1 320	147	1 065
12	1 575	259	1 220	1 475	215/194	1 145	1 410	171	1 090
14	1 640	302	1 245	1 525	251/228	1 170	1 475	202	1 120
16	1 690	344	1 270	1 575	288/261	1 195	1 510	232	1 145
18	1 730	387	1 295	1 625	324/295	1 220	1 550	263	1 170
20	1 780	429	1 320	1 675	360/328	1 245	1 600	293	1 195
22	1 815	472	1 345	1 700	397/361	1 270	1 625	323	1 220
24	1 865	515	1 370	1 750	434/395	1 295	1 675	354	1 245

In closing

- Heifers should be grouped according to age, especially when they are being fed. Age differences within any one group should preferably be limited to a maximum of two months. The reason for this is that smaller heifers are intimidated by larger heifers, with the result that their voluntary feed intake is reduced.

- Heifers do not require sophisticated or expensive housing. However, grouping them in small paddocks should be prevented as the ground surface quickly becomes wet and dirty. Protection against extreme temperatures and particularly the provision of shade on hot summer days are essential.

- Correctly designed and well-built feed troughs should be provided for feeding heifers in order to prevent injuries and feed wastage. Trough space should be fitted to the size of heifers within each specific age group, i.e. 600 mm for older heifers.

- Calves and heifers should be weighed or measured regularly, at least monthly, in order to monitor their development and growth. A growth curve of each heifer's live weight gain in comparison to her age at weighing should be kept. By comparing the live weight gain of heifers to an ideal growth curve, the efficiency of management can be monitored. This will ensure that adjustments to feeding programmes, amongst other things, could be made well in advance before they have a lasting detrimental effect on the animal's growth and performance.

- Heifers should be treated calmly and quietly with workers moving amongst them daily. This should particularly be done during the last three months before the expected calving date. If practically possible, heifers should be introduced at an early age to the milking parlour environment, so that they become familiar with the facilities and daily routine. This can be done by keeping the heifers with dry cows in late pregnancy, i.e. the steam-up group. Usually these cows are fed a specific steam-up dairy meal in the milking parlour. This means that they visit the dairy at least twice a day. A wild, uncontrollable heifer at first calving suffers enormous stress, and this could be extremely detrimental to her production during her first lactation, while also affecting the mood in the milking parlour upsetting other cows.

- Before the age of one month, heifer calves should be dehorned with a branding iron and extra teats should be removed.

- A vaccination and immunisation programme, compiled in collaboration with a local veterinarian, should be followed according to instructions.

- Vaccinating heifer calves against contagious abortion (*Brucellosis*) at five months of age is compulsory by law and is also essential because the cows cannot be vaccinated for this disease at a later stage.

CHAPTER 10

MANAGING REPLACEMENT HEIFERS TO FIRST CALVING

Introduction

Rearing replacement heifers from birth to first calving is an important part of a dairy herd as this supports genetic progress and herd growth. Cows must calve down to start a new lactation period. Heifer or bull calves are born from this. While bull calves are usually marketed soon after birth, heifers born in the herd are reared to be taken up into a dairy herd at first calving, replacing cows that, over time, are culled from the herd. At low culling rates of dairy cows, surplus heifers could also be a source of income for a dairy herd. Although being regarded as important, heifer rearing is often neglected, getting less attention than required. This is observed as a high age at first calving, often past 27 months of age and in some cases, as high as 30 months of age. This problem is often further exacerbated by lower than expected live weights at first calving. The rearing cost of heifers increases when age at first calving is later than 24 months of age, while low live weights at first calving have a negative effect on the milk yield of cows in first, and in some cases, second lactation. Heifers reared well are well developed at 24 months of age which results in little benefit at a later age at first calving. A low live weight at first calving is a problem, because cows keep on growing towards their genetic potential. This means that feed consumed during the lactation period is used for growth rather than to produce milk. The aim of heifer rearing should be to reach a live weight of at least 90% of mature live weight at first calving at about 24 months of age.

The main reason farmers find it difficult to manage this part of a dairy herd efficiently is probably because rearing heifers is a major cost factor, while not providing a direct income as is the case with lactating cows. Heifer rearing should be regarded as a long term investment. A lower than expected milk yield during first lactation is usually the result of a low feeding level during the heifer rearing period. Therefore, the milk production profit or loss of well or poorly reared heifers is not as obvious as is the case when feeding a high quality diet to dairy cows. Poor heifer rearing increases the overall production cost of milk on a dairy farm, through a late age at first calving, low live weights at first calving, a higher number of heifers than cows (because of a late age at first calving) and slow herd growth rate because of a low survival of heifers to first calving. Although the feeding cost of heifers has the largest effect on rearing cost, reproduction management and the survival of heifers from birth to first calving also affects their rearing costs.

Feeding management

Dairy farmers tend to keep the cost of heifer rearing as low as possible. Although this is to be expected, this should not be done by using a low feeding level as this extends the interval from birth to first service and because of that, a later age at first calving. Recent research has shown that the lifetime efficiency of dairy cows is affected by age at first calving, i.e. increasing from 18 months of age and peaking at 23 - 24 months of age. Increasing the age at first calving reduces lifetime efficiency to levels below an early (less than 20 months) age at first calving.

Heifers at higher growth rate reach target live weights for breeding at an earlier age, i.e. Jersey heifers growing at 0.35 and 0.45 kg/day reach a live weight of 200 kg at 16.4 and 12.8 months of age, respectively. Although the daily feeding cost of heifers growing at a faster growth rate is higher, the total feeding cost of heifers to first calving is lower because of a shorter feeding period. It should be kept in mind that heifers, in order to calve down at or before 24 months of age, should be pregnant by 15 months of age. This means that putting heifers at 15 months of age into a service group would result in a later age at first calving.

The feeding programme of heifers tends to be similar in most dairy herds, i.e. calves receiving colostrum at birth, after which full cream milk or a milk replacer is fed until weaning at about two to three months of age. Weaning from milk is usually done once calves consume at least 0.7 kg of a calf starter meal per day. After weaning, the intake of the calf starter meal increases quickly. A growth meal containing less CP and energy than the calf starter meal is fed from about four months of age. From six months of age, the feeding programmes of heifers usually vary between farms, as each farmer has its own system. This may be a highly intensive system using total mixed rations according to age and expected growth rates to an extensive feeding system, putting heifers on natural grazing, which is usually a low quality diet on a remote part of the farm.

At 12 - 13 months of age, heifers should be weighed and put into a service group for artificial insemination if they have reached breed specific live weights, i.e. 200 kg for Jersey and 300 kg for Holstein heifers. It is recommended that a nutritionist should be consulted to develop a suitable feeding programme for dairy heifers and that their growth rate be monitored on a regular basis. This means that heifers should be weighed at least once a month and that their feeding programme is corrected when heifers grow too slowly or too quickly. A simple graph showing the live weight of all heifers against their age at a specific weighing date usually gives a quick indication of the success of the feeding programme of heifers (Figure 10.1).

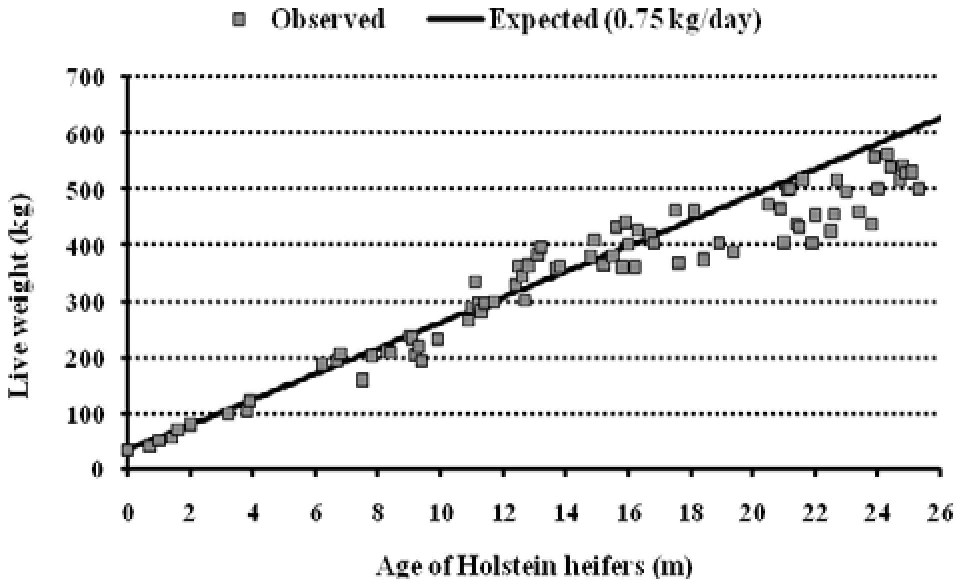


Figure 10.1. The observed live weights of Holstein heifers between birth and 26 months of age in comparison to an expected growth rate of 0.75 kg per day

Figure 10.1 shows that the live weight of heifers up to 16 months of age is within the target range, although heifers older than 17 months of age have lower live weights than the expected live weights. In this herd, heifers are being fed specific diets suitable for each age group. Once confirmed pregnant, usually at about 18 months of age, heifers are put with the dry cows until first calving. This means that the diet heifers receive during the gestation period is not sufficient to ensure a sufficient growth rate to first calving. This results in heifers calving down at live weights below breed standards which will have a negative effect on their milk yield in first lactation. The figure also shows that a number of heifers are already past 24 months of age, which indicates a later age at first calving for these heifers. Weighing heifers regularly is an indirect way of monitoring their feed intake and whether diets provide sufficient protein and energy. The only way to save on the feeding cost of heifers is to reduce the age at first calving.

The reproductive programme of heifers

Getting heifers pregnant early is an important way to reduce the age at first calving. Usually heifers are put into a service group once they have reached a specific age or live weight. This could be 200 kg for Jersey or 300 kg for Holstein heifers. Depending on the efficiency of heat detection, the breeding (service) period of heifers could be about two to three heat cycles, i.e. 42 to 63 days. When the heifer reproduction programme is poor, i.e. heats being missed or insemination failure, the service period would be longer, resulting in a later age at first calving, even though first service may be early. The group of heifers to be inseminated should be kept close to the dairy for easy heat detection. They should be in a separate camp from younger heifers and heifers that have been confirmed pregnant. Stickers or paint could be applied to the tail-head area for easier heat detection, while the inseminator should observe heifers at least twice a day for standing heat. In some cases, a catch-up bull may be put with the pregnant heifers to service heifers that have had a resorped embryo.

The pregnancy rate of heifers should be monitored at least monthly to determine the success rate of inseminators, as well as the general breeding programme. A list of all the heifers in the herd should be kept up to date with information about their name or number, birth date, first and last insemination date and whether she is pregnant or not. From this list a number of variables can be estimated, i.e. the age of heifers, age at first insemination, age at conception, the number of inseminations per conception, the expected calving date, age at first calving, as well as the proportion of heifers being inseminated for the first time before 15 months of age and the proportion of heifers that are confirmed pregnant by 15 and 17 months of age. Included is a table showing information on the reproductive performance of heifers in a dairy herd.

Table 10.1. The reproductive performance of heifers in a Holstein herd

Parameters	Values
Age at first insemination (months)	17.9
Proportion of heifers inseminated before 15 months of age (%)	22
Inseminations per conception	1.50
Insemination efficiency (%)	67
All inseminations per conception	2.91
All insemination efficiency (%)	34
Age at conception (months)	18.5
Proportion of heifers confirmed pregnant older than 15 months of age (%)	36
Expected age at first calving (months)	27.8

Table 10.1 shows that average age at first service was about 18 months of age and that only 22% of heifers were inseminated before 15 months of age. While the number of inseminations per conception was 1.50 for an insemination efficiency of 67%, a different efficiency indicator, e.g. all insemination efficiency, was only 34%. This indicator includes all the inseminations that have been done on all the heifers up to a specific date divided by the number of confirmed pregnancies. This means that a number of heifers have had more than two inseminations while not being confirmed pregnant. This can be related to poor heat detection or poor inseminator techniques. In this herd only 36% of heifers older than 15 months of age are confirmed pregnant. Because age at conception is only 18.5 months, the expected age at first calving would be almost 28 months of age.

The survival of heifers to first calving

The survival of heifers to first calving receives very little attention as most dairy farmers only consider calf mortalities around calving and up to weaning. The number of heifers reaching first calving has a direct effect on the rearing cost of heifers, as well as the genetic progress and growth of a dairy herd. Heifer survival is defined as the number of heifers reaching first calving in relation to the number of heifers born in a specific year. The effect of heifer survival on the increase in the number of cows in a herd is shown in Figure 10.2.

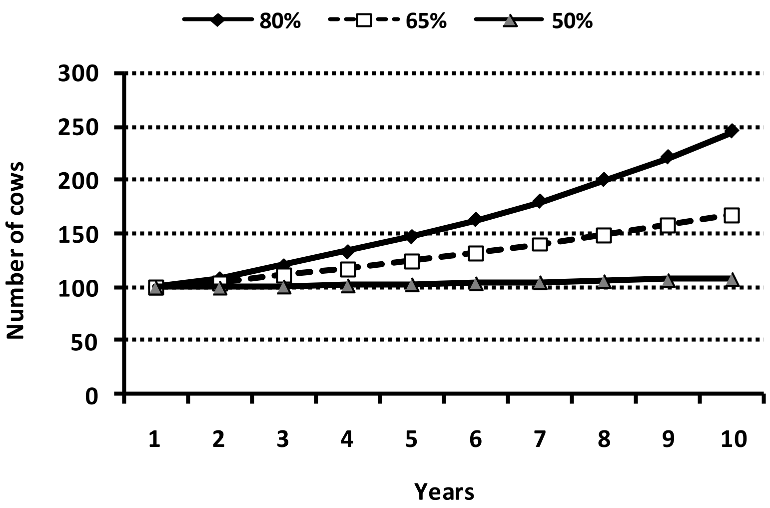


Figure 10.2. The effect of heifer survival to first calving on the number of cows in a dairy herd over a 10 year period

From a base herd of 100 cows, heifer survival from birth to first calving ranging from 50 to 85%, results in an increase in the number of cows in the herd from 108 to 245 cows in year 10. This is important because the age when heifers are lost from the herd determines the mortality cost of heifers which should be regarded as part of their rearing cost. Usually, the attention of dairy farmers is well fixed on the survival of heifers at calving and up to weaning, while the number of heifers lost past weaning to first calving is often not considered. In the Elsenburg dairy herd, it was found that although most deaths of heifers occur in the first month after calving, 46% of heifer loss due to various reasons occurs after six months of age. Although the survival of heifers from birth to first calving varies annually, on average only 65% of heifers born survive to first calving. As the feeding cost of heifers increase with age, the number of heifers lost to first calving has a major effect on the rearing cost of heifers. The mortality cost of heifers includes feeding, labour, veterinary, and insemination costs up to the age of culling. Information about this could be determined by keeping a cull list up to date of all the heifers leaving the herd. From this the reason and age of culling could be determined.

A study in the UK showed that about 15% of heifers do not survive to first calving. This implies a survival rate of heifers born alive of 85%. The reason for heifers leaving the herd before first calving is presented in Table 10.2.

Table 10.2. A summary of reasons for dairy heifers failing to reach first calving

		Heifers born not reaching first calving (%)	
Stage	**Description**	**Mean**	**Range among herds**
Perinatal	Stillbirth < 24 h	7.9	2.7 - 14.3
Neonatal	Died 24h to 28 days	3.4	0 - 12.1
Calves	Died or culled 1 - 6 months	3.4	0 - 28.6
Heifers	Died or culled 6 m - breeding	3.5	0 - 18.5
Heifers	Died or culled breeding - calving	4.2	0 - 21.1
Overall	Heifers born failed to calve down	14.5	0 - 28.6

In closing

The cost of rearing heifers in a dairy herd is about 20% of the production cost of milk. The only way to reduce this cost is to maintain a high growth rate without heifers becoming over conditioned for an early age at first calving. The reproduction performance of heifers also affects the age at first calving, while the survival of heifers to first calving affects the genetic progress and herd numbers, as well as the rearing cost of heifers.

CHAPTER 11

FEEDING LACTATING DAIRY COWS

Introduction

The correct feeding of dairy cows is the cornerstone of a successful dairy farm. The feeding cost of dairy cows in a herd constitutes approximately 60 - 75% of the total production cost of milk. As milk is the main source of income for a dairy farm, the total daily milk yield and the feeding costs of all the animals in the herd are therefore the main factors affecting the farm's profitability. For this reason, cows with the highest genetic merit for milk production should be used in the herd. These cows should be fed in such a way that the highest milk yields are produced at the lowest feeding cost. Cows producing the most milk at the same concentrate level use less feed for maintenance resulting in a higher gross margin above feed cost (Table 11.1).

Table 11.1. The effect of the daily milk yield on feed intake, feed cost, percentage used for maintenance requirements and income above feed costs for a 400 kg dairy cow (Adapted from Hinders, 1995)

Milk yield (kg/day)	Feed intake (kg/day)	Feed cost* (R)	Maintenance (%)	Income* (R)
0	10.1	26.26	100	–26.26
5	11.0	28.60	71	–12.60
10	11.9	30.94	54	1.06
15	14.1	36.66	44	11.34
20	15.8	41.08	37	22.92
25	17.6	45.76	32	34.24
30	19.4	50.44	29	45.56
35	22.0	57.20	25	54.80

*Feed cost: R2.60/kg, Milk price: R3.20/ℓ

Table 11.1 shows that the daily feeding cost of a cow producing 15 kg/day is R36.66. Maintenance requirements constitute 44% of the total feeding costs and the gross margin above feed cost is R11.34. Similarly, the feeding cost of a cow producing 30 kg/day is R50.44, while its maintenance requirements constitute 29% of the total feeding cost, while the gross margin above feed cost is R45.56. This means that although the feeding cost of the higher-producing cow is 37% higher than that of the lower-producing cow, the portion of the feed used for maintenance is 34% less. The milk income above feed costs is therefore four times higher for the higher producing cow.

The lactation curve

The milk yield and milk composition of dairy cows follow a specific pattern (Figure 11.1). The greatest challenge in feeding dairy cows is to feed them according to the lactation curve in order to optimise milk yield and profitability. Naturally, this means that cows should not at any stage during the lactation period be either over- or underfed.

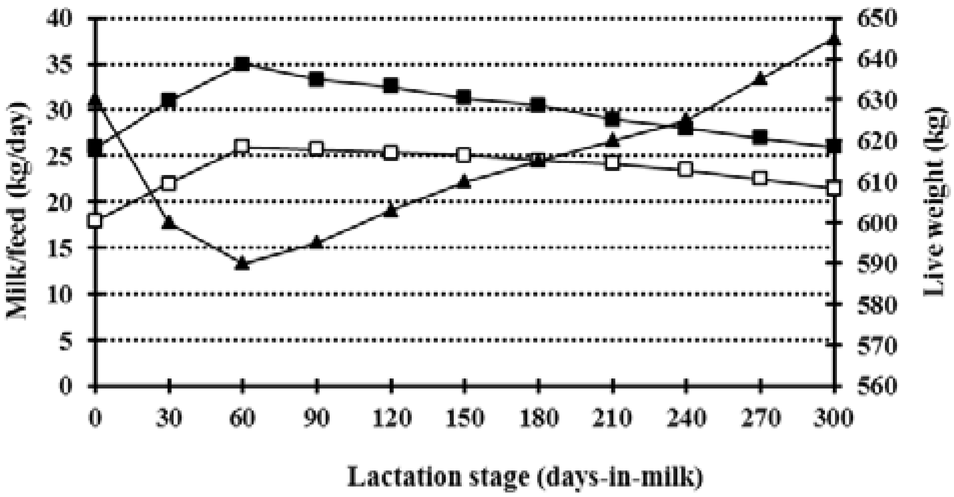


Figure 11.1. The change in feed intake (□), milk yield (■) and live weight (▲) of Holstein cows during the lactation period

After calving, the daily milk yield of cows increases and reaches peak yield at about 30 - 60 days after calving. After this peak in production, the daily milk yield of cows gradually decreases at a rate of approximately 3 - 5% per month. When cows are about five months pregnant (in calf), the decline in milk yield occurs at a faster rate. Peak yield is not as high in first lactation cows as in older cows, while the decline in milk yield is at a lower rate, i.e. approximately 1 - 3% per month.

Figure 11.1 further shows that the live weight of cows decreases after calving, reaching a minimum at about 60 to 100 days after calving, after which it gradually increases once again at approximately 0.5 kg/day. In contrast to this, the feed intake increases quickly after calving until a maximum intake is reached at about 8 to 10 weeks after calving. After approximately 150 days, the feed intake of cows starts to decline gradually. The lactation period of dairy cows could be divided into four main phases, namely:

Early lactation	:	from calving to 100 days
Mid-lactation	:	101 - 240 days
Late lactation	:	from 241 days to drying off
Dry period	:	from drying off to calving (50 - 60 days)

1. Early lactation

The total milk yield of dairy cows over the lactation period is mainly determined by their daily milk yield at the start, peak and end of the lactation milk yield. The milk yield trend after peak to the end of the lactation is referred to as the persistency of milk production. Naturally, the total milk yield per lactation period is higher, at higher daily milk yields, at the start, peak and end of the lactation period and a higher persistency. Trials have indicated that total milk yield per lactation increases by 180 to 200 kg for each one kg increase in peak milk yield. This implies that correct feeding should be applied during the early lactation period. During this stage, high quality roughage and a high energy content concentrate should be provided. Different studies have shown that a decrease in milk production during the early part of the lactation period, as a result of underfeeding or malnutrition, reduces the total milk yield per lactation by four times (Table 11.2).

Table 11.2. Reduction in milk yield as a result of poor feeding during early lactation as demonstrated in four trials

Trial	Reduction in early lactation (kg)	Reduction over the lactation period (kg)	Lactation effect
A	136	590	4.3
B	45	181	4.0
C	180	862	4.8
D	190	680	3.6

It is well accepted that during early lactation, the feed intake of high producing dairy cows is not sufficient to satisfy their nutritional requirements because of the rapid increase in milk yield. This is demonstrated in Figure 11.2, showing the effect of energy demand and feed energy intake on the body reserves of dairy cows.

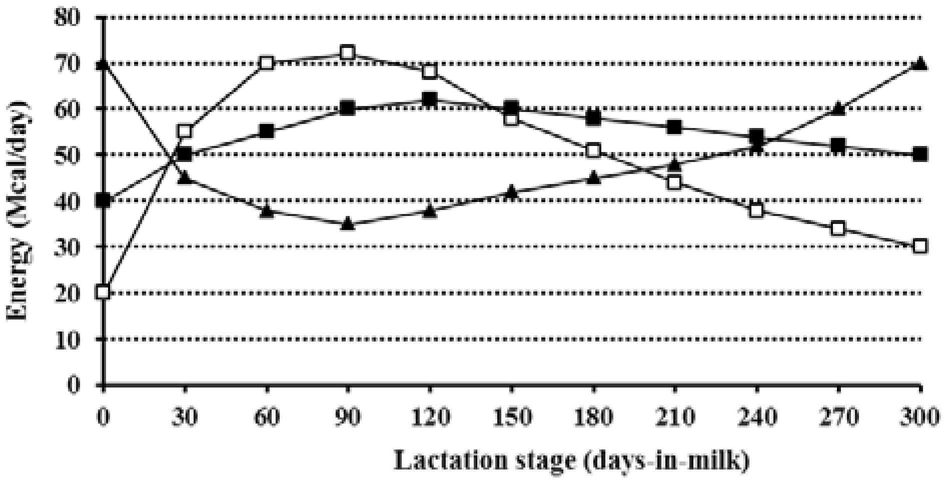


Figure 11.2. The effect of milk energy demand (□) and intake of feed energy (■) on the body reserves (▲) of dairy cows during the lactation period.

During the early lactation stage, when initial feed intake is low and a rapid increase in demand for milk energy because of an increasing milk yield takes place, the body reserves of cows are broken down to provide energy for this demand. Therefore, by breaking down fat reserves, dairy cows are able to sustain a higher milk yield than is possible from their feed intake alone. It is estimated that 6 to 10 kg of milk can be produced from one kg of body fat. This characteristic of dairy cows is usually observed as a reduction in the live weight of dairy cows within the first two to three months of the lactation period. This further emphasises the need for proper feeding in the late lactation, as well as the dry period ensuring that cows are in a good body condition at the time of calving. Depending on the condition scoring system, cows should have a condition score of at least 3.0 to 3.5 (out of 5.0) at drying up. Their condition should be maintained during the dry period. Preferably, cows should not calve down at condition scores less than 2.0 or higher than 3.5 as both these conditions can have a detrimental effect on milk production in the following lactation period.

A study conducted at Elsenburg showed that dry cows receiving a small amount of concentrates instead of a mineral supplement together with ammonia treated wheat straw, produced more milk during the following lactation period. During the first eight weeks of the lactation period, cows supplemented with a mineral mixture produced on average 33 kg of milk per day while cows receiving 2 kg per cow per day of a dry cow concentrate mixture produced on average 38 kg of milk per day. Because of the long term effect of feeding dairy cows, an improvement in the body condition of dairy cows is often only observed in the following lactation period.

In the past, the amounts of concentrates being fed to cows were increased daily during the first 14 days after calving, after which it was increased weekly if milk yield responded by increasing further. This was done up to a maximum amount equal to approximately 2% of live weight, i.e. 8 kg per cow per day for Jersey cows weighing 400 kg. Presently, the preferred way of feeding concentrates to cows is to provide a fixed amount of concentrates from directly after calving, i.e. 6 to 12 kg per cow per day. The daily amount of concentrates being fed depends on the genetic merit of cows in the herd, as well as the quantity and quality of the roughage being fed. Cows receiving low-grade roughages require more concentrates per day than cows having access to high quality pasture. The concentrate intake of cows on a total mixed ration increases as their daily feed intake increases. Because the energy content of all roughages does not always sustain high milk yield levels, the energy content of the concentrate should be high. In early lactation, cows should, to a certain extent, be overfed in order to ensure that their milk yield potential is fully utilised. However, farmers should realise that overfeeding cows of low genetic merit for milk production will not transform them into high producing cows. Such cows tend to become fat which is an indirect way of showing their genetic merit.

2. Mid-lactation

During this phase of the lactation period, feed intake is usually sufficient for the energy requirements for milk production. Production is maintained although declines in weekly milk yields may occur because of differences in genetic merit for persistency. Observation studies indicate that both peak milk yield and the persistency of milk production are important factors affecting lactation milk yield levels. An improvement in the feeding level from a low level during mid-lactation usually results in only a minor increase in milk yield (Figure 11.3).

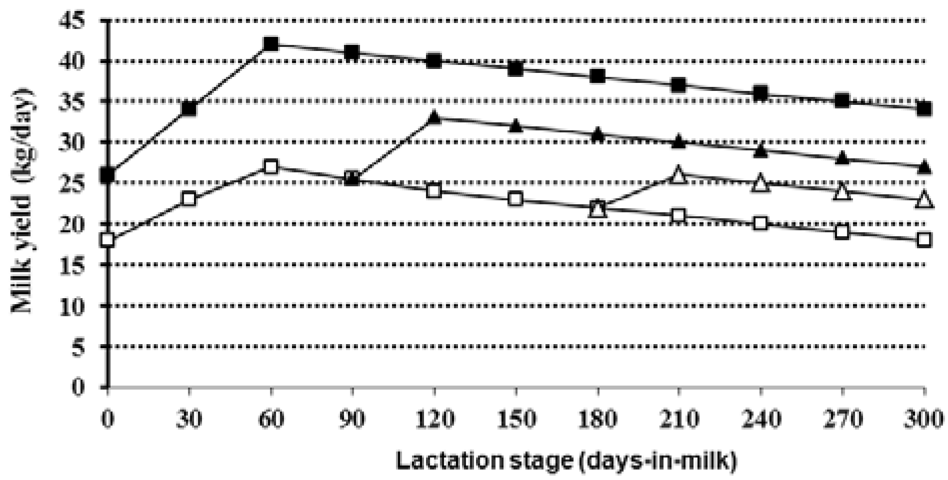


Figure 11.3. The effect of feeding level during the lactation period on milk yield recovery for Holstein cows (■ = consistently feeding at a high level from the start of the lactation period, □ = consistently low feeding level from the start of lactation period, ▲ = higher feeding level after peak production, ∆ = higher feeding level after mid-lactation)

The positive effect of improved feeding on the milk yield cows is smaller when the feeding improvement occurs longer after peak milk yield. The highest milk production is obtained if proper feed management is maintained from the beginning of the lactation period. The recovery of milk production decreases as the feeding level is improved at a later stage during the lactation period. The amounts of concentrates can be adapted on a monthly basis during mid-lactation.

3. Late lactation

Until fairly recently, this stage in the lactation period was considered to be of less importance in the feeding of lactating cows. The reason for this is during the late lactation stage, cows are once again in a positive energy balance due to the fact that more feed energy is consumed than is required for maintenance and milk production. The recovery of body reserves during this period is more effective than during the dry period, i.e. 65% versus 48%. This means that cows should already be prepared for the following lactation period in the late lactation period.

4. Dry period

A dry period of 50 to 60 days is essential for the recovery of the milk secreting cells in the udder towards maintaining a high lifetime performance. When the dry period is less than 40 days or more than 80 days, a 5 to 10% decrease in milk production could be expected during the following lactation period. When cows become pregnant soon after calving, the lactation period should preferably be shortened to provide sufficient time for the udder to recover after milking. Milk secreting cells in the udder require at least 5 to 6 weeks for full recovery.

Dry cows should be kept separately from other cows, while receiving a diet specifically formulated for them. Their lower nutritional requirements should be taken into consideration which should be aimed at them not becoming too fat or over-conditioned. Cows that become fat often develop various problems after calving, such as mastitis, ketosis, displaced abomasum, and even milk fever. However, the diet during the dry period should also prevent them from losing body condition, as this will adversely affect their milk production during the following lactation period.

In closing

Correct feeding of dairy cows determines the financial survival of a dairy herd. The milk yield of cows follows a distinct pattern during the lactation period and feeding should follow this pattern. This means cows should receive more and better quality feed during early lactation and less feed towards the end of the lactation period when milk yield is lower. Increasing the amount of feed during late lactation should only be done when the condition score of cows have not reached specific targets. The dry period is important for the recovery of cows after the lactation period and should not be too long or short as both would affect the cow's milk yield in the following lactation period.

CHAPTER 12

FEEDING AND MANAGEMENT OF DRY COWS

Introduction

The dry or non-lactating period between consecutive lactation periods is a crucial phase in the production cycle of dairy cows. Cows calve down to start a new lactation period and are then milked for at least 300 days, depending on the next expected calving date. Usually, cows are dried off at about 60 days before the next calving date. The lactation period is usually extended more than 300 days when the interval from calving to conception is longer than the expected 85 days. Dairy cows are dried off to recover from the previous lactation period. The dry period lasts from the drying off date until the next calving down date. This is a critical period as cows are then heavily pregnant carrying a fast-growing foetus. Although generally regarded as a very important part in a cow's production cycle, the feeding of dry cows is often neglected. The main purpose of the dry period is to give cows time to recover after being in milk for the previous 10 months or longer. During this time, the rumen recovers from the high concentrate diet usually fed during the lactation period, while the milk secreting cells in the udder also stop producing milk. There are mainly three aspects about the dry period, i.e.:

1. **Involution of the udder**
   The main purpose of the dry period is to give the milk secreting tissue in the udder an opportunity to renew itself. This process takes approximately six weeks. For this reason, the dry period should not be shorter than 50 days. When cows do not have a dry period, the loss in milk production during the subsequent lactation could be as much as 30%.

2. **Recovery of the rumen**
   During the dry period, the rumen wall gets the opportunity to recover, particularly after the lactating phase when cows were fed high levels of concentrates.

3. **Recovery of body reserves**
   During the dry period cows also get the opportunity to build-up body reserves. However, because the dry period is short, the body condition of cows should be improved during late lactation. Research has shown that the recovery of body reserves is more efficient during the late lactation period in comparison to the dry period, i.e. 65% vs. 48%. During the dry period, the condition of cows should be maintained. Although difficult because of the short time frame, cows in poor condition at drying off should be fed additional energy towards improving their body reserves during the dry period.

Foetal development

Although the gestation period of cows is about nine months, foetal growth is particularly fast during the last eight weeks before calving down. About 60% of the birth weight of calves is gained in the last three months of the gestation period. During the dry period, on average, the live weight gain of Holstein cows should be approximately 0.75 kg/day. The feeding programme of dry cows should ensure that the foetal and placenta growth takes place at a normal rate.

Length of the dry period

In general, it is recommended that the dry period should be about 42 to 60 days. Both a short and excessively long dry period have a detrimental effect on the milk production of cows during the subsequent lactation period. A study conducted in the USA showed the importance of a 60 - day dry period (Figure 12.1). Records of 281 816 cows showed that those cows that were dry for a period of 50 to 70 days produced the most milk during the subsequent lactation. The lactation milk yield of cows was 143 kg higher when the dry period was 60 days, while milk yield was reduced by 448 kg when the dry period was only 20 days long. Cows that were dry for less than 40 days or more than 90 days produced less milk.

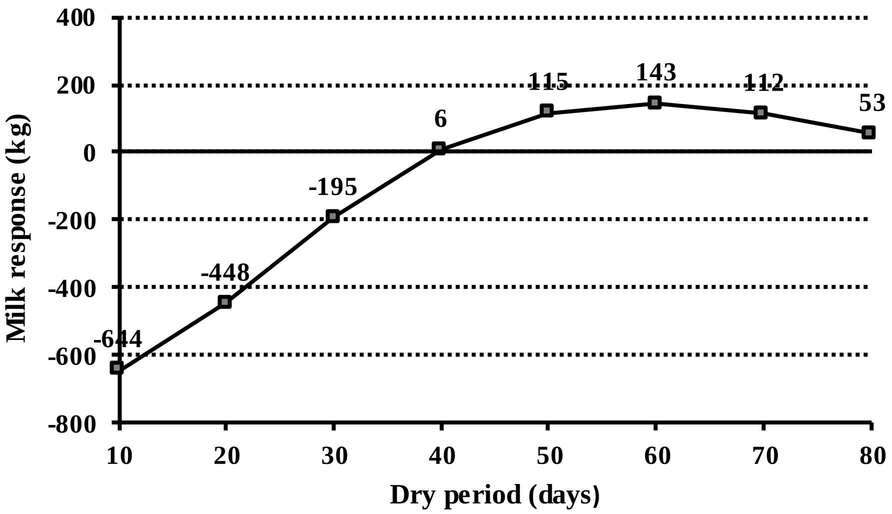


Figure 12.1. The effect of the dry period length on milk production during the subsequent lactation period

A study using a smaller number of milk production records from the Elsenburg Holstein herd also showed that the subsequent lactation milk yield of cows was significantly lower when the dry period was less than 60 days in comparison to dry periods of 61 to 90 days, 91 to 120 days and more than 121 days. This pattern was the same for cows whether they were in second, third or fourth-plus lactation. Overall, the milk production of cows was 6703, 7162, 7260 and 7612 kg for cows with dry periods of less than 60 days, 61 to 90 days, 91 to 120 days and more than 121 days, respectively. The higher milk yields of cows after a longer (more than 60 days) dry period were, however, not sufficient to produce the same amount of milk per day as for the short dry period group. In this study, long dry periods indicated that cows had experienced reproductive problems which resulted in an extension of the interval from calving to conception (days open). However, in a practical farming situation, cows would be milked for longer than the standard 300-day lactation period when the interval from calving to conception (days open) increases. This would, to a limited extent, reduce the milk yield loss resulting from a poor reproductive performance. Other studies showed that the milk yield loss, compared to the standard dry period of 6 to 8 weeks, can reach 10% when the dry period is reduced to a month and 20% when there is no dry period. The milk loss from short dry periods may be due to (1) inadequate time for complete replenishment of body reserves, (2) reduced mammary epithelial regeneration, and (3) incomplete endocrine events near parturition.

Drying off date

To determine the drying off date for a specific cow, the expected calving date should be known. This is estimated from the insemination (AI) date following confirmation that the cow is pregnant. As the average gestation period of cows varies between 275 and 283 days, 280 days could be added to the AI date to estimate the cow's expected calving date. Sixty days are then subtracted from the expected calving date to determine the drying off date.

Drying off cows

The best and most rapid way of drying off cows is to stop milking them abruptly. For persistent or high producing cows, their milk production could be reduced by not feeding them concentrates anymore and by feeding them, for a few days, low quality roughages, like wheat straw. Sometimes the water intake of cows is limited; however, this is not advisable in hot weather conditions. When milking has stopped, some cows may show swollen udders. This is normal as the milk secreting cells in the rumen keep on producing milk. When the udder is very swollen from missing a few milkings, cows could be completely milked out once or twice. In time, because the udder is not being emptied, pressure builds up in the udder resulting in the gradual resorption of the milk, suppressing milk secretion.

Cows should be observed carefully during the first week after being dried off as cows with severe mastitis may at this stage become ill because the infected milk is not being removed from the udder. The infected quarter must be milked dry once or twice, while the cow is being treated.

At the last milking session, a long-acting dry cow antibiotic should be administered in each of the four quarters to ensure that mastitis causing bacteria do not contaminate the udder during the dry period. For some cows not getting mastitis often, a dry cow antibiotic only needs to be administered in a quarter that had been infected with clinical mastitis during the lactation period. On some farms, where mastitis does not occur regularly, dry cow treatment is only used on cows with a known history of mastitis. After cows have been dried off successfully, they can be moved to a dry cow group where they are to be fed a suitable diet.

Feeding in the dry period

During the first four to six weeks of the dry period, it is important that cows receive good quality roughage with a coarse texture. During this period, maize silage, grass hay, small-grain hay or silage, and grass pasture or grass-clover pasture can be used as roughage sources for dry cows. However, the intake of maize silage has to be limited to prevent cows from becoming too fat. Together with the roughage, a suitable lick should be made available in order to ensure that the cows' mineral and trace-element status is not reduced, but rather improved. A diet consisting mainly of roughage will ensure that the rumen papillae recover completely making the rumen healthy for the next lactation period.

During the last three weeks of the dry period, dry cows should be accustomed to consuming concentrates again. Concentrates should contain the same feedstuffs as those they are to receive during early lactation. By doing this, the population of rumen microbes is being adapted for the subsequent lactation diet. The cow's metabolism also changes in such a way that less fat from the fat reserves is mobilised to the liver. Concentrate feeding can start at 1 kg/cow/day being increased gradually to about 3 kg/day just before calving. In cases where milk fever occurs regularly, anionic salts in addition to extra calcium (Ca) may be provided in the dry cow meal. Preferably, only roughages containing low levels of potassium (K) should be fed during this period. Good examples of such roughages are maize silage and small-grain hay or silage. Roughages with low levels of K (< 1.5%) have the lowest suppressing effect on Ca mobilisation while contributing to an optimum Ca status at the time of calving. Roughages containing high levels of K, such as kikuyu, rye-grass and clover, result in Ca mobilisation being suppressed. Consequently, these cows have a poor Ca status at the time of calving, which may bring about problems such as milk fever, dystocia and retained placenta.

The trace-element status of cows is important at the time of calving, as it is related to preventing retained placenta and mastitis after calving. Because of this, dairy cows can get an injection of vitamins A and E about 14 days before calving.

Body condition of dry cows

Because milk production in cows in early lactation increases at a faster rate than their feed energy intake, cows are at this stage generally in a negative energy balance. This stress condition usually results in a number of metabolic disorders. Recently, it has become increasingly clear that these stress conditions stem from earlier nutritional disorders, i.e. in the dry period before calving down and even during the previous lactation period. It seems that the last two to three weeks before calving is a critical period for dry cows, as their hormonal status undergoes dramatic changes in preparation for the approaching calving process and subsequent production phase. At or around calving, cows usually lose their appetite and therefore eat less. The lower feed intake means a lower energy intake, which, together with the previously mentioned hormonal changes, results in the mobilisation of the fat reserves in the cow's body. Studies indicate that a lower feed intake directly before calving has a significant effect on fatty acid levels in the blood. This can also lead to the occurrence of disorders, such as ketosis, fatty liver, a displaced abomasum, and retained placenta after calving. High fatty acid levels also indicate that the cow breaks down fat reserves due to the fact that she does not take in sufficient energy.

Studies also show that there is a strong relationship between dry matter intake before and after calving. In other words, cows eating poorly before calving tend to do the same after calving. Consequently, such cows will yield less milk and tend to experience more physiological and reproductive problems.

To stimulate feed intake after calving, one should prevent cows from becoming too fat in the dry period.

It is important that cows should be in good condition when they are dried off. A condition score of 3 to 3.5 is ideal. Thin cows at a low condition score do not have sufficient fat reserves to be used as a source of energy to maintain high milk yield levels in early lactation, when energy requirements exceed energy intake. Cows should also not be too fat (having a condition score of 4 or higher) as such cows eat less when they calve down and are more prone to metabolic and reproductive problems.

The condition of cows should be recovered as early as in the last three months of the previous lactation. Research has shown that feed energy (metabolisable energy) is converted to body fat more efficiently in cows in milk than in dry cows (65% vs. 48%, respectively). The body reserves utilised during early lactation is replaced more economically during late lactation than during the dry period. Thin cows need to receive more grain and/or fat during late lactation in order to obtain a condition score of 3 to 3.5 out of a possible 5. Cows with a condition score higher than 3.5 should receive less grain and more roughage in order to prevent them from becoming too fat.

Metabolic problems in dry cows

1. Milk fever

Milk fever is often observed in dairy cows at the start of the lactation period. It occurs when the Ca level in the blood serum suddenly drops from a normal 10 mg/100 mℓ to 3-7 mg/100 mℓ. The disease is also known as hypocalcaemia. Initially, in coordination of the muscles is observed, after which paralysis and loss of consciousness follows. Cows not treated quickly could die as a result of suffocation. Secondary effects of milk fever often include a retained placenta, infection of the uterus, mastitis, and a reduced milk yield. The name of this disease is actually misleading as the body temperature of cows generally does not increase because of milk fever. Milk fever is only seldom observed in first and second lactation cows and it is mainly a problem in older cows, particularly high producing dairy cows. Furthermore, its occurrence is possibly of a genetic nature as it occurs much more frequently in Jersey cows than in Holstein cows.

Low Ca levels in the blood stem from the large requirement for Ca in colostrum (the early milk after calving) and the cow's inability to withdraw sufficient amounts of Ca from the skeleton. This results in the development of an imbalance in the Ca to P ratio. Magnesium deficiencies and/or too high levels of potassium (K) in the diet of dry cows usually contribute to this problem. By feeding roughages containing low levels of K and stimulating the Ca metabolism of the dairy cows by means of anionic salts or low Ca diets, this problem can be largely prevented.

The electrolyte balance in the cow's diet could be changed by supplementing the diet with anionic salts, increasing the cow's Ca status. Anions are negatively charged causing a negative electrolyte balance when sufficient amounts of anions are included in the diet. The negative electrolyte balance results in Ca being transported to the blood from the skeleton and the digestive tract, so that the Ca status of the dairy cow is supplemented from these two sources. The following anionic salt recipe has been shown to produce positive results:

NH_4Cl (Ammonia Chloride)	118 g
$(NH_4)_2SO_4$ (Ammonia sulphate)	36 g
$MgSO_4.7H_2O$ (Magnesium sulphate – Epsom salt)	68 g
Total	222 g

Cows should consume this amount of anionic salts daily for at least 21 days before calving. In some studies it was found that feeding a further 120 to 150 g Ca/cow/day in addition to the anionic salts also helped to reduce hypocalcaemia. However, feeding very high concentrations of dietary Ca (> 1.0% Ca) have reduced dry matter intake and animal performance. It is important for the efficient use of anionic salts that the K contents of the total diet on a DM (dry matter) basis is not higher than 1%. It should be kept in mind that anionic salts are very unpalatable and it should therefore be fed as part of a palatable concentrate. Commercial feed companies presently have a pre-partum concentrate containing the required anionic salts. A representative of a feed company should therefore be consulted for the correct mixture for prepartum cows. Feeding anionic salts should be stopped completely on the day of calving and should not be fed during the lactating phase.

2. Swelling (oedema) of the udder

Oedema of the udder sometimes occurs at certain times of the year or in specific herds. Some cows are also genetically prone to oedema of the udder, regardless of the feeding programme. Feeding high levels of sodium (Na) and/or potassium (K) during the dry period are probably the most important causes of udder oedema.

3. Ketosis

Ketosis often occurs in excessively fat cows (having a condition score of 4 +), especially when such cows are not adapted to the concentrates or the total mixed ration being fed early in the lactation period. When a cow calves down, her nutritional requirements increase immediately by 300 to 700% mainly because of the rapid increase in energy requirements for milk processing. Often, because of poor feed intake immediately before and at calving, as well as a slow increase in feed intake after calving, cows do not have sufficient energy to supply in the demand for milk production in the early lactation period. To supply this demand during the post-calving period, body reserves are mobilised for milk production. However, when the cow's body reserves are broken down too quickly, it leads to an increase in the number of ketone bodies in the blood and urine, causing ketosis.

4. Retained placentas

A number of factors, such as nutrition, stress and diseases, can cause the retention of the placenta after calving. Infection of the uterus should be prevented during the removal of the placenta. For this, a high level of hygiene must be maintained when removing the placenta. Nutritional problems which may lead to retained placentas include deficiencies of macro minerals like calcium (Ca) and phosphorus (P), trace elements like iodine and selenium and Vitamins A and E. A deficiency of vitamin E and selenium, as well as a low Ca status, are the most important causes of this condition. For this reason, an injection containing vitamins A and E, as well as zinc and selenium injected about 14 days before calving, is often an essential preventative measure.

In closing

The dry period following a lactation period is a critical phase in the production cycle of dairy cows. Cows should be dry for about 50 to 60 days as both short and long dry periods have a negative effect on the subsequent lactation milk yield. The feeding of dry cows should consist of good quality roughage with a coarse texture. This will keep the rumen distended, while the interior wall of the rumen can recover from high acidic levels when large amounts of concentrates are fed. From about 3 weeks before the expected calving date, a small amount of concentrates should be fed once a day. The amount could be increased to about 3 kg/cow/day at the expected calving date. This is to accustom cows to the diet to be fed during the lactation stage.

CHAPTER 13

THE LIVE WEIGHT AND BODY CONDITION SCORE OF DAIRY COWS

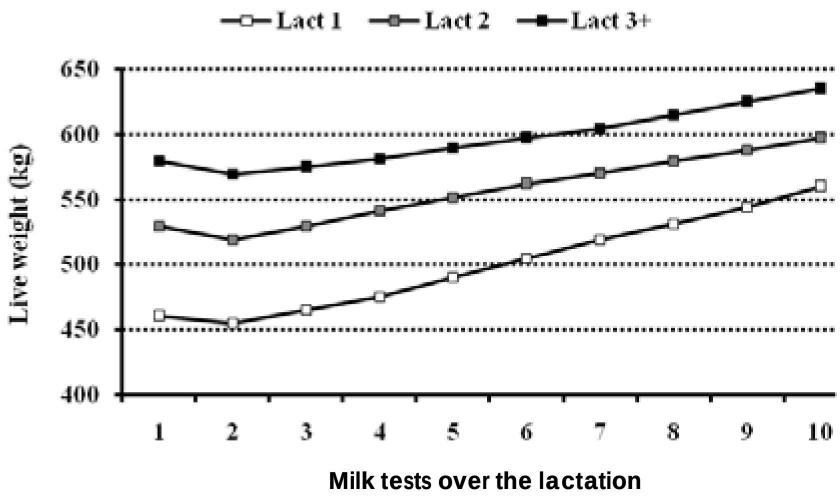
Introduction

The nutritional requirements of dairy cows have been established in different feeding trials under controlled conditions. The chemical composition of feeds has been determined in laboratory analyses using standard methods and is available in a number of reference manuals. Additional components are estimated from basic nutrient components. Therefore, in practice, the feeding of dairy cattle rests on these two principles, i.e. the nutritional requirements of cows and the chemical composition of feeds. However, practically, using the science of these two components to their full extent to feed dairy cattle is difficult. Farmers and their advisors must try to satisfy the “estimated” nutrient requirements of the “average” cow based on its “expected” daily feed intake using the chemical values of feeds as recorded in a number of reference manuals. The problem is that the actual nutrient requirements of dairy cows differ from estimated values because the average cow does not exist as each cow has its own nutrient requirements as determined by its live weight, feed intake, body condition, daily milk yield and milk composition. Therefore, even with using all this information, it is quite possible that not all cows are fed correctly all of the time. Fortunately, dairy cows have the ability to buffer the negative effects of over- and underfeeding during their milk production cycle by using their own body reserves stored away as adipose tissue (fat). Farmers can, by monitoring the breaking-down and recovery of the body reserves of cows, improve feeding management and bringing it closer to feeding cows correctly in a more scientific way. The response to feeding changes can be done by monitoring the live weight and body condition as indicators of the body reserves of dairy cows.

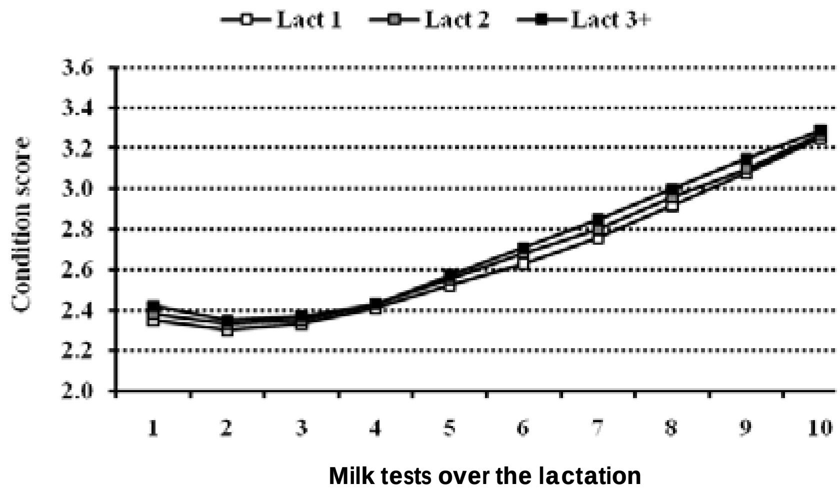
Live weights and body condition scores of dairy cows

Lactating dairy cows show a specific trend with regards to live weights which is affected by their body fat reserves as indicated by body condition score. In the past at Elsenburg, dairy cows were weighed once a month and the amount of body reserves scored by using the Mulvaney system that was developed in the 1970s in Britain. Presently, cows are weighed at each milking using a walk-over scale. By monitoring the live weight of cows on a regular basis, the change in the body reserves is also observed. However, when a scale is not available, a simple scoring system can be used to determine the amount of body reserves in cows. For this, cows have to scored on fixed times during the lactation period, such as at calving and thereafter once a month to drying off. There are a number of scoring systems in use and while actual condition scores may differ, the amount of body fat that is described is approximately the same. Most scoring systems give an indication of the amount of fatty tissue under the skin of cows at the tail-head and loin areas as an indication of the cows’ body reserves.

The change in live weight and body condition score for Holstein cows in the Elsenburg herd in different lactations is shown in Figure 13.1 (Muller *et al*., 2006). It is clear that the live weight of cows is affected by age (lactation number) with cows showing an increase in live weight within each lactation period and up to third lactation. Although large variations were observed in actual live weights, on average cows in first, second, and third-plus lactation weighed about 500, 560 and 600 kg, respectively. In contrast to this, the lactation curve for the body condition score was not affected by lactation number (age) and was the same for cows in all lactations. The pattern in body condition score was very distinct, i.e. cows losing body condition during the early part of the lactation reaching nadir at about 60 days after calving after which the condition of cows increased as each lactation period progressed. The decrease in live weight is the result of the loss in body condition during the early part of the lactation.



(a)



(b)

Figure 13.1. The change in (a) live weight and (b) body condition score over the lactation period for Holstein cows in different lactations based on monthly recordings

On the other hand, the lactation curve for milk production follows an opposite trend to that of live weight and body condition score. Milk yield increased after calving, reaching a peak production at about 60 days after calving, after which the daily milk yield started to decline towards the end of the lactation period. Cows lose weight after calving to about 60 to 90 days after calving, because of a reduction in the body condition of cows. The reason for the reduction in the live weight and body condition is because feed intake of cows early in the lactation is not sufficient to satisfy the nutritional requirements for cows just after calving and into the early lactation period because of a rapid increase in milk yield. Often, just before calving, cows lose their appetite and eat very little at or around the time of calving down. The initial low voluntary feed intake and increasing energy requirements for the production of milk results in cows going into a negative energy balance with regards to milk production. For this reason, the breakdown of body reserves aids in the production of milk during early lactation, commonly known as cows milking off their backs. Higher genetic merit cows have higher peak milk yields and therefore a larger negative energy balance during early lactation. It is for this reason that cows should be in good condition when calving down, preventing them from using all their body reserves at peak production, as this could lead to poor reproductive performance or metabolic disorders.

The body condition of cows should be improved during the late lactation stage as the conversion of feed energy to fatty reserves in the body is then more efficient than in the dry period, i.e. 65% vs. 48%. This means that cows in late lactation that are in a poor condition should receive more concentrates per day or a concentrate containing higher levels of grain or fat. The body condition of cows at drying off should be about 3.0 - 3.5 (from a possible 5.0). Cows being dried off at a condition score higher than 3.5 should be fed a smaller amount of concentrates per day during the dry period to prevent them from becoming too fat. Anecdotal data in KwaZulu-Natal showed that a one condition score change resulted in a live weight change of about 45 kg. However, differences were found between first lactation cows and older cows. Some cows may lose up to 90 kg in live weight in early lactation, while each kg live weight loss may account for 5 to 6 kg of milk. It is for this reason that cows should be in a good condition when they calve down.

When to do condition scoring

Farmers should score cows on a regular basis, i.e. once a month. Cows should also be scored at drying off, again when they are put in the steam-up group at about 3 to 4 weeks before their expected calving dates and also within the first week after calving down. The condition score of cows in early, mid, and late lactation should be recorded separately to determine the effect of lactation stage. The average condition scores of cows in the different production groups could also be recorded in a table showing the change in condition score over time (Table 13.1).

Table 13.1. The condition score of cows in different lactation stages and months per year towards monitoring the feeding programme

Lactation stage	Month of the year			
	January	February	March	April
Dry cows	3.2	3.1	3.1	3.0
Early lactation (< 80 days-in-milk)	1.8	1.8	1.8	1.7
Mid lactation (81 – 200 days-in-milk)	2.4	2.2	1.8	1.8
Late lactation (> 201 days-in-milk)	2.9	2.6	2.1	1.9

The mean condition score of the cows at the start of the recording shows the correct balance between dry cows and cows in early, mid and late lactation. While the mean lactation score of dry cows and cows in early lactation showed small declines over time, cows in mid and late lactation showed a sharper decline in condition score, indicating a change in feeding conditions for cows in these groups. This will eventually result in a deterioration of the condition score of cows in the dry period which may further reduce their condition scores in early lactation with negative effects on the subsequent lactation milk yield and possibly reproductive failures.

Effect on production performance

Farm surveys in the United Kingdom showed that the body reserves of cows, as indicated by their condition scores at calving, have an effect on the milk yield and reproductive performance of cows in the subsequent lactation. In Table 13.2 the difference between actual and expected milk yield for Holstein cows during the first 84 days of the lactation period and conception rate as affected by condition score is presented. These results show that milk yield losses of 1000 kg would occur over a lactation period for very thin (condition score below 1.5) and very fat (condition score more than 4.0) cows. The highest milk yield was achieved when cows had a condition score of 3.5 at calving, as they produced 182 kg more milk than their expected milk yields. Conception rate of cows increased at higher (more than 2.0) condition scores at calving.

Table 13.2. The effect of condition score at calving on the milk yield and conception rate of dairy cows

Condition score at calving	Number of cows	Milk yield difference (kg)	Condition score	Conception rate (%)
0.5 - 1.5	283	-150	**< 1.5**	52
2.0 - 2.5	159	0	**1.5**	56
2.5 - 3.5	213	+95	**2.0**	68
> 3.5	8	-150	**> 2.0**	72

The same principles apply for heifers which should be at a condition score of 2.5 to 3.5 at first service for a high conception rate. The conception rate of heifers at condition scores of less than 2.0 should improve when they are fed additional feed for about 12 weeks before insemination. On the other hand, over fat heifers will also have poor conception rates. Feeding of heifers should ensure an even growth rate to first service rather than fixing poor growth rates at the time of first service.

Condition scoring technique

Currently, there are a number of ways to determine the amount of fat reserves on the body of dairy cattle. It basically consists of an arbitrary scale in which the amount of fatty reserves underneath the skin at the tail-head and loin areas is estimated. The Mulvaney system commonly used in South Africa was developed at the British National Institute for Dairying at Reading in the early 1970s. Currently, different countries have their own system. It is important to use the same scoring system at all times to prevent confusion in the condition scores recorded.

With some training (and patience), cows get used to the routine and with one helper, at least three cows can be weighed and scored per minute. This information should be recorded on the byre sheet or, preferably, on a separate computer spread sheet file. It is generally recommended that the person doing condition scoring should rate himself at least twice a year against another person to prevent becoming biased. Often because of a heavy workload, persons doing condition scoring may move away from using the definitions and handling the cows using only an eyeball method. When comparing scores of two individuals, the final body condition score should not differ by more than half a score.

For each score, a specific definition for the tail-head and loin area is provided and scoring should be done by physically palpating each area by hand. Estimating the amount of fat is done by feeling how much fat is between the skin and bone underneath. Body condition scores vary from 0 (very poor) to 5 (grossly fat). For each score a specific description applies. The condition score at the tail-head area is used as the reference score. When the condition scores at the tail-head and loin area differ by 1 and more, the tail-head score is adjusted by half a score going up or down. This adjustment for differences between the tail-head and loin areas gives the Mulvany score an 11 point scale. For a condition score of 3 at the tail-head area and a conditions core of 2 at the loin area, the final score for the cow becomes 2.5. Recently, new research has shown that it is possible to determine the condition score of cows using images automatically recorded in the milk parlour.

Descriptions of condition scores

The system currently in use at Elsenburg is described in an Extension Circular (no 363) of the College of Agriculture from Penn State University in the USA (Heinrichs & Ishler, 2015). The technique of condition scoring entails both visual and tactile (hands-on) methods. The hands-on method entails using the finger tips pressing down on muscles and bones at specific areas on the body of cows to judge the amount of fatty tissue under the skin. Specific areas include the tail-head and loin areas. The feeling is compared to previous described definitions for each condition score. The following definitions could be used as guidelines (Pictures from Elanco Body Condition Scoring poster):

Condition score 1:

- Individual short ribs have a thin covering of flesh.
- Bones of the backbone, loin and rump regions are prominent.
- Hook and pin bones protrude sharply, with a thin covering of flesh and deep depressions between bones.
- Severe depression below the tail-head and between pin bones. Bony structure protrudes sharply and ligaments and vulva are prominent.

There is a deep cavity under the tail and around the tail-head and no fatty tissue is felt under the skin. The skin is drawn tightly over the pelvic bones and the coat condition may be rough. There is no tissue detectable underneath the skin. The short ribs in the loin area are sharp and clearly visible and can be felt easily. No fatty tissue is felt under the skin. The cavity between the backbone and transverse processes is deep. The animal looks emaciated.

Condition score 3:

- The cavity around the tail-head is shallow with little fat covering the bones in the tail-head area.
- The skin feels supple and can be pinched (picked-up) using finger tips.
- The pelvic bones can be felt easily.
- The ends of the transverse processes feels rounded, but the upper surfaces are only felt with pressure.
- There is depression visible in the loin area between the backbone and the transverse processes.

Condition score 5:

- The cavity around the tail-head is small and fatty tissue can be felt easily.
- The pelvic bone can still be felt easily.
- The ends of the transverse processes feel more round and the top surface of the transverse processes can be felt only with firm pressure.
- The cavity between the backbone and transverse processes is shallow, although still visible.

Condition score 7:

- The cavity around the tail-head is not visible and fatty tissue can be felt easily.
- The pelvic bone can be felt, although only with firm pressure.
- The ends of the transverse processes are very round and can only be felt by using firm pressure.
- The cavity between the backbone and transverse processes is filled up with fatty tissues.

Condition score 9:

- The cavity around the tail-head is not visible and folded fatty tissue is clearly visible around the tail-head area.
- It is difficult to feel the pelvic bone, although possible with very firm pressure.
- The ends of the transverse processes cannot be felt anymore.
- The cavity between the backbone and transverse processes is filled up with fatty tissues and may even have a bulging appearance.

In closing

Body condition scoring can be used as a tool to evaluate the feeding programme of dairy cows. It has been shown that the body condition of cows at calving affects their milk yield and reproductive performance in the subsequent lactation period. To condition score cows at specific times during the lactation period should therefore be part of the feeding management of a dairy herd. It needs to be done regularly to correct the feeding programme of cows in the different stages of the lactation period. The body condition of cows is scored at the tail-head and loin area separately after which it is combined in a final score. The tail-head area is used as the reference score with the score in the loin area confirming or adapting the final tail-head score. There are currently a number of different body condition scoring systems each with its own definitions indicating scores. It is therefore important when discussing condition scores with feed company representatives and the herd veterinarian that the same system is being used by different people. Some systems use half scores while others use full scores. A condition score of 3.0 to 3.5 is similar to a score of 5 to 6 on another scoring system. To improve the accuracy of body condition scoring, camera technology is being developed to measure the amount of fat at specific body parts. This technology is expected to be used at the same time as when cows are being weighed on a walk-over scale.

CHAPTER 14

ESTABLISHING AND MANAGING CULTIVATED PASTURES

Introduction

The main focus of dairy farmers producing milk from cultivated pastures is to produce sufficient amounts of high quality, palatable roughage to fulfill the nutrient requirement of grazing animals, while conserving the farm's natural resources. This has to be managed in a profitable manner in order to compete with world markets.

Soil as the basis for plant production

Soil is a non-renewable natural resource and provides a medium that hosts essential functions for plant (or pasture) production. Soil quality is a term used to describe 'the capacity of the soil to function' (Karlen *et al.*, 1997) and includes soil fertility (soil chemistry) along with physical and biological processes in the soil. The potential of the soil for pasture production is determined not only by the soil nutrient content, but also by the microbial activity in the soil and the physical nature of the soil. The physical, morphological, chemical, and biological features of soils, as the basis for plant growth are unique to each farm. Soil is generally chemically manipulated, while the physical and biological components are neglected. This has an important effect on the production potential, sustainability, and economic viability of the pasture system.

Scientific data is available to identify the physical and morphological aspects of the soil and the expected effect it would have on the production potential of different plant species. This information is unfortunately seldom used for farm planning purposes and is one of the main reasons why selected pasture species are often not suited to the physical features of the soil and, as a result, do not produce to its full potential. The chemical aspects of soils are well documented and soil chemical imbalances are rectified using researched indicators.

The biological component (living component) of soils is important for sustainable production, but the assertion thereof is mostly incorrectly based on the organic carbon content as it relates to the organic matter content of the soil. Researched indicators should be used for identifying the biological component of the soil and how to rectify it (Swanepoel *et al.*, 2014a).

1. Soil profile map

Before any choice can be made regarding the selection of pasture species, a map showing the different soil types, and based on an evaluation of soil profiles, is required to divide soils with the same features into different camps or management areas. This makes it possible to align different pasture species with specific requirements regarding soil physical characteristics, i.e. texture, depth, drainage etc. to different soil types. The concept of bringing the plant to the soil is introduced to ensure optimum plant production on different soil types.

2. Managing soil physical quality

Dairy farmers predominantly adopt minimum-tillage pasture systems with a kikuyu-base to protect the soil from physical and biological degradation. A detailed study undertaken at the Outeniqua Research Farm at George in the southern Cape, which endeavoured to quantify soil quality, showed that some of the physical characteristics of the soil were improved in long-term kikuyu-ryegrass pasture systems compared to systems where soil is disturbed by tillage (Swanepoel *et al.*, 2013). Water infiltration rate did not change while the water holding capacity of the soil increased in kikuyu-ryegrass pasture systems. The increased water holding capacity was particularly high in the top 10 cm of the soil. These soil functions were closely related to some functions in the biological component, such as cycling of organic carbon. Generally speaking, soils with a carbon content of 5% have the capacity to hold roughly 60% more water than soils with a carbon content of 1%. High soil organic matter levels in the soil surface layers results in the soil being fit to efficiently absorb and assimilate water, nutrients, organic matter and air from the external environment. On the opposite side to these beneficial impacts of kikuyu-ryegrass pastures, soil compaction and the formation of stable soil aggregates were adversely affected by kikuyu-ryegrass pasture management. This is possibly caused by tractor traffic and trampling by cattle, although the inherent soil quality may also play a strong role. Inherently, the soils in large parts of the southern Cape usually have a high (> 70%) well-sorted, fine, sandy texture, which contributes to it having lower aggregate stability and being highly compactable.

It is important to monitor the physical condition of soils. Pasture crops that are suited to grow in the specific soil environment should be cultivated. Lucerne, for instance, needs to be cultivated in deep, well-drained soils, as opposed to kikuyu-based pastures that are capable of being productive on marginal soils. Reduction of soil disturbance by tillage will also be beneficial for the physical component of soil.

3. Soil fertility

Annual soil sampling is required to obtain and monitor soil nutrient levels. Soil analysis results indicate whether or not additional nutrients are required to improve the soil nutrient status to specific required levels, or simply to apply nutrients to ensure maintenance of current levels. Once the maintenance rates have been established, soil sampling can be undertaken every second year. The main advantage of soil analysis should be achieved by repeated testing procedures over a number of years. A trend in the soil fertility status of the farm, on a per camp basis, could then be recorded and used to monitor the progress in achieving or maintaining required nutrient levels. This picture of trends is an important tool for the management of soil fertility for each pasture on the farm.

Lucerne and kikuyu over-sown with perennial grass-legume pastures are fertilised to raise soil fertility to the levels required for optimum growth and to maintain those fertility levels by replacing nutrients lost through grazing and leaching.

The recommended soil fertility levels for mixed grass/legume pastures are:

Parameters	Levels
Organic carbon (C)	> 2%
pH (KCl)	> 5.5
Phosphorus (P) (citric acid)	> 30 mg/kg
Potassium (K)	> 80 mg/kg
Calcium (Ca)	> 400 mg/kg
Magnesium (Mg)	>.70 mg/kg
Ca:Mg ratio	4:1
Sulphur (S)	> 11 mg/kg
Copper (Cu)	> 1.0 mg/kg
Zinc (Zn)	> 1.0 mg/kg
Manganese (Mn)	> 25 mg/kg
Boron (B)	> 1.0 mg/kg

Since lime is not mobile in soil and most of these pastures are managed as minimum-tillage pastures, it is not possible to incorporate lime into the deeper soil layers. It is recommended that soil tests are done regularly and lime top dressed annually according to soil test results. This is also applicable to other soil nutrients. It must be stressed that fertiliser management strategies should be strictly followed for a specific tillage system for specific pasture crops. This can only be achieved when soil samples are taken regularly (every 1-2 years) to correct any deficiencies in soil nutrient levels. It is important that guidelines that fit the tillage system should be strictly followed, in order to prevent nutrient loading of soil, especially nitrogen (N), phosphorus, zinc, and possibly other nutrients (Swanepoel *et al*., 2015a).

4. Strategic fertilisation management

Soil tests are, however, not sensible to determine the nitrogen (N) requirement of pastures. This is because N changes rapidly as a result of changes in soil water conditions, temperature, and crop growth stage to name but a few. Unfortunately, many farmers force soil productivity to absolute maximum levels and attempt to hasten pasture productivity by applying ever increasing levels of N. The consequences of applying high levels of N fertiliser on long-term productivity and environmental quality may be detrimental. Injudicious application of N during the rainy season, especially, increases the risk of N leaching, N accumulation in the sub-soil, and possible pollution of natural resources (Swanepoel *et al.*, 2015b).

The strategic management of N fertilisation can be based on the following important principles:

- The strategic applications of N during the active growth period of grasses are important.
- Applying high levels of N fertiliser at the wrong time in an attempt to create out-of-season pasture is uneconomical.
- Fertilise N at recommended amounts according to the pasture species and expected yield.
- The amount of N should be applied in conjunction with pH, macro- and micro element
- status of the soil.
- Within 10 to 14 days after N is applied to pasture, the N level in plants is high and the dry matter (DM) content of the plant material is low. From that point onwards, plants will use the nitrogen for growth. The DM content and grazing capacity of the pasture will increase. Therefore, the timing of grazing on a newly fertilised pasture is a critical management decision. The influence of this on milk per hectare will positively influence fertilisation cost.
- Irrigation scheduling is essential. Maintaining the soil moisture content is a critical management requirement for optimum plant production. Without irrigation scheduling, the soil nutrients, like N, K and Mn, will be leached from the soil and shortages will occur, resulting in lower DM production. Soil moisture management depends on the rooting depth of the pasture species, the growth rate of the plants, soil type, and the availability of water.
- Incorporating legumes, such as clovers, into grass pastures reduces pasture reliance on N fertiliser inputs. Such a system will further enhance soil quality, as the diverse rooting systems supports diversity of the microbial community (Swanepoel *et al.*, 2011).

5. Soil tillage

Soil quality is adversely affected by continuous soil disturbance by tillage. Soil aggregates protect soil organic matter and disruption of soil structure through tillage physically exposes soil organic matter to microbial degradation. Continued soil disturbance therefore eventually leads to a reduction in the organic matter content of the soil (Swanepoel *et al.*, 2015c). This is one of the main reasons that minimum tillage systems have been adopted world-wide. In the southern Cape region of South Africa, kikuyu-based pastures have been successfully managed under a no-tillage regime since the 1990s.

It was shown in studies by Swanepoel *et al.*, (2013; 2014b & 2015a) that the soil quality of kikuyu-ryegrass pastures was improved by long-term minimum-tillage. Not only did the physical condition of the soil improve, but also the organic matter content, enzyme activities, biodiversity, and abundance of the microbial community. Furthermore, it was shown that tillage should be minimised to prevent and mitigate soil compaction.

Choice of the tillage system is therefore an important consideration when pasture crops are to be planted, or over-sown into a pasture base.

6. Effects of grazing on soil quality

The grazing capacity of a pasture affects the amount of nutrients recycled through animal urine and manure. Grazing management can therefore have a large effect on soil quality. Grazing also affects the amount of material available, which in turn affects the root biomass available for microbial degradation. When pastures are grazed, the growth of roots is reduced and root hairs die off. This subsequently contributes to active carbon in soil, and provides the microbes with energy. Moderate grazing, along with sound fertilisation practices, is the most suitable management option to sustain pasture production and soil quality.

Ambient temperature

The ambient temperature has a significant effect on the growth of kikuyu and ryegrass pasture. The DM production of kikuyu is the highest at a maximum air temperature of 21°C and minimum air temperature of 9°C (Andrews & Jagger, 1999). The active growing period of kikuyu pasture is during summer and autumn. The production rate of kikuyu pasture is also higher at high temperatures with high moisture content than that of ryegrass. The DM production of kikuyu pasture is negatively affected by soil temperature, i.e. decreasing by 11 kg DM/ha/day for each 1°C that the soil temperature, at a depth of 50 mm, decreases below 18°C (Whitney, 1974).

The optimum ambient temperature for ryegrass pasture growth is 18°C. This is one reason that ryegrass can be established successfully into kikuyu pastures during autumn and to be dominant during winter and spring (Fulkerson *et al.*, 1993). The kikuyu component increases as the soil temperature increases above 18°C with the kikuyu being dominant during summer and autumn. Ryegrass reacts to N fertilisation at temperatures as low as 5°C. This ability of ryegrass to react to nitrogen at low temperatures will stimulate higher grass production during the winter.

Over-shadowing

Light is needed to trigger the growing points of parent clover stolons and -ryegrass tillers to produce new daughter stolons and -tillers. Shading reduces the production of daughter tillers and stolons. The reduction of daughter stolons and -tillers means fewer growing points resulting in lower clover and ryegrass production. Under grazing is the main cause for the over-shadowing of pasture. To prevent under grazing, it is important to implement the correct management practices with regards to grazing management.

The strategic choice of pasture plant species and varieties

The selection of pasture species and varieties is based on the physical and morphological characteristics of the soil, soil fertility (availability of macro-, micro elements, and organic material content), availability of water, climate (atmospheric pressure, rainfall, temperature, wind, humidity) and fodder programme requirements. Species best adapted to these conditions in a specific area need to be selected in fodder flow programmes.

The strategic over-sowing of an existing pasture with other pasture species is a management approach to improve seasonal fodder flow, forage quality and the milk production potential of pasture systems. The over-sowing of kikuyu with temperate grass and legume species in the coastal milk producing regions of the Eastern and Western Cape of South Africa is an example of such pasture systems (Botha, 2003; Botha *et al.*, 2008; Van der Colf, 2011). It is important that the varieties selected must have the ability to produce adequate, high quality, palatable fodder during the periods when the production and/or quality of kikuyu cannot provide for the nutritional requirements of high producing dairy cattle.

1. **Kikuyu over-sown with ryegrass**
   Perennial ryegrass (*Lolium perenne*), annual ryegrass (*L. multiflorum*) varieties Italicum and Westerworldicum, white clover (*Trifolium repens*) and red clovers (*T. pratense*) species are popular species for over-sowing into a kikuyu pasture base.

2. **Perennial ryegrass**
   The persistence of perennial ryegrass depends on environmental and management factors. The seasonal DM production of perennial ryegrass decreases annually. For this reason, it is over-sown annually during April/May into kikuyu (Van der Colf *et al.,* 2015). This gives perennial ryegrasses the ability to overshadow kikuyu during winter and spring, and thus compete with kikuyu during summer and autumn.

3. **Annual ryegrass**
   Annual ryegrass consists of *L. multiflorum var. westerwoldicum* and *L. multiflorum var. italicum*, commonly named Westerwolds and Italian ryegrass, respectively. Although Westerwolds and Italian ryegrass are closely related, there are some very important differences.

4. **Italian ryegrass**
   Italian ryegrass has a vernalisation gene that delays flowering. This vernalisation gene is switched off by a combination of low (winter) temperatures and/or short days followed by increasing day-length (spring), resulting in the initiation of flowering (Nash & Ammann, 2006). Italian ryegrass also has the ability to produce new daughter tillers

after flowering (Fairy & Hampton, 1997; Wallace & Yan, 1998; Nash & Ammann, 2006). The degree to which the variety is able to produce daughter tillers depends on the persistency of the variety in spring and summer (Nash & Ammann, 2006). Italian ryegrass is therefore not considered a true annual ryegrass. Persistency depends on how cold it is during winter, when established before the onset of winter and day-light length when established in late winter or early spring. Strategically, this variety can also be used to seasonally compete with and overshadow kikuyu during the growth period of kikuyu.

5. **Westerwolds ryegrass**
   Westerwolds ryegrasses are true annuals. When established in autumn, it tends to flower earlier than Italian ryegrasses. Westerwolds ryegrasses also do not produce as many daughter tillers after flowering and consequently the plants die and the pasture does not persist after flowering. Therefore, as a true annual, the fact that it has a strong seedling which quickly become a vigorous fast growing grass plant with the only aim to go into seed within 5 to 6 months, Westerwolds ryegrass can be established during late summer (February) or early autumn (March) into kikuyu for winter (June, July and August) pasture. Because it can be established during autumn, it also plays a vital role in the strategic over-sowing of kikuyu. It is the only annual ryegrass which fits into the strategy where the removal of the stem material of kikuyu is part of the plan to deplete kikuyu of its growth reserves. Because Westerwolds ryegrass is over-sown when kikuyu is still growing, it has the ability to establish fast, overshadowing kikuyu and preventing it from creating new leaves and supplementing its root reserves.

Westerwolds and Italian ryegrass cultivars are commonly recommended for their total herbage production. This has some merit, but attention should rather be given to how these varieties match the fodder flow requirements in a given enterprise (Goodenough *et al.*, 1987). Westerwolds ryegrass cultivars have a similar yield performance to the Italian ryegrass cultivars during the colder winter months, but the Italian ryegrass cultivars generally out-yield the Westerwolds ryegrass cultivars during mid-spring (Botha *et al.*, 2015).

The different ryegrass species are usually established into kikuyu pasture during autumn in an attempt to provide animals with adequate fodder of high quality during winter and spring months when the production of kikuyu pasture is low. When different ryegrass species are established into kikuyu pasture, inter-species competition can be expected. The characteristics of different ryegrass species will determine their persistence during spring or if it will eventually set seed, die off, resulting in kikuyu pasture dominating the pasture (Van der Colf *et al.*, 2015).

The greatest effects of inter-species competition occurs during autumn, when ryegrass is over-sown into kikuyu for winter fodder production, and during spring, when kikuyu starts to recover from winter dormancy. The rate at which the kikuyu-ryegrass pastures will change from ryegrass-dominant to kikuyu-dominant during spring will vary between different ryegrass types (Van der Colf *et al.*, 2015). Westerwolds ryegrass is usually the first to show a decrease in abundance and production during spring. As a result, Westerwolds ryegrass presents less competition to the emerging kikuyu, especially in terms of sunlight during spring, allowing kikuyu to be well established with high DM during summer. In contrast, Italian ryegrass continues to dominate pastures well into spring, often displaying higher DM production rates during this period than Westerwolds ryegrass-kikuyu pastures. The end result is that the summer production of kikuyu pastures is negatively affected by the overshadowing effect of the dense spring Italian ryegrass sward (Van der Colf *et al.*, 2015).

Perennial ryegrass is intermediate in terms of the competitive effect that it has on the summer production of kikuyu. Although perennial ryegrass plants may still be found in kikuyu pastures, even at the end of summer, summer production of such pastures was found to be higher than the Italian ryegrass-kikuyu pastures (Van der Colf *et al.*, 2015). It is possible that the differences in growth form of the annual and perennial ryegrass types play a role. In the same manner kikuyu can have an effect on the successful establishment of ryegrass during autumn. This may be attributed to the “strength” of the kikuyu component during autumn when planting commences. The Westerwolds ryegrass-kikuyu pastures seem to have a stronger and more vigorous kikuyu basis than both Italian and perennial ryegrass-kikuyu pastures. The end result is that emerging Westerwolds ryegrass seedlings compete with kikuyu for sunlight, water, and nutrients to a greater degree than Italian or perennial ryegrass seedlings. The understanding of how Italian, Westerwolds and perennial ryegrass interact with kikuyu has a significant effect on the production potential, botanical composition, and persistence of these pastures.

Kikuyu over-sown with clover

Without a legume component, kikuyu pasture is dependent on the application of nitrogen, thus increasing the input cost (Botha *et al.*, 2008). The inclusion of a legume component would potentially reduce the N fertilisation requirements and increase the quality of the forage produced by the pasture. The rotavator method (Table 14.1) is the preferred method of establishing perennial white and red clovers into kikuyu.

Table 14.1. The recommended seeding rate and over-sowing methods for planting different pasture species and varieties into kikuyu pasture (Botha *et al.*, 2008)

Pasture species	Seeding rate (kg/ha)	Over-sowing method
Westerwold ryegrass	25	Graze pasture to 50 mm Broadcast seed Use a mulcher Roll using a Cambridge roller
Perennial or Italian ryegrass	25	Graze pasture to 50 mm Use a mulcher Use a no till planter Use a Land roller
Perennial ryegrass **White clover** **Red clover**	12 4 4	Graze pasture to 50 mm Use a Mulcher Rotovate top soil Use a Land roller Broadcast seed Use a Land roller

While it is not difficult to establish clovers into kikuyu, the high cost of establishing clovers using expensive implements in preparing a seedbed, and maintaining a high intensity of grazing, together with strategic nitrogen applications, makes it an unpopular production system for dairy farmers (Botha *et al.*, 2008).

Overshadowing is the main reason that clover is not persistent in a kikuyu-clover pasture. If clover is over-shadowed, then the production of daughter stolons is reduced. Clovers need sunlight for the production of daughter stolons. The more stolons, the more growing points; the more growing points the more leaf production and growth (Curtis & O'Brien, 1994). Overshadowing because of under grazing is the main reason that the 30% to 40% clover fraction, required in a kikuyu-clover pasture to have a positive effect on nitrogen fixation and the quality of the pasture, cannot be maintained.

The inability of farmers to manage kikuyu in such a way that it is always grazed short enough for clovers to persist, starts annually during spring. The growth rate of winter growing ryegrass pastures increases during spring, resulting in the production of more fodder than can be effectively grazed by the dairy herd. A similar problem occurs during autumn when the growth rate of kikuyu is high but the palatability is low. Animals will then find it difficult to graze the pasture down to the recommended height of 5- 10 cm. As result, the under grazed kikuyu does not allow sufficient light to penetrate the canopy, over-shadowing the clover component's stolons and resulting in lowered clover persistence. The declining clover component reduces organic N availability to the pasture and, since only strategic nitrogen applications during winter are recommended as part of the management tool to sustain clover in kikuyu-clover pasture, the outcome is a decrease in DM production and grazing capacity. Farmers are then forced to apply nitrogen on a regular basis to boost the growth rate of the ryegrass component of the pasture. This further aggravates the loss of the clover component due to competitive effects.

Grazing management

An effective grazing management system is based on the optimum production (kg DM/ ha) of adequate, high quality, palatable dry matter and the highest possible animal intake (kg DM/cow/day). A well-planned fodder flow programme and utilisation management system of kikuyu-ryegrass is the basis for a successful grazing management system. It requires that kikuyu should be over-sown with ryegrass according to a specific plan, that grazing only takes place when adequate high quality, palatable pasture is available, and that the intensity of utilisation (how short) and frequency of utilisation (grazing intervals) is accurately executed. To obtain these goals, the pasture should be grazed at a point where the kikuyu and ryegrass are mature before they are grazed. Kikuyu and ryegrass should be grazed at the 4.5 and 3 leave stage, respectively (Fulkerson *et al.*, 1999; Fulkerson & Donaghy, 2001). This can vary between 3 and 6 weeks depending on factors like temperature, light intensity, day length and availability of water which influences leaf appearance. If ryegrass pasture is allowed to get older, the third ryegrass leaf will die, resulting not only in pasture wastage, but also in unpalatable roughage and in the overshadowing of the growth points of the ryegrass. This will prevent the development of new daughter tillers. Not only will the life of the pasture be shortened but the ryegrass component in a kikuyu-ryegrass pasture will also decline over time.

Correct grazing intervals and grazing intensity are the only management practices that will ensure optimum utilisation of kikuyu-ryegrass pasture. However, the intensity of grazing and grazing intervals should not be measured in time or in pasture height, but by the DM availability and the residual DM of a pasture (kg DM/ha) after grazing. To achieve this goal, pasture allocation is one of the most important management factors to prevent over- or under grazing of kikuyu-ryegrass pasture. The allocation of inadequate or excessive pasture will result in pasture wastage or lowered milk production.

At the Outeniqua Research Farm, the quantity of available ryegrass from July to August is estimated using the following regression equation:

pasture available higher than 30 mm (kg DM/ ha) = 62 x Rising Plate Meter (RPM) height - 360.

The pasture DM intake of Jersey cows, weighing 400 kg and fed 6 kg/day of a concentrate supplement, is estimated to be about 8 kg DM per day. This would require a pasture allocation before grazing of about 10 kg DM per cow per day. Using the above equation, it can be estimated that at a pasture height reading before grazing of 25 units on the RPM, the amount of pasture available before grazing would be about 1190 kg DM per ha. This means that about 119 Jersey cows per ha could be put on such a pasture. Alternatively 100 Jersey cows would require about 0.84 ha for a similar pasture intake.

Pasture should be grazed down to a level of about 50 mm or a RPM height of 10. By regularly measuring pasture levels before and after grazing, pasture utilisation would be improved. As the growth rates of pasture vary according to season, it is to be expected that the allocated area as well as pasture rotation will similarly vary.

Pasture intake is reduced by the feeding of concentrates. In a study conducted at the Outeniqua Research Farm, Jersey cows, grazing mainly on ryegrass-clover, were fed 0, 2.4, 4.8, or 7.2 kg of concentrate per day over two lactations and produced 12.8, 15.2, 15.8 and 17.0 kg of fat corrected milk per day, respectively (Meeske *et al.*, 2006). The feeding of each additional kg of concentrate resulted in production of 1.0, 0.71 and 0.58 kg fat corrected milk (FCM). The poor response to concentrate feeding can be attributed to substitution of pasture by concentrates.

The substitution rate (SR) can be calculated as follows: SR = 0.093 X kg of concentrate fed per cow/day. Feeding high levels of concentrates result in reduced pasture intake, higher feeding cost, and under-utilisation of pasture (Meeske, 2006).

Methods of planting different species into kikuyu

Different methods are required to plant different pasture species into kikuyu. The following methods have proven to be effective namely:

1. **Perennial or Italian ryegrass pasture**
   Perennial and Italian ryegrass species are established into kikuyu using the mulcher-planter method. Kikuyu pasture is grazed down to 50 mm, mulched to ground

level and afterwards established with a no-till planter. The seedbed is then rolled once with a land roller and irrigated. It is recommended that Italian ryegrass should be planted during March or April, while perennial ryegrass should be planted during April to May (Van der Colf, 2011).

2. **Westerwolds ryegrass**
   Although Westerwolds ryegrass can also be established with a planter, it can effectively be established using only a mulcher (Botha, 2003). Using this method, kikuyu pasture is grazed down to about 50 mm, after which ryegrass seed is broadcasted onto the remaining kikuyu stubble. The kikuyu pasture is then mulched to ground level without the blades of the implement touching the soil. The mixture of mulched plant material and seed is then rolled once with a land roller and irrigated. The superior competitive ability of the Westerwolds ryegrasses results in it being the best suited for pastures where kikuyu pastures have to be over-sown relatively early during late summer (February) and early autumn (March) to provide winter grazing, i.e. June to August.

3. **Clover or a mixture of ryegrass-clover**
   An effective way to establish clover or perennial ryegrass-clover pasture into kikuyu pasture is to cultivate the kikuyu pasture using a rotavator (Botha, 2003; Botha *et al.*, 2008). The kikuyu pasture is grazed to 50 mm, mulched to ground level, and afterwards rotavated to a depth of 100 mm. The seedbed is then rolled once with a land roller, broadcasted by hand, rolled again and irrigated. The clovers or mixtures of ryegrass-clover are established during April/May when the soil temperature at a depth of 10 cm is 18°C and the kikuyu is dormant.

   From a strategic point of view, it is a good option to plant clovers or mixtures of ryegrass-clover into kikuyu pasture that has been over-sown the previous two years during February or March with Westerwolds or Italian ryegrasses. The negative effect of mulching the kikuyu during the previous two autumns as related to storing of root reserves and overshadowing during autumn and summer decreases the ability of kikuyu to compete with the perennial clovers or mixtures of ryegrass-clover during the first year of growth.

- The seeds of perennial ryegrass, perennial clovers, and Italian ryegrass need to make contact with the soil for the seedling to establish well. The seedlings also don't have the ability to compete with active growing kikuyu. The planting method or time of planting must be chosen in such a way to benefit the over-sown crops, hamper the growth of kikuyu, or selected at a time when kikuyu is dormant.
- Clovers need a well-prepared seedbed. It is recommended that a kikuyu pasture should be grazed or the leaf and stem (stolons) material should be removed to a height of 50 to 100 mm before being mulched, regardless of the planting method or species being planted. The reason for this is that a large amount of mulched material will cause a nitrogen negative period in which it will be difficult for the Westerwolds ryegrass seedlings to germinate and grow fast enough for the roots to reach the soil. It will also cause clotting of the planter's coulters, affecting planting depth and the overshadowing of emerging seedlings. The recommended seeding rate and over-sowing methods for planting different pasture species and varieties into kikuyu were shown in Table 14.1.

4. **Lucerne established into kikuyu**
   Although kikuyu/grass pasture systems can be highly productive, sustainable production is dependent on expensive nitrogen fertiliser inputs. The successful introduction of clovers into kikuyu pasture should reduce the nitrogen fertiliser requirements; however, the utilisation of water by clovers will in most cases not be efficient resulting in a low grazing capacity. This will have a negative effect on the milk yield per hectare while the higher water requirements would increase irrigation input costs. Lucerne can also be successfully established into kikuyu reducing the input cost of a kikuyu pasture system. The main reason for this is that lucerne, as a legume, is not nitrogen dependent, its water use is efficient, and is the only legume that can compete successfully with grasses on the basis of DM production, quality, and palatability.

   Lucerne has been successfully established into kikuyu pastures using minimum till methods, producing up to 19 t DM/ha/annum without any nitrogen fertilisation and achieving a lucerne content of up to 57% after a two year period. The success of such a system will be dependent on using an herbicide during establishment, ensuring that it is established on a deep, well-drained soil, and managing the pasture according to lucerne guidelines.

Sustainable fodder flow

The production potential of cultivated pasture in a fodder flow system on farms is based on the selection and effective management of different species within the natural resources on the farm. It would be wise to follow the "bring-the-plant-to-the-soil" concept. This means that the choice of pasture species is then based on the physical and morphological characteristics of the soil, soil fertility, availability of water, climate and fodder flow requirements.

A sustainable and economic fodder flow system is based on the optimum utilisation of pastures. It is important that management and decision making factors focus on optimum production (kg DM/ha/day), pasture quality (NDF 40%, ADF 30%, CP 23%, ME 10.5 MJ/kg DM) and the palatability of the pasture. These factors should enhance DM intake and milk production per hectare; therefore, management practices should be based on the correct grazing intervals (rotation) and grazing intensity (how short). The utilisation of pasture should preferably not be measured in grazing time or pasture height, but by the amount available before grazing and residual amount of pasture after grazing. These factors affect the accessibility of root reserves to plants between grazing intervals, prevent over-shadowing and thus ensure sufficient sunlight on the growing points of plants. Within these guidelines the availability of fodder, within a well-planned fodder flow programme, can be maintained.

In closing

A number of factors are important for growth and persistence of pasture species. It is important that all the factors discussed above should be addressed in order to achieve optimum production, quality and palatability. Quality pasture production, the amount of pasture utilised by the animals, and the actual cost in relation to production cost are imperative indicators to produce milk competitively on an international market.

CHAPTER 15

CONCENTRATE FEEDING OF DAIRY COWS ON CULTIVATED PASTURE

Introduction

Concentrate feeding of lactating cows has developed because their nutrient requirements are higher than that provided by consuming only roughages. The type of concentrate to be fed depends on the quality of the roughage being fed as the basis of the diet. Cows on ryegrass pasture require a different concentrate to cows being fed oat hay as the crude protein (CP) and energy contents of the two roughages differ substantially. Supplementation of concentrates also reduces pasture demand when there is a shortage of roughage. The demand for supplementation has further increased because cows are producing more milk today than 40 years ago. Dairy concentrates are mixtures of concentrated feeds that contain high levels of energy, like maize and cereal grains, protein from feeds such as soybean-, cottonseed and canola oil cake meals, and mineral components, like bone meal and feed lime. The mineral content of concentrates should address imbalances in macro and micro minerals of the roughage fed. Ryegrass and kikuyu pastures in the Southern Cape usually have a calcium (Ca) content of 0.4% and a phosphorus (P) content of 0.4% on a dry matter (DM) basis. However, the Ca requirement of lactating cows is 0.8% in the total diet; therefore, it requires some Ca supplementation to maintain the cow's Ca status.

Furthermore, the supplementation of concentrates is required because roughage intake is determined by rumen volume or rumen capacity. When the rumen is full, pasture has to be digested by micro-organisms, after which partly digested feed flows from the rumen into the omasum and abomasum for further digesting. The rumen must therefore be partly empty before more roughage can be ingested. However, the emptying rate of the rumen is affected by the digestibility of roughages, slowing down when digestibility is poor. This affects roughage intake negatively, which results in reducing energy and protein intake, resulting in a lower milk yields. By feeding concentrates, this negative effect on energy intake and milk production is reduced. However, as the cost of concentrates is often 3 to 4 times higher than that of roughages, it should be used very strategically to increase milk production and farm profit. This is further emphasised by the fact that by increasing the level of concentrate feeding, pasture intake decreases. This increases the feed cost of dairy cows and could, depending on the milk yield response, increase or decrease profit margins.

Nutrient requirements

The nutrient requirements of cows have been well established and are documented in various publications. Nutrient requirements depend on a number of factors, such as the amount of milk cows produce, milk composition, stage of pregnancy, live weight, condition score of the cow, distance and gradients cows have to walk on a daily basis to the milking parlour and back to pasture or housing systems. Climatic factors, such as ambient temperature, rain and wind speed, also affect their nutrient requirements. Various computer programmes from the NRC (2001) and CNCPS, as well as nutrient requirement tables, are available to determine the nutrient requirements of dairy cows.

Jersey cows should produce 12 kg of milk from good quality ryegrass pasture without any concentrate supplementation. However, the amount of protein in high quality ryegrass is often in excess of the protein requirements of cows, while energy is limiting. Increasing the amount of dairy concentrate containing 12% CP and 76% total digestible nutrients (TDN) from 4 to 6 kg/cow/day should increase milk production from 16 and 18 kg milk/cow/day. However, when pasture availability and quality are high, usually from August to October, the response on concentrate feeding may be only 0.5 kg milk/kg concentrate. Under such conditions and depending on the ratio between the milk price and concentrate cost, it may be more profitable to feed less concentrates to cows.

Composition of dairy concentrates

Dairy concentrates fed to cows on pasture often contain maize as the main energy source and soybean, cottonseed or canola oilcake as protein sources. Cereal grains, such as barley, triticale, wheat, and oats, could also be used as energy sources. An example of a dairy concentrate suitable for cows on pasture is presented in Table 15.1. In this case with cows on pasture, energy would be limiting; therefore, this specific concentrate mixture contains 85% maize grain. The rest of the mixture includes soybean oilcake meal and minerals. In some areas, macro minerals such as calcium (Ca) and micro minerals such as magnesium (Mg), copper (Cu), zinc (Zn), manganese (Mn) and selenium (Se) may be in short supply and should be supplemented through the concentrate mixture. Usually, micro-minerals are supplied as a premix pack and should be formulated to address mineral shortages in specific areas.

Table 15.1. An example of a dairy concentrate providing 12% crude protein on a dry matter (DM) basis (TDN = total digestible nutrients; MJ = Mega Joules)

Feeds	DM basis (%)	As is (kg)
Maize grain	85.0	857
Soybean oilcake	11.7	112
Feedlime	2.0	18.5
Salt	0.4	4.7
MgO	0.3	2.8
Mineral premix	0.5	5
Composition (% of DM)		
Crude protein (%)	12.0	
Metabolizable energy (MJ/ kg DM)	12.5	
TDN (%)	83.3	
Calcium (%)	0.8	
Phosphorus (%)	0.4	

Concentrate feeding systems

1. **Flat rate concentrate feeding system**
   It is a simple system in which cows receive a fixed amount of concentrate throughout the whole lactation period, e.g. 4 or 6 kg/ cow/day for Jersey cows. Holstein cows may receive higher levels at 7 or 9 kg per day, although proportionally at the same level of about 0.3 to 0.4 of total daily DM intake. Usually, concentrates are fed during milking or in a post-parlour feeding barn. The amount of concentrate feeding should be reduced when cows become fat (a condition score of 3.5 on a 1 to 5 point scale). This, however, seldom happens in this feeding system, as the condition score of cows usually ranges between 2 and 2.5 because the aim of the system is to increase roughage or pasture utilisation by feeding low to medium levels of concentrates. However, during pasture shortages or when stocking rates are too high in relation to the amount of pasture available, the condition score of cows usually decreases, indicating that cows are milking from their body reserves. This change in body condition score can be used as an indicator of the feeding programme for cows in the herd. Increasing concentrate supplementation levels increases feeding cost, which may not be economically positive.

   Cows producing higher levels of milk when concentrate feeding is fixed and limited do so by ingesting more pasture and digesting pasture better. This allows for a lower feeding cost, resulting in a good basis for profitable milk production from pasture. The rumen pH of cows grazing high quality pasture (in spring and early summer), while receiving 4 kg of concentrate per day may reach levels as low as 5.5. When the pH of the rumen fluid reaches levels below 5.8, fibre digestion in the rumen is reduced, which results in reducing the milk yield of cows from pasture. In this system it is accepted that cows lose condition during the first 100 days of lactation while regaining it during the last 100 days of the lactation period. High producing cows may not fit into this system well, as they will be in a negative energy balance for a longer period after calving. This may reduce fertility because of poor conception extending the calving interval. The level of concentrate feeding can be adjusted according to pasture availability and pasture quality, i.e. 6 kg/day from January to June and 4 kg from July to December. This system is simple to use and also has the advantage that it favours cows that utilise pasture well.

2. **Step-rate concentrate feeding system**
In this system cows are fed different amounts of concentrate during the lactation period, i.e. 8 kg of concentrate/cow/day for the first 150 days of the lactation period followed by 4 kg concentrate per day for the second 150 days of the lactation period. This means that on average, 6 kg concentrate is fed per cow per day. Alternatively the amount of concentrate can vary from 8 kg concentrates per cow/day during the first 100 days of the lactation period, after which the amount of concentrates is reduced to 6 kg/cow/day up to 200 days in milk and then 4 kg concentrates per cow/day. The advantage of this system is that cows are fed more concentrates in early lactation when their energy requirements are high because of high milk yield levels, while less concentrates are fed when energy requirements are low in late lactation when milk yield is low. Because more concentrates are fed in early lactation, live weight losses and loss of body condition will be less in early lactation compared to the flat-rate concentrate feeding system. To apply the step-rate feeding system in a practical way, cows in milk should be separated into different groups according to stage of lactation or days in milk, i.e. early, mid, and late lactation groups. This also makes it possible to allocate paddocks that produce more and better quality pastures to cows in early lactation when feeding requirements are high because of high milk yield levels.

3. **Feeding concentrate according to daily milk yield**
In this system, cows are fed concentrates according to milk yield at a set rate, i.e. 0.25 to 0.35 kg concentrates per litre of milk up to a set maximum amount of concentrate per day. The maximum amount may be set at about 2% of live weight which, in the case of Jersey cows, is about 8 kg/cow/day. The maximum level should be adjusted according to the quality of the pasture. Experience has shown that Jersey cows grazing high quality pasture in spring should not be fed more than 8 kg of concentrate per day. Moreover, during autumn the fibre content of kikuyu is high. This reduces the digestibility of pasture and also pasture intake, requiring a higher feeding level of concentrate to maintain milk yield levels. Concentrate feeding of 3 to 6 kg/cow/day for Jersey cows and 4 to 8 kg/cow/day for Holstein cows should not result in digestive upsets and the response on concentrate feeding should be between 1 and 0.8 litre milk/kg concentrate. At the start of lactation period, concentrate feeding is gradually increased to limit digestive disorders over a period of two weeks until concentrate level is sufficient for a production of 25 litre per cow/day (8 to 9 kg concentrates/cow/day).

Feeding concentrates to cows according to milk yield levels is a complex system requiring milk meters, a feeding system and a computer programme. In Table 15.2 suggested amounts of concentrates to be fed at different milk yield levels are shown. High producing cows are rewarded with higher levels of concentrates, while pasture intake is reduced. This system favours higher producing cows, while low to medium genetic merit cows for milk yield often show an increase in body condition score.

Table 15.2. Suggested amounts of concentrates to be fed according to the milk yield of Jersey cows on pasture

Milk production (kg/cow/day)	Concentrate level (kg/kg of milk)		
	0.25	**0.30**	**0.35**
> 25	6.3	7.5	8.8
20 - 25	5.6	6.7	7.8
15 - 19	4.4	5.3	6.2
10 - 14	3.1	3.8	4.3
< 10	2.0	3.0	3.5

When feeding high levels of concentrates to cows on pasture, stocking rates (cows per ha) should be higher to maintain a similar pasture utilisation as at lower concentrate levels. An advantage of this system is that the effect of a negative energy balance of cows is smaller than on a flat rate concentrate feeding system. Regular calibration of milk meters and feed dispensers, as well as an accurate electronic cow identification system, is required to operate this feeding system effectively.

Use a simple system

For concentrate feeding a simple or easy-to-use system should be used, i.e. cows could be divided into two or three production groups, tagging cows to identify those that are to receive a low, medium or high level of concentrate. The level of concentrate feeding should be adjusted to ensure that cows have a condition score of 3.0 to 3.5 at the end of lactation period. Higher levels of concentrate supplementation should coincide with high stocking rates to ensure high milk production and optimal profit per hectare.

Automated computer feeding systems are currently available. Such systems estimate the amount of concentrates to be fed to cows on a daily basis based on their current (or the previous week's) average milk yield, live weight, and condition score. In this way, cows can be fed individually. Separate feed bins are required to provide specific feeds, such as energy and protein feeds, as well as minerals. The accuracy of the milk meters should be checked regularly, while the amount of concentrates that are fed should also be determined.

Early research

In the early 1970s, concentrate feeding was not a common practice in the pasture-based areas of the Southern Cape. This was probably because of the unavailability of suitable concentrate mixtures while farming was on a small scale with farmers reluctant to use high-cost feeds. In most cases, concentrate feeding consisted of a few cups of ground maize meal and possibly bone meal. The genetic merit of cows for milk production was also poor and the response in milk yield to concentrate feeding was not high. To encourage the use of concentrates for dairy cows a trial was conducted at the Outeniqua Research Farm to demonstrate the effect of higher concentrate feeding levels on the milk yield of Jersey cows on kikuyu pasture. At the time, concentrate feeding level was based on the daily milk yield of cows. Therefore, three concentrate feeding levels were used, i.e. 0, 0.25, and 0.45 kg concentrate/kg of milk produced. Concentrates were fed to three groups of 15 cows each over two lactation periods. In Table 15.3 the average milk yield and milk composition of Jersey cows as affected by concentrate feeding level is shown.

Table 15.3. The average production performance of Jersey cows on kikuyu pasture as affected by concentrate feeding level

Production parameters	Concentrate level (kg/kg milk)		
	0	0.25	0.45
Concentrates fed (kg "as is")	0	1285	2514
Milk (kg)	3639	4568	5003
Fat (%)	5.09	5.43	4.81
Fat (kg)	185	248	241
Protein (%)	4.14	4.30	4.29
Protein (kg)	151	196	215
4% Fat corrected milk (kg)	4246	5232	5616
Response (kg milk/kg concentrate)	-	0.723	0.354

Concentrate feeding followed the milk yield of cows over the lactation period. The average concentrate feeding level was on average 4.2 and 8.2 kg/cow/day, respectively, for the 0.25 and 0.45 kg/kg of milk concentrate feeding levels. As expected, the milk yield of cows increased at higher concentrate levels in the diet. However, the response to concentrate feeding decreased as more concentrates were fed, i.e. 0.723, and 0.354 kg milk/kg concentrate when the concentrate feeding level increased from 0 to 0.25 kg/kg milk and from 0.25 to 0.45 kg/kg milk, respectively. At the highest concentrate feeding level, the response in milk yield was 0.543 kg milk/kg concentrate in comparison to the no concentrate feeding level. This indicates that concentrate feeding at this level would only be economically viable at a concentrate to milk price ratio that is less than 0.543 of the price of milk. These results should, however, not be extrapolated to farm income or income per ha. It is to be expected that at higher concentrate feeding levels, higher stocking rates would be possible which would increase the milk production per hectare.

Limited work has been conducted in South Africa on the effect of stocking rate on milk production per cow and per ha. In countries with strong pasture-based production systems, research emphasis has always been on stocking rates rather than concentrate levels to increase pasture utilisation as a way to reduce the production cost of milk. Only a few short term stocking rate trials have been conducted in the Western Cape. However, these trials do not provide clear answers to the milk production potential per ha for specific pasture types and pasture systems. Jones & Sandland (1974) showed the relationship between stocking rate and production per animal and per ha. As stocking rate increases, production per animal declines while production per ha increases. At low stocking rates, pasture is under-utilised while production per cow is high. Once past an optimum stocking rate level, pasture is over-grazed reducing production per animal. This may eventual lead to a reduction in the production per ha. Overseas results also do not provide much help either as rainfall and temperature differ to South African conditions. Research in Ireland (McCarthy *et al.*, 2013) showed (over a 3-year period in a seasonal calving system), that the milk yield of Holstein cows decreased from 21.8 to 19.3 kg/day at low (2.51 cows/ha) to high (3.28 cows/ha) stocking rates. Cows only received 1 kg of concentrates per day. The reduction in milk production per cow was attributed to a reduction in pasture DM intake. However, in this study the negative effect of stocking rate on milk yield per cow was reduced by a later calving date in the seasonal calving system indicating the complex nature of pasture-based trials. The response per cow and production is largely affected by pasture production.

Pasture production is highly dependent on natural rainfall supplemented by irrigation. As annual and seasonal droughts are common occurrences in South Africa, stocking rates for different production areas are difficult to establish. The emphasis has been to maintaining conservative stocking rates, while feeding extra roughages and concentrates to ensure high milk yields. However, this increases the production cost of milk requiring higher milk yield levels to reach a break-even production level. This has created the push for higher milk yields in dairy cows which is in contrast to keeping feeding cost low.

New research

The effect of concentrate feeding on the production of Jersey cows was further determined using a step-rate concentrate feeding system. Cows were fed concentrates at no, low, medium, and high levels comprising 0, 3, 6 and 9 kg/cow/day from day 1 to 150 days in milk and thereafter 0, 1.5, 3.0 and 4.5 kg/cow/day to the end of the lactation period. The 4% fat corrected milk (FCM) yield of cows receiving these concentrate feeding levels was 3741, 4645, 4868, and 5282 kg/lactation, respectively. The milk yield response to the zero level of concentrate feeding was 1.34, 0.83, and 0.76 litres of 4% FCM for each kg of concentrate fed at the low, medium, and high level of concentrate feeding level. The milk composition and live weight of cows were not affected by concentrate feeding level, while calving interval increased at higher concentrate feeding levels. The condition score of cows improved as the level of concentrate feeding increased. However, this study did not consider different stocking rates or milk yield per ha as when feeding higher levels of concentrates, higher stocking rates should be applied to ensure better pasture utilisation and a high milk yield per ha.

In a systems-study at the Outeniqua Research Farm, kikuyu was over-sown with ryegrass. Pasture production was 18 ton DM/ha and 31000 kg milk/ha was produced per year. The average stocking rate was 6 Jersey cows/ha while cows received 1200 kg concentrate per lactation, i.e. 4 kg/cow/day. Another study showed that the response to concentrate feeding of cows being fed 7.2 kg concentrate per day, was 0.5 kg milk/kg concentrate. As the level of concentrate feeding increased, the milk response per kg concentrate decreased and more pasture is replaced by concentrate. This increases the production cost per litre of milk reducing the profit per litre of milk. It is recommended that the economics of concentrate feeding should be evaluated on a total farm basis.

In closing

For concentrate feeding, a simple feeding system should be used. From a practical point of view, farmers should focus on pasture production and management rather than on spending much time on estimating exact amounts of concentrates to be fed to individual cows on a daily, weekly or monthly basis. Emphasis of management should rather be on pasture production and ensuring that pasture allocation is correct. This can be done by measuring the available amount of pasture before grazing, using a tool like the RPM. For most ryegrass pastures the RPM reading should be 20 to 25 before grazing and 10 to 12 after grazing. Presently the most economical level of concentrate feeding seems to be 4 to 6 kg/cow/day for Jersey cows. Farmers should be well aware of the response of the milk yield of cows per kg of concentrate fed as feeding high levels of concentrates could be uneconomical. The reason for this is that the cost of concentrates per kg is about 3 to 4 times higher than that of pasture.

CHAPTER 16

MANAGING COWS ON CULTIVATED PASTURES

Introduction

Cultivated pastures for dairy production are used when the annual rainfall is sufficient and well distributed over the year or when sufficient water for supplementary or permanent irrigation is available. Because pastures are established and then utilised for a number of years, requiring mostly seasonal fertiliser to maintain high production levels, the cost of herbage is lower than that of annual forage crops or bought-in hay or silage. Most cultivated pastures have high crude protein (CP) contents, i.e. in excess of 18% on a dry matter (DM) basis, high energy and low fibre contents, therefore, requiring limited concentrate supplementation to maintain high milk yield levels. Increasing concentrate levels should be accompanied by higher stocking rates to keep pasture utilisation at a high level. The high moisture content, often higher than 80%, and lower DM production, in comparison to forage crops like maize silage, are two major disadvantages of cultivated pastures. These factors limit the milk production per ha. Recent research in countries making use of cultivated pasture has focused on increasing DM production per ha by including other forage crops into the farm production system. However, this increases the production cost of milk which results in an increase in the milk yield break-even level. Because of its low cost, pastures are often under-utilised. Surplus pasture during spring and early summer should be harvested as silage, in wrapped large bales. This can be fed during pasture shortages, usually during winter. Alternatively, concentrate levels being fed to cows could be reduced or surplus material could be used for beef production.

Voluntary feed intake of cows

The voluntary feed intake of cows is the single most important factor affecting the milk yield and profitability of a dairy. Research under intensive feeding conditions at Elsenburg showed that the feed intake of Jersey and Holstein cows in first lactation differed, being 14.2 and 17.3 kg DM per day, respectively. However, the feed intake of Jersey cows was proportionally higher than that of Holstein cows, being 4.0 vs. 3.4%, respectively. At similar concentrate feeding levels, the proportional pasture intake of Jerseys would be about 5 to 10% higher than that of Holstein cows. However, it is important that the feed intake, specifically pasture intake, is estimated by using the amount of pasture available before grazing and residual pasture after grazing.

The daily pasture intake of cows is often estimated based on the time cows have access to pasture. The following guidelines can be used:

Time on pasture (hr)	DM-intake (kg/day)
2 - 3	3 - 4
3	5 - 6
5	7 - 8
8	10
24	14

However, pasture intake would be less when the pasture availability is limited. Therefore in situations when pasture is limited, i.e. at less than 5 cm, the above mentioned levels of pasture intake would not be possible. Pasture at a height of approximately 15 to 20 cm should ensure a maximum pasture intake. Pasture intake increases when pasture availability increases. However, the relationship between pasture availability and pasture intake is not linear. At high pasture availability levels, pasture intake is determined by rumen size as indirectly indicated by live weight. Usually, when cows are on pasture for a shorter period, pasture increases because of large bites. When pasture is short, bites will be smaller, reducing pasture intake. The following equation could be used to estimate the pasture intake of dairy cows, indicating factors affecting pasture intake:

Pasture intake (kg/DM/day) = GT x RB x IB where

GT = grazing time (in minutes)
RB = rate of intake (number of bites/min)
IB = intake per bite (g)

For an optimum pasture intake, at least 50 g pasture DM per kg of live weight should be available before grazing. This means that dairy cows weighing 400 kg require at least 20 kg DM (above ground level) per day to ensure a pasture intake of about 10 kg per cow per day. When pasture availability is high, cows will stop grazing after about 1 to 1½ hours because the rumen is filling up. They will then lie down to rest and to ruminate. This provides time for the rumen to empty. The digestibility of the roughage determines the emptying rate of the rumen.

The herbage intake of poor quality pasture, like rank kikuyu with a thick mat, is not high. This is because of poor palatability while the crude fibre (CF) content of the pasture is high causing a physical limit on pasture intake. This results in the rumen filling up quickly, while the emptying rate is slowed down because of the poor digestibility of the herbage material.

Roughage supplementation on pasture

The amount of supplementary feeds, such as hay or silage and concentrates being fed, also affects the pasture intake of dairy cows. Generally, the daily DM intake of dairy cows varies between about 2.7 to 4.0% of live weight. This means that cows weighing 400 kg would consume about 11 to 16 kg DM per day. The actual feed intake is affected by the production stage, i.e. cows being dry or lactating. Jersey cows producing 25 kg milk per day should consume about 16 kg DM per day. Therefore, because of limited rumen space, the expected pasture intake of cows being fed 6 kg concentrates per day, as well as 4 kg oat hay per day, would be about 6 kg DM per day.

In a study conducted at Elsenburg comparing different production systems which included two pasture-based systems, the estimated pasture intake of Jersey cows being fed 3 and 6 kg concentrates per day was 10.7 and 4.7 kg DM/day, respectively. Because of the higher concentrate feeding level, while also receiving additional oat hay, the stocking rate of this group was higher than the system in which concentrate feeding level was lower, i.e. 6 vs. 2 cows per ha, respectively. When all the supplementary feeds, such as oat hay and a small amount of a high-protein-concentrate were included, total daily feed intakes of cows in the two pasture-based systems were 14.3 and 14.8 kg DM/cow/day. In comparison, cows on a zero-grazing system being fed a total mixed ration (TMR) consumed 15.1 kg DM/cow/day. The total DM intake of cows in the pasture-based systems was approximately 3.4 to 3.6% of live weight. This is in accordance with nutrient requirements, suggesting that the expected daily feed intake of Jersey cows weighing 400 kg producing 20 kg milk/day at 4.0% fat should be 14.4 kg DM/day. The feed intake of cows on pasture is generally expected to be lower than for cows on a TMR-based system. An earlier study at Elsenburg showed that Jersey cows being fed a TMR had a feed intake of 14.1 kg DM/day, which is equivalent of 4.0% of live weight.

Although feeding more concentrates and additional hay to cows on pasture increases the milk output per ha, it also increases the production cost of milk. In Figure 16.1 an example of the annual change in pasture intake, as affected by season showing the need to feed additional hay to maintain a constant daily feed intake of 15 kg DM per day, is demonstrated. During the winter pasture growth slows down reducing pasture intake while it increases in spring. The problem with this feeding system is that because of the higher cost of hay in comparison to the cost of pasture, the break-even milk production level increases as the amount of additional hay being fed increases, being 20% higher in July than in January. Hay at a higher cost increases the break-even milk production level.

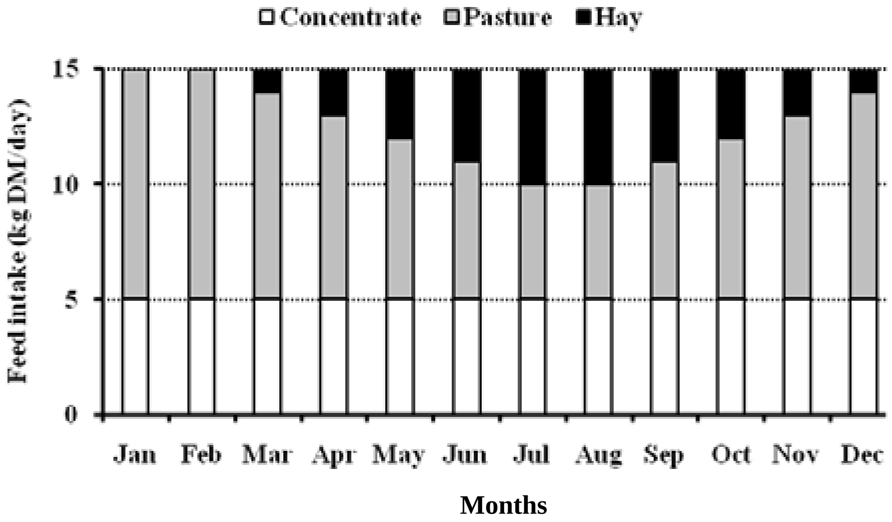


Figure 16.1. The daily pasture intake as affected by pasture availability and supplementary hay being fed during pasture shortage

The voluntary pasture intake of cows is affected by the CF content of herbage material. For this reason, pasture intake can be estimated using the NDF fraction of the CF in herbage material. Research has shown that cows on pasture consume at least 1.5% of live weight as NDF. This means that for cows weighing 400 kg the NDF intake would be 400 kg x 1.5/100 = 6 kg NDF; therefore, cows on pasture containing 48% NDF, would consume about 6 kg NDF x 100 kg DM/48 kg NDF = 12.5 kg pasture. From this it can be estimated that pasture intake would be reduced at higher NDF levels in pasture.

Furthermore, the pasture intake of dairy cows is also affected by the amount of concentrate being fed. At high concentrate feeding levels, pasture intake is reduced, as pasture is replaced by the concentrates. The pasture replacement rate (PRR) is estimated as follows:

PRR = 0.093 x kg concentrate per cow per day

The PRR for cows being fed 4 kg concentrates per day would be 0.093 x 4 kg = 0.372 kg pasture per kg concentrate. This means that the pasture DM intake of cows consuming 4 kg concentrate per day would be 0.372 x 4 = 1.5 kg DM less per day. Therefore, the estimated pasture intake would be 12.5 – 1.5 kg = 11 kg per cow per day.

Estimating pasture intake

It is difficult to determine the amount of pasture cows consume on a daily basis. Farmers tend to use the eye-ball method, i.e. judging the amount of pasture before and after grazing. This method, however, is very subjective as farmers usually do not collect (harvest) pasture samples before and after grazing to obtain some standard of pasture availability or of residual material. Usually, the amount of pasture available before grazing is judged to be higher than the actual amount, resulting in lower pasture intakes than expected. Under experimental conditions feed markers are used, while for farming conditions the rising plate meter (RPM) is commonly used to estimate pasture intake.

To be really useful, the RPM has to be calibrated for each pasture type and season. This is done by recording a number of pasture height meter readings and sampling the amount of herbage material underneath the disk. Pasture is harvested at a standard height of usually 30 or 50 mm above the ground. All harvested pasture material is collected, weighed (as is), and the material dried to estimate the DM content of the pasture material. The linear relationship between RPM and pasture material underneath the plate is estimated with the correlation coefficient providing an indication of the "correctness" or reliability of the regression equation. Increasing the number of samples collected and RPM readings usually increase the reliability of the regression equation. It is advisable that samples and height meter readings are recorded for pre-grazing and residual pasture material separately. To estimate the pasture intake of cows, RPM readings before and after grazing should be recorded. The average of 50 to 100 RPM reading before grazing, fitted to the regression equation, gives the amount of material available before grazing. Preferably, regression equations have to be established for different pastures as the physical characteristics of pasture species differ. However, in many cases farmers tend to use a standard regression equation for all pasture types. Although this is strictly not correct, usually this method gives a better indication of pasture intake and pasture utilisation than the eye-ball method.

In a systems study at the Outeniqua Research Farm the relationship between RPM readings (x) and pasture production (y) in kg DM/ha for kikuyu-ryegrass pasture is described by the following regression equation:

$y = 62x - 360$; $R^2 = 0.80$.

From this, it can be estimated that at a RPM reading of 25 about 1190 kg DM/ha is available above 30 mm. The daily grazing area required per cow at this pasture height is approximately 100 m^2. From this, it follows that a larger grazing area has to be provided when the RPM reading is lower as the amount of herbage per ha would be less. Post-grazing RPM readings give an indication of the amount of herbage removed (consumed) by cows. This can be used to estimate pasture utilisation. The RPM reading after grazing should be between 10 and 15 indicating over-grazing at levels below 10.

Using the RPM it is also possible to determine the rotation cycle for specific pastures, as this varies according to the season. For a maximum pasture intake at least 1000 to 1500 kg herbage DM 30 mm above ground level should be available. During summer, when pasture growth is high, a sufficient amount of pasture could be available from 21 to 28 days after grazing, while during winter the regrowth period may be 50 to 60 days.

The aim is to get an indication of pasture intake and whether sufficient amounts of pasture are available before grazing. Rising plate meter readings below 10 would indicate low herbage mass. When cows look hungry at RPM readings below 10, the grazing area should be increased or the number of cows on a specific camp should be reduced to ensure higher pasture intake for all cows.

In earlier studies, a so-called falling plate or disc meter was used to estimate pasture intake and pasture utilisation. This device uses the relationship between compressed pasture height readings (in cm) and pasture material underneath the disc meter plate. The difference between the amount of material before grazing and residual material after grazing is used to estimate the pasture intake of cows. Such a disk meter was used in a study conducted at Elsenburg in which the production performance of Jersey cows in two pasture-based production systems were compared to a TMR system. Disk meter height readings were recorded and the pasture (a mixture of white and red clovers, ryegrass and cocksfoot) harvested underneath the disk. Material was cut at ground level to reduce the variation in pasture cutting height. Before and after grazing regression equations were developed for pasture systems.

Pasture allocation in both systems was managed daily using moveable electric fencing (poli-wire). A fresh strip of pasture was provided after each milking, while a second poli-wire was used as a back-fence to prevent cows grazing on the pasture regrowth. When pasture growth slowed down in autumn and winter, a large grazing area was provided to ensure a minimum amount of herbage was available before grazing. Estimated pasture intake for Jersey cows was 10.7 and 4.7 kg DM/cow/day, which was in accordance with their expected pasture intake levels.

In a study conducted in Australia, it was found that the amount of pasture available before grazing affects pasture intake, as well as the response to concentrate supplementation. Pasture intake increased from 10.8 to 14.5 kg DM/cow/day when the amount of pasture available before grazing increased from 13.7 to 40.2 kg DM/cow/day. Although milk yield increased from 18.0 to 21.0 kg/cow/day, pasture utilisation was reduced from 79 to 36% for the limited vs. high pasture availability levels, respectively. This indicates the importance of increasing stocking rates as pasture availability increases. In the same study, the response in milk yield, as affected by concentrate supplementation, was higher for cows having access to a limited amount of pasture before grazing, i.e. 0.50 vs. 0.03 ℓ/kg concentrate at the low and high pasture availability levels. This means that concentrate has as add-on effect when pasture availability is low, while at high pasture levels, concentrate supplementation has little effect.

Grazing systems for dairy cows

For effective pasture management a simple system is required. Two systems are mainly being used, i.e. strip grazing in a rotational system using movable temporary fencing or a permanent camp system using a fixed grazing system.

Strip grazing

This is accomplished using movable electric fencing. It is easy to move fences, as it is usually a single strand of electric wire which is used to allocate grazing areas according to the number of cows and amount of pasture that is available before grazing. In this system, cows receive a fresh strip of pasture, once or twice a day, usually after milking, depending on the amount of pasture available. To increase the utilisation of pasture, a smaller area can be allocated to cows. This, however, requires a good concept of the amount of pasture available before and residual pasture after grazing to prevent affecting daily pasture intake negatively. It has been found that by forcing cows to eat deeper into the herbage material, i.e. closer towards ground level, cows move slower through a specific area. This could create the problem that the pasture towards the end of the grazing cycle could become more mature, thereby reducing its feeding value and voluntary feed intake. If this is the case, it means that the stocking rate is too low, requiring more cows or fewer pasture camps. Under wet soil conditions, a heavy concentration of cows on an area could result in the pugging (the soil being trampled) of the soil, which could affect post grazing recovery of pasture. Each time the electric fence is moved, a management decision has to be made regarding the amount of herbage available in the next strip and the amount of residual pasture. Someone not well trained in this regard could provide too much or too little pasture for grazing. The advantage of this system is that the pasture stand is often more homogenic, as pasture is utilised more uniformly. A disadvantage is that moving fences once or twice a day requires more labour inputs. This, however, creates another opportunity as cows are seen more often which could improve heat detection or noticing sick cows.

Fixed sized pasture camps

For this system grazing areas are divided into permanent camps using fixed fences. Usually, camps are large enough to provide grazing for 1 to 4 days. The size of camps is determined by the number of cows to be put onto the pastures. It is common that in some camps surplus herbage has to be removed by cutting it at ground level using a grass cutter and removing the cut material. When this is not done, pasture quality deteriorates forming a thick mat or becoming tall and rank. This is often observed in kikuyu camps, which are grazed at low stocking rates or when concentrate supplementation is high. This is usually observed as small pieces of grass lying on top of the pasture mat. By cutting the mat down to ground level, stolons of kikuyu move underground, thereby increasing the leave growth above ground.

Permanent grazing

In this system a fixed number of animals are put onto a specific camp for the duration of the grazing period. Stocking rate is estimated on the amount of material available before grazing. Because fewer cows per area are put onto the pasture, the risk of pugging (the soil being trampled) during rain storms is reduced. In this system, pasture areas could be divided into day and night camps, which may improve the management with regards to the collection of cows in the early morning for milking. Fertiliser application must be done very systematically as camps are fertilised once only. A disadvantage of this system is that the pasture forms a thick mat. Usually small pieces of the unpalatable stems (stolons) are observed on top of the pasture mat. However, continuous heavy stocking rates would reduce the survival of the root system of specific young pasture.

In closing

The cost of pasture is low in comparison to other roughages. Large amounts of pasture are wasted when pasture management is poor. The milk yield of cows is affected negatively when pasture availability is low, while milk yield per ha is similarly affected when pasture utilisation is low. Both these problems can be overcome by measuring the amount of pasture before and after grazing to determine actual daily pasture intake of cows. Using the RPM, an indication of the amount of pasture available before grazing can be obtained, while pasture intake can be estimated when the residual pasture is determined. Pasture intake is affected by a number of factors which include other feeds being fed as well as the quantity and quality of pastures. Pasture production and pasture utilisation affect the profitability of pasture-based production systems. Surplus pasture during spring and early summer should be harvested as silage, wrapped in large bales. This can be fed during pasture shortages usually during winter. Alternatively, concentrate levels being fed to cows could be reduced or surplus material could be used for beef production.

CHAPTER 17

ESTABLISHING FORAGE CROPS FOR SILAGE AND HAY PRODUCTION

Introduction

The Western Cape has a winter rainfall pattern which means that rain normally occurs from about May to September of each year. This means that mainly winter growing crops, for example cereal grains, lupins, vetch, etc., could be grown under natural dry-land conditions. For farmers with access to water for irrigation, there is an opportunity to produce summer growing forage crops, for example maize or sorghum. The successful establishment of forage crops for silage and hay production in the Western Cape is dependent on a number of basic principles. There are no short cuts and all aspects covered in this chapter should be adhered to for the production of silage and hay of acceptable quality and quantity.

Soil

Soil is not only a medium that anchors plants, but is of absolute importance to maintain crop productivity, quality and longevity in the case of perennial crops. The first step is to determine the soil family or soil series as that affects the choice regarding the possible forage crops and pasture types that can be grown in a specific area. A handy "tool" is the National Soil Classification system (Soil Class Working Group), a document that describes the profile of South African soils. Profile holes must therefore be dug first for soil classification, which entails determining soil depth and other physical properties affecting root penetration, root functioning, and water drainage potential of the soil. Well-trained soil scientists (soil pedologists) are able to describe soil profiles, including recommending best management practices for specific soil conditions. A list of crops best suited to the soil profile description (in combination with other factors such as climate, etc.) can be compiled to determine the soil chemical requirement (correcting pH and fertiliser requirements) and how it must be managed.

When the soil profile shows that the soil is suitable for forage crop production, the next step is to take a representative soil sample. Such a soil sample is used to assess both the physical condition and chemical composition of the soil. Determining the physical properties of the soil, as indicated by sand, silt and clay fractions, are useful in developing management strategies such as nitrogen fertilisation programmes and herbicide application rates.

The soil chemical analysis usually includes determining the pH resistance, the mineral content for phosphorous (P), potassium (K), calcium (Ca), and trace elements like magnesium (Mg), sodium (Na), copper (Cu), zinc (Zn), manganese (Mn), boron (B), sulphur (S), as well as organic carbon (C). This information is supplied to the producer as a soil report. The soil report is used by a fertiliser company or consultants to develop a fertilisation programme for the crop under consideration. Although the ratios between some of these elements are important, it will not be discussed here.

In terms of soil fertility, it is important that the soil pH levels are corrected to ensure maximum availability of plant nutrients. When the soil pH is not at the desired level, it must be corrected before embarking on soil cultivation for seedbed preparation. It is important to note that soil pH levels at Elsenburg are determined by the so-called KCl method. As a general rule, optimum pH levels for grasses are close to 5.0 pH(KCl), while it is 5.5 for legume crops. It is best to put lime on the soil to establish a pH level of 5.5 or slightly higher. If the pH was determined according to the "water" method, the optimum pH values would be about 6.0 and 6.5 for grasses and legumes, respectively. Lime requires at least 3 weeks under absolute favourable soil conditions to change pH levels to reach desired levels. It is therefore recommended that lime should be applied 4 to 5 months before the expected planting date.

Soil preparation

Soil preparation should start only once it has been established that the soil is capable of sustaining high crop productivity.

The restriction of natural drainage because of layers of clay, or naturally weak drainage, needs to be rectified before establishing pastures.

Poor soil drainage results in waterlogged conditions when it rains, depending on rainfall patterns and seasonal rainfall. Soil drainage can be improved by installing drainage pipes at predetermined depths and spacing to drain excess water from fields. Open drains or trench drains are less effective.

Soil compaction is the most important physical restriction that may occur in the soil. When a compaction layer or layers are identified, this must be broken up before any crops are established. Various implements are available that could be used to break the restricting layer(s), mostly heavy duty chisel ploughs and rippers. Switching to conservation agricultural practices should reduce the development of restricting layers due to stubble management and reduced tillage of soil, before establishing crops. The benefits of conservation agriculture may, however, take years to develop.

Persistent weeds must be eradicated before establishing any crops. Chemical companies employ experts who assist with chemical weed control before and after establishing pastures. The success rate of establishing pastures is higher on sites with low numbers of viable seed in the seed bank.

Seedbed preparation or no-till seeding should only be done when the soil (as factor) has a high pasture production potential. The current belief is that conservation agriculture is the way to prepare seedbeds. No-till knife and disc planters result in minimum soil disturbance and can be used to establish almost any crop, regardless of seed size. A level, fine, firm, moist, and weed-free seedbed is required to:

- ensure better contact between soil and seed, ensure maximum water absorption by the germinating seed and rapid germination and initial root growth,
- ensure accurate depth control resulting in uniform planting depth and seedling emergence,
- promote upward movement of soil water to keep the shallow planted seed in contact with water and
- improve the efficiency of cutting, baling and other management operations using implements.

Achieving the abovementioned seedbed conditions does not necessarily require overworking the soil with implements. Soil disturbance must be restricted to the absolute minimum to ensure maximum germination, emergence, and survival of seedlings. Maintaining soil structure must be kept in mind when the cultivation of soil is planned and this is only achieved with, amongst others, reduced tillage.

Cereal forage crops

The western parts of the Western Cape are predominantly winter rainfall areas and only winter cereals can be grown successfully as forage crops. In this chapter no cultivars will be discussed. It is suggested that the seed companies be contacted for more information regarding recommended cultivars suitable for the area under consideration. If crops are produced under conditions where conservation agriculture has been practiced for at least 15 years prior to establishment of forage crops, successful forage production can be achieved with slightly less in season rainfall than indicated in this document.

Oats (*Avena sativa*)

Oats is a very palatable annual winter forage cereal crop with a high leaf to stem ration suitable for grazing, hay, and silage production. Oats can be grown in areas receiving more than 300 mm rain. Under good conservation agriculture conditions successful oats production may be achieved with less rain. Seeding rates vary between 75 and 100 kg per ha when planted from March to May. Oats is widely adapted to most soil conditions prevailing in the Western Cape grain producing areas. Comparing the cereal fodder crops, oats can be grown on lower pH soils than other cereal crops. Most of the oats cultivars are susceptible to leaf rust and require the necessary control measures. Oats makes good quality silage. The dry matter (DM) content of forage oats increases from 27% at milk stage to 37% at the soft dough stage approximately 14 days later. The DM production of oats varies between 4 and 8 ton per ha.

Saia oats (*Avena strigosa*)

Saia or Black Oats is planted for high biomass production, both above (forage) and below (roots) the soil. The crop is hardy and well adapted to sandy soils. The best sowing time for Saia is April and May with sowing rates not exceeding 60 kg per ha. Saia intercropped with vetch is very popular as the mixture results in a high DM production.

Barley *(Hordeum vulgare)*

Barley is an important, very palatable, annual forage cereal crop suitable for grazing as well as grain for feeding purposes. Barley is sown from April to May at seeding rates of between 60 to 110 kg per ha in areas receiving more than 300 mm rain per year. Barley is more drought resistant and performs better than the other cereal crops under conditions of low soil water availability. Barley is widely adapted to most soil conditions of the Western Cape but does better on alkaline brackish soils than other cereal crops. The stooling (tillering) capacity of barley tends to be better than that of oats and triticale. Barley produces high quality silage, although yield may be less than some of the other cereals. Most barley cultivars are earlier maturing than oats and triticale.

Triticale *(Triticosecale)*

Triticale provides good quality grazing within 40 days after sowing (before stem elongation), especially when sowing was early in autumn. The crop remains palatable until late September. Grain may contain 10 to 13% protein. Triticale can be grazed, or conserved as silage or hay. The recommended seeding rate for triticale is between 75 and 120 kg per ha during April or May in areas receiving at least 300 mm during the growing season. Triticale is well adapted to soil conditions in the Western Cape. Triticale also does well on light sandy soils. The aggressive root system binds soil particles better than wheat, barley, or oats. Triticale has better resistance to leaf rust and insects than other cereals. Triticale has superior lodging resistance compare to oats and barley. It makes good quality silage. The DM content of triticale increases from 30 to 40% from the milk to the soft dough stage about 14 days later. The crop matures rapidly, leaving only a narrow window in which to harvest. At soft dough stage, the bio-mass yield is normally higher than oats and barley (less at milk stage).

Rye (*Secale cereale)*

Rye can be classified as spring- and stooling (or winter) rye. Spring rye requires an increase in day length and increasing temperatures to initiate its reproductive stages for seed production. When rye is sown early in April, it is ready for grazing within 50 days. Rye produces good quality grain with a protein content of 10 to 13% when growing conditions are favourable. Rye is suitable for grazing, hay, silage and grain feed. Spring rye must be seeded between 25 to 80 kg per ha, depending on cultivar and rainfall in areas receiving at least 300 mm of rain in the growing season. The recommenced planting time is April to May. Spring rye is well adapted to Western Cape soils and also does well on sandy soils. The quality of rye silage is comparable to other cereals when harvested at the flowering to early milk growth stage. Rye intercropped with vetch, peas, lupins, and annual legumes results in a high dry matter production.

Stooling rye requires a long cold spell to initiate the reproductive stages and can therefore be planted earlier than the spring types. However, winter temperatures in the Western Cape might not be low enough to initiate the reproductive stages. Stooling rye shows a more prostrate growth than spring rye. Early plantings can be ready for grazing after 60 days. Grain quality is the same as for spring rye. Stooling rye is good for grazing, hay, and silage or for the production of grain. Seeding rate for stooling rye is 25 to 50 kg per ha during February to April in areas receiving at least 300 mm of rain during the growing season. Stooling rye does well on soils of the Western Cape, including sandy soils. Silage from cereal crops

The best time to cut cereal crops for silage is between early flower and soft dough stage. Silage quality, in terms of crude protein (CP) and energy, decreases when crops mature from boot stage to physiological maturity when fibre content reaches maximum levels. Postponing cutting increases DM yield, although it reduces the feeding value of forage crops because of an increase in fibre content and reduction in energy and protein contents. To balance quantity and quality, it is recommended that cereal crops should be ensiled in the milk stage, preferably not later than the soft dough stage.

Legume forage crops

A few legume forage crops combine well with cereals in mixtures. Legumes are included as pure stands or mixture due to the palatability and high nutritional value. Pure legume crops usually have a lower DM production per ha than cereal crops. Because of a high moisture content and low sugar content, it is usually a challenge to ensile legumes as pure stands.

In a mixture, higher rates of cereals will increase total forage yield, but at the expense of legume content and forage quality. Cereal cultivars with a high tillering potential should be sown at lower rates to avoid cereal dominance as a result of over shadowing the legume component.

Vetch

Grazing vetch combines well with cereal crops in producing good quality hay and silage. Optimum planting time for grazing vetch is March-May at 20 to 35 kg per ha in pure stands or 15 to 25 kg per ha in mixtures with cereal crops. Its performance is good with spring rye, because of its lower propensity for tillering. Vetch grows well on most soils at neutral to high pH and soils that are not subjected to being waterlogged in regions receiving more than 350 mm of rain during the growing season. Vetch is usually grazed or cut only once (after maturation, so-called dry grazing) or early grazing as green pasture. To prevent lodging, it is recommended that vetch is sown in a mixture with oats. Other vetch species available include sweet and purple vetch.

Serradella

Two species, namely, pink (*Ornithopus sativus*) and yellow (*Ornithopus compressus*) serradella are available on the market. The most important difference is that pink serradella is not hard seeded and is therefore less efficient in re-seeding the following season. Yellow serradella is hard-coated and re-seeding in the following season is effective.

Pink serradella can be used for grazing, as well as hay and silage production. It can be used as a single forage crop or in combination with cereal crops. Pink serradella is well adapted to most soils in the Western Cape with the advantage that it prefers acidic (pH 4.5), sandy soils and can withstand wet soils. Seeding rate is 15 - 25 and 10 - 15 kg per ha as a pure stand or in a mixture, respectively, in areas receiving more than 400 mm of rain per year. Recommended planting time is from March to May.

Yellow serradella can also be used for grazing, as well as hay and silage production. Similarly to pink serradella, yellow serradella is also well adapted to most soils in the Western Cape and does well on acid, sandy soils and can withstand wet soils. Seeding rate is 2 - 5 kg per ha as a pure stand. Planting time is from March to May in areas receiving more than 350 mm of rain per year.

Forage peas *(Pisum sativum)*

Forage peas are mainly grown for seed, hay, and silage production. Although forage peas grow well in most soils in the Western Cape, it is not well adapted to poorly drained soils. The recommended seeding rate is 120 kg per ha when planted in May or June in areas receiving more than 350 mm rain per annum. Forage peas planted as a pure stand is likely to lodge. Forage peas are very susceptible to the disease complex Ascochyta blight that can kill the crop. The crop is suitable for hay, silage or seed production with seed containing 21 to 25% CP.

Sweet lupin *(Lupinus albus)*

Sweet lupin (broad leaf) can be included in mixtures for silage production. Planting time is from April to May. It can be grown in well-drained heavier soils, although sweet lupin prefers sandy soils and is sensitive to high pH soils. The crop is also sensitive to high temperatures during flowering as senescence of flowers may occur at temperatures above 25°C. It is more sensitive to drought and requires well-distributed rainfall of at least 300 mm of rain during the growing season, which is from April to October. Harvesting (cutting) may commence when the seed of the lower pods on the main stem hardens, being the hard dough stage. Lupin is susceptible to several diseases. Powdery mildew control is required in most seasons. Diseases like Anthracnose and brown leaf spot can destroy the entire crop.

Faba beans *(Vicia faba)*

Conditions permitting, faba beans are a good alternative to sweet lupin. It is mainly used as a silage crop in mixtures with cereal crops. Faba beans are not well adapted to heavier soils with relatively high pH levels. The best seeding time is during April to May in areas receiving more than 300 mm of rain during the growing season.

Medics *(Medicago trancatula, Medicago polymorpha and Medicago littoralis)*

The different medics species are important legumes which are often included in short rotation pasture-cash crops. The crop is well adapted to the grain producing areas of the Swartland. Seeding rates vary between 3 and 15 kg per ha, depending on the annual rainfall. Inoculation of seed is important (as for lucerne). Medic species are well adapted to grazing, and baling is a possibility; however, this is not extensively practiced in the Western Cape. Forage production varies between 1 to 4 t DM per ha.

Lucerne *(Medicago sativa)*

Lucerne is a long-living perennial legume with high spring, summer and autumn production. Seasonal production differs between cultivars. Winter-active cultivars usually produce one cut more than winter-dormant cultivars if grown under irrigation; however, the annual DM production may not differ from winter-dormant cultivars. Lucerne can be grown in areas receiving more than 300 mm rain per year. Lucerne is adapted to a wide range of soils, but do best on neutral to slightly alkaline, well-drained, deep soils. Although lucerne can withstand short periods of flooding, it is susceptible to water-logged conditions. Lucerne is grown extensively in pasture-cash crop systems under rain-fed (dry-land) conditions in the Rûens area of the Southern Cape. The long, extremely dry summers of the Swartland are not conducive to lucerne production under rain-fed conditions.

Before establishing lucerne, all restricting underground layers, if any, must be broken and the pH and general soil fertility level corrected to ensure a high production for several years. A fine, firm weed-free seedbed must be prepared before planting. Recommended seeding rates for dry-land production varies between 5 to 10 kg per ha, while for production under irrigation the seeding rates is 10 to 20 kg per ha. Seeding is preferably done on a wet soil profile. Lucerne is a legume crop that can fix atmospheric nitrogen as a nitrogen source. Fixing nitrogen is, however, only possible if the seed was treated with a legume inoculant. Inoculants are crop specific and instructions on the label must be followed to ensure successful inoculation of seed. Many inoculants contain molybdenum, a very important trace element needed for effective biological nitrogen fixation. Seed treatment with insecticides and fungicides is advisable but should be done 10 days before inoculation of the seed. The best time for establishing lucerne in the Rûens area is in autumn. In this area it is a popular practice to under-sow canola with lucerne towards establishing lucerne as a forage crop. Although lucerne, under irrigation, may be established anytime during the year, autumn or spring seeding provides the best results. The recommended seeding depth is 5 to 10 mm and care must be taken not to place seeds too deep as lucerne is small-seeded and therefore sensitive to deep seeding. Although yields of 25 t per ha have been reported under trial conditions under irrigation at the Elsenburg Research Farm, yields of 16 to 18 t DM per ha is more realistic under farming conditions. The production of dry-land lucerne in the Rûens area and Southern Cape varies between 0.5 to 4 t DM per ha depending on the soil type and environmental conditions.

Silage maize

In the Western Cape maize silage can only be produced under irrigation. One of the main advantages of maize silage is the high nutritive value due to the high ratio of grain to total dry mass. Silage production varies between 60 to 85 t per ha. When water for irrigation becomes a limiting factor, sorghum can be considered as an alternative to maize. Although seed companies may recommend selected cultivars specifically to silage production, most maize cultivars can be regarded as suitable for silage production. Maize cultivars designated for silage production usually produce more overall biomass due to a longer active growing season compared to grain cultivars. The choice of cultivar may also be influenced by biotechnology traits, like Glyphosate or Roundup herbicide tolerance, stalk borer resistance etc. It is therefore important to know the relevant pests and weeds in the field designated for silage production. Representatives from seed companies should be able to provide information regarding site specific recommendations.

Germination is best at soil temperatures between 18 and 24°C. Staggering the planting date to extend the ensiling process is an option, especially when the capacity of harvesting equipment is limiting. Staggering the time of planting would also reduce the risk of unfavourable weather conditions during pollination and early grain filling. The recommended seeding rate is higher than for grain maize. Depending on cultivar (single cop cultivars require higher densities), aim for a stand of 50 000 to 90 000 plants per ha under irrigation. Although higher forage yields may be achieved at higher seeding rates, silage quality could be slightly less. To ensure seedling emergence before seven days after planting,

planting depth should not exceed 70 and 50 mm in sandy and clayish soils, respectively. Row spacing may vary between 910 and 760 mm depending on available equipment. Reducing row spacing to 500 mm is currently under investigation. Soil must be limed to a pH(KCl) of 5.5. Due to the high biomass production, fertiliser requirement is high. The nutritional status of the soil will determine individual fertiliser programmes, but a typical programme could be 250, 40, 90 and 30 kg/ha N, P, K and S, respectively, depending on soil analyses. Micro-element requirements are site specific and must be applied accordingly, usually six weeks after emergence or later. To ensure starch accumulation in the grain until harvesting, plant-available soil water must be maintained until the crop is ensilaged.

In closing

In most parts of the Swartland mainly winter growing crops like cereal grains, lupins, vetch and faba beans can be grown under natural rainfed conditions. To produce summer crops like maize or lucerne, water for irrigation during the summer is required. The correct soil preparation is required for different crops. For lucerne underground clay or rock layers should be broken to ensure a high DM production.

CHAPTER 18

ENSILING FORAGE CROPS AND SURPLUS PASTURE

Introduction

In the pasture-based production areas, pasture growth during spring and autumn usually exceeds the demand by dairy cows. Surplus pasture then becomes available. This could then be ensiled in a bunker or preserved as big bale wrapped silage. Silage making has been practiced for many years with the process and principles of making good silage well described in a number of publications. Each crop has a specific optimal growth stage at which it should be ensiled to ensure maximum meat or milk production per ha. Plant material is chopped with a silage harvester to enable proper compaction in a bunker. To make good quality silage, three principles must be applied:

1. air must be excluded from the ensiled material to limit growth of yeasts and molds within the ensiled material,
2. a sufficient amount of sugars, or water soluble carbohydrates (WSC), must be available as energy source for bacteria, and
3. plant material must contain a high number of efficient lactic acid bacteria to convert sugars to lactic acid which preserves the plant material. This ensures a rapid drop in pH to 4 and preservation of the silage.

Bacteria at work

Lactic acid bacteria are referred to as a group of bacteria from several genera that have the ability to produce lactic acid. Lactic acid bacteria are further classified as homo-fermentative and hetero-fermentative bacteria. Other microbes that affect the ensiling process are enterobacteria, clostridia, yeasts, and moulds. Enterobacteria are undesirable as they compete with lactic acid bacteria for nutrients, while producing endotoxins and are responsible for much of the ammonia produced in silage. Clostridia grow under anaerobic conditions, utilise sugars and lactic acid, break down protein, and produce butyric acid. Butyric acid reduces the palatability of silage and reduces silage intake. Growth of clostridia is inhibited when the pH in silage drops below 5.5. Yeast numbers increase during wilting, and after anaerobic conditions occur in the silo, fermentative yeasts continue to grow. Most yeast species grow within the pH range of 3 to 8 utilising sugars as an energy source under anaerobic conditions. Yeast growth in the silo is inhibited by acetic acid and lactic acid under anaerobic conditions. However, when air enters the silo, yeasts will utilise lactic acid and other short chain organic acids. The ensiling process is very complex and is affected by numerous micro-organisms.

Silage making

Well-preserved silage can be stored for many years, provided air or water does not enter the silage bunker or silo. The silage bunker should therefore be well sealed with a plastic sheet to prevent air and water infiltration. Soil should be put on the sides of the bunker to weigh the plastic down, while the plastic sheet covering the plant material should be in close contact with the top layer of the compacted material in the bunker. Plastic moving because of wind action may expose the top layer of silage in the bunker to air, resulting in top layer losses. Tires can be placed on top of the plastic sheet to weigh the sheet down. Old conveyor belts are excellent to protect the plastic covering and to ensure a close contact between the silage and the plastic sheet. When silage has to be stored for longer than one year, the plastic sheet should be protected from sunlight by placing a layer of soil on top of the sheet. However, this must be carefully removed during feeding-out silage to prevent silage being contaminated by soil. Water must always be diverted and should never enter the bunker.

The amount of effluent flowing out of the bunker indicates the dry matter (DM) content of the silage when the material was ensiled. Usually effluent is observed when the DM content of the silage is below 25%. This is not optimal as the DM content of silage should preferably be between 30 and 35%. For a quick test to determine the DM content of the silage material, a hand-grab sample of silage can be squeezed. When moisture can be squeezed out of the silage, its DM content is below 25%. This indicates that the crop should have been ensiled at a later stage or should have been wilted for a longer period of time before ensiling. When the moisture content of silage is too high, favourable conditions for growth of clostridia are created. This results in unpalatable silage with a high content of butyric acid.

Silage should have a sweet fruity smell; this is caused by lactic acid. This is an indication that fermentation was dominated by homo-fermentative lactic acid bacteria. High levels of acetic acid result in a sharp acidic smell. Although this may reduce the palatability of silage, it may also improve the aerobic stability of silage. Silage that contains butyric acid has a bad smell and is unpalatable. The butyric acid is produced by *Clostridium tyrobutyricum*. These micro-organisms grow well when air is excluded, the moisture content is high (75 to 80%) and the pH is above 5. When the moisture content is 65% and the pH drops rapidly to 4, very little, if any, butyric acid is found in silage. Butyric acid is volatile and the bad smell remains on one's hands even after washing.

The pH level required for plant material preservation depends on the DM content of the silage. This can be described by the following equation:

pH = 0.00359 x DM (g/kg) + 3.44

Therefore, the pH of silage with a DM content of 30% should be below 4.5 to be well preserved.

The pH of silage can be determined on farm by the following method:

Place a sample of silage in a 300 mℓ container with a lid, cover it with distilled water and shake well. The pH can then be measured with a properly calibrated portable pH meter. Alternatively, paper pH strips that are sensitive enough to indicate pH from 4 to 6 with 0.1 unit increments can be used. The pH of silage will clearly show if it is well preserved. Well-preserved silage should not contain any visual mould or yeast.

Compaction

Compaction is the key to making good quality silage and is crucial to prevent air penetration into the bunker. Maize silage should be compacted at 750 kg fresh silage/m^3 or 250 kg DM silage/m^3. The compaction of a bunker can be determined by taking a core sample with a silage corer and weighing the sample. A silage corer consists of a 1.2 m long piece of 110 mm drain pipe. The pipe is fitted with a collar through which a hole is drilled. A broomstick should fit through the holes in the collar to enable turning of the corer. Teeth with a 2 cm base and 1.5 cm height are cut on the edge of the corer using a jig-saw. Teeth should be cut alternatively with an angle to the inside and outside to improve the cutting action of the corer.

Such silage corers were used to collect 270 core samples from 90 silage bunkers on dairy farms to determine the compaction and quality of maize and sorghum silage. The average compaction of maize silage in the 20 to 40 cm layer of the bunker was on average 745 kg/m^3 and 726 kg/m^3 during two following production years. The poorest compaction found in maize silage bunkers was 400 to 540 kg/m^3. On these farms, compaction could be improved by compacting for a longer period with a larger number of heavier tractors which have narrower wheels. The layer of chopped material to be compacted should not be more than 20 cm.

The compaction of the top layer of plant material in the bunker is crucial as this is where air penetrates ensiled material resulting in top layer losses. The survey showed that the compaction of the top layer in 45 maize silage bunkers varied from 238 kg to 708 kg silage/m^3. Top layer losses varied from zero to 90% of the organic matter (OM) in the top 10 cm and from zero to 62% in the top 10 - 20 cm layer, indicating that top layer losses can be prevented. Apart from the loss of OM, the risk of mycotoxins increases when mould is present in silage. In a 10 m wide x 60 m bunker, a total of 36 tons of silage can be lost in the top 20 cm. Results from silage samples collected on farms during two production seasons indicated that compaction in the top layer of the bunker could be improved which should result in reducing OM losses.

Aerobic stability of silage

Exposing silage of poor aerobic stability to air increases the ash content, pH, and temperature of such silage. Heating occurs as a result of the growth of yeasts and moulds that consume lactic acid and WSC. The growth of yeasts and moulds can be inhibited by acetic and propionic acid. Hetero-fermentative lactic acid bacterial inoculants containing *Lactobacillus* *buchneri* have the potential to improve the aerobic stability of silage by producing acetic acid. Mould growth drastically increases the risk of mycotoxins that may have a negative impact on health and reproduction of cows. Under conditions where homo-fermentative bacteria have dominated fermentation, maize silage may be unstable when exposed to air, resulting in an increase in temperature and pH, as well as reduced palatability and digestibility when fed to animals.

The aerobic stability of silage can be determined with a simple test. Place silage loosely in a 2 litre plastic container fitted with a lid and with holes in the sides. The silage is then left exposed to air for 5 days at ambient temperature. The DM, ash, and pH of silage before and after aerobic exposure are determined. Organic matter losses can be calculated by using ash as a marker. Samples collected on farms as part of a competition to determine the best quality silage, showed that the average loss in OM in 45 maize silage samples after 5 days of aerobic exposure was 12.5%, ranging from no loss to a maximum of 58.3%. The average pH of maize silage before and after 5 days' aerobic exposure was 3.85 and 5.58, respectively. Aerobic stability can also be determined by measuring the temperature of silage. As soon as the temperature of silage increases 2°C above ambient temperature, silage is regarded as unstable. For this reason, the rate of feeding silage out of a bunker should be at least 20 cm per day. The face of the bunker should be clean and all silage that has been loosened should be fed to animals. The aerobic stability of maize silage can still be improved and maize silage should never be warm in the feed trough when being fed to animals.

Fermentation characteristics of silage

The fermentation characteristics of silage are described by pH, lactic acid, volatile fatty acids (acetic, propionic and butyric), and ammonia nitrogen as a percentage of total nitrogen. Well-preserved maize silage should have a pH of 3.8 to 4.2, lactic acid content of 3 to 6%, acetic acid of 0.5 to 1.5%, propionic acid of 0.5 to 1%, while containing no butyric acid. The ammonia nitrogen as a proportion of total nitrogen of well-preserved silage is below 6%, which gives an indication of protein breakdown. Silage is regarded as poorly preserved when the ammonia nitrogen as a proportion of total nitrogen is higher than 10%.

Nutritional value of silage

The nutritional value of silage is affected by a number of factors which include the crop, cultivar, stage of ensiling, ensiling process, and aerobic stability. The aim should always be to produce silage containing the highest possible energy and protein contents. Maize silage should have an energy value of 10.5 MJ ME/kg DM (total digestible nutrient content of 70%), crude protein (CP) content of 8 to 9%, neutral detergent fibre (NDF) content of 40 to 45%, and a starch content of 25 to 30% on a DM basis. Other analyses include ash, NDF digestibility, starch digestibility, acid detergent fibre (ADF), ether extract (EE), calcium (Ca), and phosphorus (P).

Maize silage

Although maize silage is not commonly used in the Westen Cape, it is used extensively in other parts of the country in diets for dairy cows and feedlot cattle. Whole crop maize is not difficult to ensile as it has high levels of WSC (10 to 12% of DM) and low levels of crude protein (7 to 9% of DM). The pH of maize silage drops to below 4 within 48 hr after ensiling. Whole crop maize silage often contains substantial levels of WSC (5 to 7% of DM), as well as high levels of lactic acid (5 to 8%). Whole crop maize should be ensiled when the DM content of the whole plant is 30 to 35%. At this growth stage the bottom leaves of maize plants start to become dry while the kernels on the maize cobs are in the ½ to ¾ milk stage. However, it is better to determine the DM content of the crop before deciding to ensile. Three representative rows of maize plants, 1 m in length, should be cut. The plants are then chopped with a silage chopper to get a representative sample. The sample is weighed and dried in a microwave oven. The DM content is estimated by dividing the amount of dried material by the initial amount of wet material multiplied by 100 for a percentage value.

Maize is often ensiled too early resulting in silage containing a lower starch content, lower energy value and low DM content as well as a reduced DM yield. Ensiling maize at 25% DM results in a 10% yield reduction as well as a less favourable fermentation and less palatable silage. The optimal chop length of maize silage should be 8 to 12 mm. When a grain processor is fitted on the silage chopper, chop length can increase to 19 mm.

Maize hybrids differ in terms of whole plant yield, CP, NDF and ADF contents, digestibility of NDF, energy value, and milk production potential. Maize silage hybrids with increased leaf content may result in a higher digestibility and improved milk production. Planting density for maize under irrigation should not be higher than 75 000 plants per hectare as higher planting densities result in a lower grain yield, lower nutritive value and reduced milk production per hectare. Drought stricken maize may have up to 20% WSC and therefore molasses should not be added as more than enough sugars are already available for fermentation. Adding molasses may reduce the aerobic stability of maize silage.

Small grain silage

Cereal crops, such as oats and barley, should be harvested at the soft dough stage. Whole crop cereal has only 5 to 8% WSC at the soft dough stage which may be limiting. An efficient homo-fermentative lactic acid bacterial inoculant can be applied when ensiling whole crop small grain to ensure efficient utilisation of the WSC and a rapid drop in pH. Adding an inoculant to whole crop oats ensiled in big round bales resulted in higher silage intake (+ 0.5 kg/day) and higher milk production (+ 1 kg/day) compared to control silage. The inoculated silage also had a lower butyric acid content.

Big round bale wrapped silage

Pasture or cereal crops can be effectively ensiled by wrapping big round bales by plastic. All the basic rules of silage making also applies with regards to ensiling plant material in big round bales. Pasture should be cut and wilted to a dry matter content of 40%. Material is picked up by a baler and bales should be compacted well. Bales are then transported to the area where they are to be stored after being wrapped with a bale wrapper. Bales should be covered with a minimum of 4 layers of plastic. This is usually about 16 turns on the wrapper. This can be estimated by counting the number of turns to cover a bale, multiplied by 2 and add 1 for the number of turns. It is advisable to cover bales with 6 layers of plastic, usually 24 turns on the wrapper, as the air tightness of bales is three times higher with 6 layers compared to 4 layers of plastic. The plastic must be of high quality and layers must cling to each other. The plastic should not stretch more than 70%. Test this by drawing a 10 cm line on the plastic roll on the wrapper, turn the wrapper and measure the length of the line on the bale. If the line is longer than 17 cm, plastic is overstretched. The settings on the pre-stretch unit of the wrapper must be checked. Poor quality plastic also tends to overstretch. The operator should not turn the wrapper too fast as this also causes overstretching. Do not continue if these problems occur as the silage will be at risk. Bales should be stored upright as more layers of plastic protect the bales at the top and bottom. Big round bale silage should be used within a year as silage made in this way deteriorates after 12 months. Make sure that rodents or birds do not damage bales and patch any holes in the plastic. Keep bales in a closed area and ensure that cattle do not damage bales. Never make wet (DM content less than 30%) wrapped round bale silage as preservation will be compromised.

In closing

Silage can be evaluated on farm by establishing the pH and DM content. Well-preserved silage should have a sweet fruity smell. The DM content of silage should be 30 to 35%. When moisture can be squeezed by hand from a hand-full of silage, its DM content is usually below 25% and is it too wet. Compaction of silage material in the bunker can be determined using a silage corer and by weighing samples. Top layer losses in the bunker can be calculated using the ash content of the silage as a marker. Aerobic stability of silage is determined by exposing silage to air for 5 days. The DM, ash and pH are determined before and after aerobic exposure to calculate OM loss. The focus should be on reducing top layer losses and improving aerobic stability of maize silage.

CHAPTER 19

FEEDING ADDITIVES TO DAIRY COWS

Introduction

Dairy farmers are under increasing pressure to produce milk more efficiently to ensure a profitable margin over feed cost. High milk yield levels usually ensure a positive margin over feed cost. However, in dairy herds already producing at high levels, a higher efficiency of production should become the focus point. Various feed additives are available that could be added to an already balanced diet to increase the efficiency of milk production. Some of these additives do not provide any nutrients, such as protein and energy, but rather supply only minerals and vitamins. Other additives function by improving the rumen environment or supplying nutrients directly to the rumen micro-organisms. Whatever the nutrient composition, additives should never be used to correct nutrient imbalances and should only be fed in addition to a well-balanced diet.

A positive production response is required to warrant the use of feed additives and the cost of the feed additive should be less than the increased income from a positive production response. Feed additives are usually only included in the diet of high producing animals. High producing animals are defined as animals producing 5% of live weight as a daily milk yield. Therefore, a 400 kg Jersey cow should produce at least 20 litres of milk/day and 6 000 litres of milk over a lactation to be classified as a high producing animal. Similarly, a 600 kg Holstein cow should produce 30 litres of milk/day and 9 000 litres of milk over a lactation period.

Feed additives must meet the following criteria to be considered for use in dairy herds:

- To modulate the rumen pH by maintaining the acidity levels in the rumen at a more constant level throughout the day,
- To reduce lactate accumulation in the rumen,
- To reduce the risk of developing metabolic diseases,
- To improve the efficiency of ruminal energy and nitrogen utilisation,
- To increase the organic matter and fibre digestibility in the rumen,
- To increase the level and efficiency of animal performance, and
- To be cost effective and approved by legislative authorities.

In this chapter, a brief overview of the use of buffers, yeast cultures, fats, and bovine somatotropin (BST)/bovine growth hormone (BGH) in dairy cow rations is presented.

Buffers

The term 'buffer' refers to various products that protect the rumen against pH imbalances. The saliva of dairy cows is a naturally occurring buffer as it contains sodium bicarbonate ($NaHCO_3$) which is responsible for the buffering action. When ruminants consume high fibre feeds such as oat hay, lucerne hay, maize silage, pastures, wheat straw and some concentrate feed components which are high in fibre, regurgitation of feed is stimulated. By this action partly chewed roughages is regurgitated from the reticulum back into the mouth to be chewed again. This helps towards further breaking up the fibre components in the diet. Through this action of re-chewing roughages (commonly called chewing the cud), the secretion of saliva is stimulated. This is swallowed and passes into the rumen buffering the rumen fluid keeping pH levels stable. In Table 19.1, two different feeding situations and the subsequent impact on saliva secretion and rumen buffering effects are shown. Diets with high levels of roughage usually have a rumen pH of 6.2 to 6.8, while diets containing high concentrate levels have a rumen pH of about 5.4 to 6.0. At these pH levels, different rumen bacteria are at work.

Table 19.1. A description of the rumen pH regulating systems of ruminants being fed high roughage and high concentrate diets

Parameters	Diet description	
Roughage content	High roughage content 60 - 100% roughage	High concentrate content 60 - 80% concentrate
Rumination period	40 - 50 min/kg DM intake	25 - 30 min/kg DM intake
Volatile fatty acids (VFA)	Lower concentrate of VFA in rumen Low absorption rate Higher proportion of acedic acid	Higher concentrate of VFA in rumen High absorption rate Lower proportion of acetic acid
Rumen pH	High levels of saliva secretion Higher rumen pH: 6.2 - 6.8 Optimum pH range for fibre digestion bacteria	Low levels of saliva secretion Lower rumen pH: 5.4 - 6.0 Optimum pH range for starch fibre digestion bacteria

The response of rumen volatile fatty acid concentration, as affected by an increase in rumen pH, is shown in Figure 19.1. While the level of butyric acid is not affected by an increase in rumen pH, acetic acid increases and propionic acid decreases (pH 5.25). This is usually associated with an increase of the roughage component in the diet.

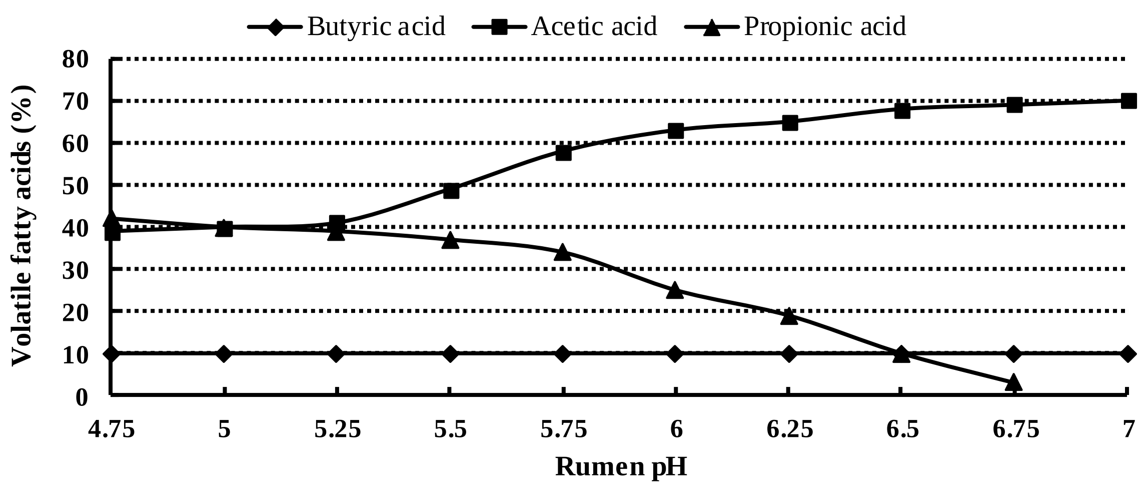


Figure 19.1. The response in rumen volatile fatty acid concentration as affected by an increase in rumen pH

Buffers are used to maintain the rumen pH at an optimum level of 6.5 to 6.8. As such, it neutralises excessive acid in the rumen, which is a by-product of the normal fermentation of feed in the rumen. Buffers are required where high levels of concentrate feed are included in the diet (more than 2% of the live weight of cows) or where roughage intake is limited. Buffers can also be fed when a large amount of maize silage is fed (more than 20 kg/day). The most common buffers used are sodium bicarbonate ($NaHCO_3$) and magnesium oxide (MgO). Sodium bicarbonate is fed at an inclusion rate of 1.5% in concentrate feeds and 0.75% in total mixed rations. Magnesium oxide is fed at an inclusion rate of 0.75% in concentrate feeds and 0.30% in total mixed rations.

Yeast cultures

The use of live yeast culture or dead yeast cells with culture extracts in dairy cow rations has been proven to be successful in modifying rumen fermentation. The presence of yeast cells in the rumen improves the metabolism of rumen bacteria, leading to overall improved rumen fermentation and increased fibre degradation. The most commonly used species are *Aspergillus oryzae* and *Saccharomyces cerevisiae*. Previous studies carried out in the USA showed a 5% increase in milk yield when yeast cultures were fed, with a greater response in milk yield for cows in early lactation. The positive production response is attributed to an increase in dry matter (DM) intake, which occurs subsequently to improved fibre degradation. There is also an increase in the rate of lactic acid removal from the rumen, through uptake by rumen bacteria, improving the rumen pH. The effect of supplementing *Saccharomyces cerevisiae* daily at 10 g/cow is shown in Table 19.2. Yeast cultures work especially well to maintain rumen metabolism under stressful situations. Stressful situations include heat stress, changing between roughages and adapting dry cows to a lactation ration. Animals receiving a high concentrate ration should also benefit from yeast culture inclusion.

Table 19.2. The effect of feeding *Saccharomyces cerevisiae* (Yeasac) as a feed additive on the milk yield and milk composition from 60 to 150 days after calving (FCM = Fat corrected milk)

Parameter	60 - 100 days			101 – 150 days		
	Control	Yeasac	Increase (%)	Control	Yeasac	Increase (%)
Milk yield (kg/day)	28.7	31.1	8.4	26.3	27.9	6.1
4% FCM yield (kg/day)	30.1	35.3	17.4	27.9	32.1	15.1
Fat (%)	4.20	4.55	8.3	4.24	4.60	8.5
Protein (%)	3.24	3.48	7.4	3.30	3.51	6.4

Fats

Fats are included in diets to increase the energy content of the total diet as they contain 2.25 times more energy/kg than carbohydrates. As energy is the first limiting nutrient in dairy cow diets, the use of fats, especially for high producing animals, is effective in meeting the energy demands of cows. For optimum energy utilisation, at least 15 to 20% of metabolic energy should be available from fats. However, cotton seed meal, soy bean oil cake meal or rumen protected fats should not make up more than 4% of the total fat content of the diet. It is important to supply animals with sufficient roughage when fats are used as a feed additive. It should be kept in mind that fat sources do not replace the roughage component of the diet but rather the concentrate component.

Fats in feeds can be grouped into three categories:

- Basic feed components such as hay, grains and oilcake meal. This normally supplies 3% fat in the total diet.
- Conventional fats such as cotton- and sunflower seeds, animal fats and animal and plant fat mixtures. This increases the fat percentage in the diet to a maximum level of 6% per kg DM.
- Rumen protected fats such as calcium soaps of long chain fatty acids and saturated fats having a high melting point. This increases the fat content in the total diet to 9%.
- Rumen protected fats are not degraded in the rumen, thus they do not inhibit microbial activity in the rumen and fibre degradation is therefore not negatively affected.

The total fat intake (basal diet components + conventional fat sources + rumen protected fats) depends on total DM intake. For high producing, cows this can mean a total fat intake of 1.5 kg (6% at 25 kg DM intake/day) to 2.5 kg (9% at 28 kg DM intake/day). The most important factor thus regulating the use of fats as a feed additive is the total daily DM intake of the ration. Palatability of the ration and the fat supplement used is vital for maximum intake. It is recommended that fat be supplemented at 0.5 to 0.7 kg/day or at 5 to 6% of the total diet.

Certain commercial rumen protected fats are less palatable, while certain animal fats and soy bean oil cake meal improve palatability. Monitoring feed intake is critical to ensure a positive response and efficient fat supplementation. In Table 19.3 different types of fat supplements are classified according to factors such as palatability, cost, etc. Some products have acceptable palatability levels, though their cost may be limiting. Cotton seed and soybean meals are generally included in diets at levels which would not affect the diet intake.

Table 19.3. The classification of various fat supplements with regards to their feeding values

Source	Palatability	Inert	Concentration	Handling	Cost
Commercial fat products	-	++	+	+	--
Animal fats	+	-	+	-	++
Cotton seed	-	+	-	-	-
Soybean meal	+	--	-	+	++
Vegetable oil mixes	-	--	+	+	+

++: Greatly beneficial; +: Beneficial; -: Limiting; --: Very limiting

While the fat content of different fat sources may vary from 23 to 100%, the amount that can be fed, range from 0.7 to 3.5 kg/cow/day. Soybean and cottonseed meal contains 18 and 23% fat, respectively, and can be fed at 3.77 and 3.54 kg/cow/day. In Table 19.4, a number of fat sources, their inclusion levels, and response on milk yield and milk composition is shown. Inclusion levels varied from 5 to 30% for specific fat sources.

While including soybeans at 25% increased milk yield and protein percentage, the fat content of milk was reduced, probably because of a too high inclusion level. Rumen protected animal fat improved fat content while having no effect on milk yield. Mostly, including fats in diets improves milk yield and milk composition; although a decrease in milk fat content is sometimes found.

Table 19.4. The effect of various fat supplements on milk production and milk composition when fed in dairy cow rations

Fat source	Inclusion level in concentrate (%)	Milk yield (kg)	Fat (%)	Protein (%)
Soybeans	0	19.1	3.56	3.12
	25	20.6	2.86	3.17
Cotton seed	0	24.4	3.19	3.24
	10	25.0	3.45	3.15
	15	25.5	3.51	3.15
	20	25.4	3.61	3.16
Rumen protected animal fat	0	31.7	3.40	3.18
	15	32.3	4.27	3.03
	30	31.0	4.31	2.85
Combination of animal and plant fats	0	26.3	4.23	3.55
	5	28.0	3.70	3.31

It is important to consider the following aspects with regards to supplementing fats:

- Calcium supplementation should be increased to 0.9 to 1.0% and magnesium supplementation to 0.3% of the total DM of the diet.
- Increase the level of protein in the ration to 1% rumen undegradable protein (RUP) per 3% supplemented fat.
- The response to fat supplementation will be highest during week 4 to 13 post-partum. Fat supplementation is less effective during week 0 to 4 post-partum due to the fact that cows mobilise their own body fat for milk production during this time.
- The fibre content of the diet must meet the minimum requirements to maintain a healthy rumen environment (19 to 20% ADF and 25 to 28% NDF).

- Fat supplementation should be gradually increased in the diet to allow time for adaptation. Ideally, it should be fed as part of the roughage component of the feed or through the use of electronic concentrate feeders. Feeding twice a day as a component in the concentrate is not sufficient for adaptation.
- Whole cotton seed has roughage characteristics while being high in fat. Soybeans are a protein feed source also high in fat. They cannot be used interchangeably.
- Whole cotton seed should not be fed at an inclusion level higher than 2.5 to 3.0 kg/day or 15% of the total ration.

Bovine somatotropin (BST)

Bovine somatotropin is a poly-peptide hormone that is made up of 191 amino acids and is secreted by the anterior pituitary gland. It can be produced artificially and is then referred to as recombinant bovine somatotropin (rBST). The general practice of administering BST to dairy cows is through a subcutaneous injection every 14 days, usually after peak production. An increase in milk yield is often observed as early as two days after the rBST administration and usually continues to increase up to 7 to 9 days after administration, at which point milk yield starts to decrease again. Research has shown that overall milk yield can increase between 6 to 36%, with an average increase of 22%. Usually, an increase in milk yield is accompanied by an increase in feed intake. Feed intake increases by 7 to 16% in response to rBST administration. First lactation animals show a 3 to 4% weaker response to rBST administration than more mature cows.

The response in milk yield is almost immediate; however, the increase in feed intake only begins within a few weeks of administration. The delayed increase in feed intake thus means that the increased milk yield is produced by breaking down body fat reserves. As such, the increase in milk production is to the detriment of body condition. It also means that the apparent effectiveness (kg milk/kg DM intake) of milk production increases. However, the increase in effectiveness is due to a diluting effect of basal maintenance requirements and not due to a fundamental physiological change. The advantages of rBST are usually not observed when animals are underfed or when management is poor. When administering rBST, the diet must be adjusted to meet the nutrient requirements of higher producing dairy cows; otherwise, the loss in body condition will be very severe. Apart from loss of body condition, reproductive issues and health problems may also arise.

Currently, rBST is not commonly recommended for use in high producing dairy herds. This is mostly due to consumer resistance of milk produced in this way. For this reason, a number of dairy processors expect dairy farmers to commit not to use rBST as a management tool. This is difficult to administer as there is no physiological difference identified between milk that was produced with and without rBST administration. Cows naturally produce BST, although at lower levels than is usually being administered.

In closing

A number of feed additives are available for use in dairy nutrition. Feed additives especially receive a lot of consideration for use in herds where milk production is high, but efficiency can be improved. It is important to remember that feed additives do not improve bad feeding and management programmes and, when used under such circumstances, they often do not yield positive results. The financial implications of a feed additive should always be considered when deciding on its usefulness. To determine whether there is a response or not, two groups of 15 to 20 cows must be compared to each other with regards to milk production, age and stage of lactation by feeding or administering the additive to one group but withholding it from the second group. The additive should be administered for at least 3 to 5 weeks before any final conclusions can be made.

SECTION 2

HOUSING FOR DAIRY CATTLE

CHAPTER 20

CLIMATIC INFLUENCES ON THE PERFORMANCE OF DAIRY COWS

Introduction

Dairy breeds being used in South Africa originated in the United Kingdom (UK) and Western Europe. Generally, these regions have a cool to cold climate. By comparison, the climate in South Africa is warmer and drier with more actual sunshine hours. The evolution of dairy breeds in European countries resulted in their being well-adapted to cold climates. Anatomical features that help them withstand cold conditions include a thick skin, a dense hair coat, subcutaneous fat layers, large muscles, and a digestive system that is based on fermentation processes in the rumen. Digestion of feeds produces a large amount of body heat while foraging for feed also increases body heat, providing further protection against cold. However, these features make dairy cows highly sensitive to a hot environment. Additional heat is further imposed on cows by direct and indirect solar radiation, i.e. the sun shining on them, as well as heat reflected from the immediate surrounding environment. Cows lose heat to the environment by radiation, convection, respiration, and by behavioural changes. They will avoid direct sunlight by seeking shade of any kind. Cows will also use water to cool down and often seek out wet places to stand or to lie down. When possible, cows often stand with their front feet inside a water trough. A large amount of internal heat in cows is lost by an increased respiration rate (panting). A change in behaviour or increase in respiration rate in cows is usually a clear sign of their experiencing heat stress.

In South Africa, there are many regions with a tropical or near tropical climate, indicating a need for protecting cows against summer heat. The Western Cape, for instance, has a temperate climate with long, hot dry summers and cool, wet winters. Winter temperatures are generally within the comfort zone of dairy cows, i.e. ranging from 10 to 18°C. On the other hand, summer temperatures are mostly above the upper level of the comfort zone of dairy cows, i.e. higher than 24°C. The average monthly maximum temperature during summer varies between 25 and 30°C. From November to March, the maximum temperatures exceed 24°C on 72% of all days being 15, 21, 26, 24 and 23 days per month, respectively. The average minimum temperature during summer in the Swartland Region of the Western Cape is about 15°C. This indicates that summer days are characterised by intense heat periods varying in duration with relatively cool nights. During summer, some farms may even experience cool breezes because of their close proximity to the sea, while prevailing south-easterly winds caused by cold fronts moving past in the southern ocean also aid in reducing the effects of heat stress.

The humidity level of the air also affects the cows' response to heat with cows showing extreme discomfort at high environmental temperatures and high relative humidity levels. The following equation was proposed by Kibler in 1964 to estimate a temperature humidity index (THI) using ambient temperature and relative humidity: $\mathbf{THI = 1.8T_a - (1- RH)(T_a - 14.3) + 32}$ where T_a is ambient temperature in degrees Celsius (°C) and RH is relative humidity (%) as a fraction. A different equation for THI using air temperature (T_a) and dew point temperature (T_{dp}), both in°C, was also developed to indicate heat stress levels, the equation being $\mathbf{THI = T_a + 0.36T_{dp} + 41.2}$.

Because of a lower relative humidity during the day, the THI in the Western Cape does not reach the same levels as in other parts of South Africa with a summer rainfall pattern. The number of heat stress hours per day, i.e. when air temperature exceeds 24°C or THI values above 72, could range from about 11:00 to 18:00. The heat stress potential of farms should be estimated as prevailing winds and mountain ranges could affect the micro-climate of the housing environment of cows.

Environmental modification

Studies concerning the climatic effect on dairy cows first started in the 1940's in the United States of America (USA). The main reason for this work was the realisation that in most parts of USA, climatic conditions differed from those in Europe where livestock originated. As specialised dairy breeds, such as the Dutch Friesian and British dairy breeds (Ayrshire, Guernsey and Jersey), were increasingly being used on a larger scale in the world, they were increasingly being exposed to climatic conditions which they are not well adapted for. While dairy cows are well-adapted for cold climatic regions, these same characteristics cause them to suffer under hot, humid conditions.

Because of an increase in the demand for milk products in the early 1950's, dairy farmers in many countries tried to improve the genetic potential of local breeds being used for milk production. The improvement in performance was, however, not quick enough to satisfy increasing consumer demands. This resulted in a widespread use of mostly the Holstein-Friesian breed. Because of the breed's relatively poor adaptability to a hot environment, the concept of environmental manipulation was created. This was specifically aimed at intensive type dairy farming systems. For pasture-based systems, which are mostly being used in temperate areas requiring limited protection, the aim has been to breed cows, albeit from a Holstein-Friesian base, that would fit the system rather than by changing the environment. However, today, because of an even faster growing worldwide demand for milk products, pasture-based systems are becoming more intensive by feeding cows additional concentrates and forages to increase farm production.

Because of the demand for knowledge on environmental manipulation, new fields in dairy research were started, resulting in regular meetings like the International Livestock Environment Symposium and Dairy Housing Conference. Initially these conferences were dominated by engineering concepts; however, the performance of cows and their behaviour became increasingly more important. This created the need to study the behaviour of farm animals using these housing structures. A new field of study, namely Animal Behaviour Science, was subsequently created.

European climatic conditions during winter are very difficult due to extreme cold; therefore, cows in those countries have, purely from a humane point of view, always been protected against winter weather conditions. Initially, various structures were used to protect cows. Herds were small and in many cases, were almost part of the household. It was, for instance, common to have the cows underneath the house where the family lived. However, in other countries with different climates, housing systems had to be adapted to fit the climatic conditions, as well as the housing requirements of dairy cows. As dairy herds increased in size with more cows, the close relationship between family and cows disappeared as additional labourers were employed to do some of the manual work. Because of increasing cow numbers and labour costs, labour saving designs had to be incorporated into housing systems. Tie-stall barns were replaced by free-stall barns, while manure removal was done by flushing passages with water rather than removing it by hand or using scrapers.

The design of buildings and structures to protect cows against extreme climatic conditions had to change to enhance production and efficiency rate because economic pressure forced dairy farms to be economically sustainable. Environmental manipulation for a hot environment includes the following: providing shade, increasing air movement by using fans, cooling drinking water, wetting cows before or after milking, wetting cows inside the housing system and using fans to increase evaporative cooling, using an evaporative cooling system underneath a shade structure, diet adjustments, intensive housing systems using free stalls or loose housing, zone cooling, and general air conditioning (the latter being the most expensive option).

Effect of summer heat on dairy cows

Even though South Africa has a hot climate, very few studies have been on the effect of the environment on the production of dairy cows. Earlier research done at Elsenburg in 1961 showed that the milk production of Friesian and Jersey cows was reduced by 50% at temperatures above 30°C. Dairy farmers in the area also recorded milk yield losses of more than 10% during summer due to heat stress. In a later study at Elsenburg, published in 1993, the effect of summer conditions on heat tolerance indicators in Holstein and Jersey cows was compared. In this study, first lactation Holstein-Friesian and Jersey cows were kept in open camps with no protection against summer heat. They were fed a total mixed ration twice a day. The heart rate, respiration rate and rectal temperature of cows were recorded at two-hourly intervals from 07:00 to 19:00 on 15 days during summer when the maximum temperature was expected to be above 27°C. The heart rate of cows was obtained at the middle and ventro-lateral coccygeal arteries of the tail for 60 seconds. The respiration rate was measured by counting the flank movements of cows over a 1-min period of uninterrupted breathing. Rectal temperatures were obtained by inserting a veterinary thermometer approximately 80 mm into the rectum for a period of 60 seconds. A halter was put on cows one week before the first observation to accustom them to being restrained. Maximum and minimum ambient temperatures during the trial were 31.7°C and 15.2°C, respectively, which were typical for summer in this area. Relative humidity levels were inversely related to ambient temperature, i.e. humidity going down with increasing ambient temperatures. Minimum relative humidity levels of 25.8% were recorded daily between 13:00 and 15:00. These ambient temperatures and humidity levels converted to a mean THI value of 76.3, which was higher than the critical THI value for milk production of 72. Earlier research in the USA showed that the upper limit of the comfort range for Holstein-Friesians is 21°C while it is 24°C for Jerseys. This means that Jerseys had a longer period every day within their comfort range than Holsteins, i.e. 13.7 vs. 10.5 h per day, respectively.

In thermo-neutral conditions, the normal rectal temperature of Holstein-Friesian and Jersey cows is 38.3°C. In this study, the rectal temperature in Holstein-Friesian and Jersey cows was about 38.3°C at 07:00. Rectal temperatures increased during the day with a noticeably sharp increase from 11:00 to 13:00 in Holstein-Friesian cows (Figure 20.1a). For Jersey cows the trend differed, showing an even increase in rectal temperature to 19:00. Rectal temperatures increased during the morning reaching 39.0°C at 13:00 in Holstein-Friesians and 38.6°C in Jersey cows. High rectal temperatures were maintained in Holstein-Friesian while in Jersey cows a lower rectal temperature was reached at 19:00. The difference in rectal temperature between the two breeds was the highest at 13:00 and 15:00. The rectal temperature of Holstein-Friesian cows showed a sharper increase from 23°C while, in Jersey cows, a linear trend was maintained over the overall temperature range up to 38°C (Figure 20.1b). The variation in rectal temperature because of ambient temperature was 63 and 30% for Holstein-Friesian and Jersey cows, respectively, indicating that Holstein-Friesian cows were more influenced by increasing ambient temperatures than Jersey cows.

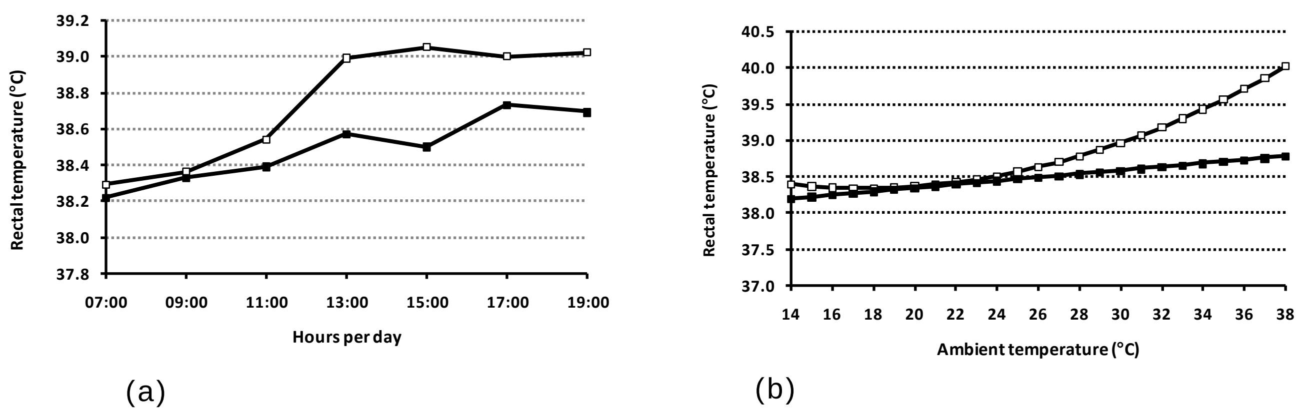


Figure 20.1. The rectal temperature in Holstein (□) and Jersey (■) cows as affected by (a) time of day and (b) increasing ambient temperature

These results agree with similar studies conducted in the USA, i.e. cows with no access to shade showed peaks in rectal temperature at midday, while the peak in rectal temperature was in the late afternoon when cows had access to shade. Other researchers found a time lag of about 3 hours between peak ambient temperatures and peak rectal temperatures. In Israel, for instance, the rectal temperatures in Holstein cows also increased sharply from 09:00 to 15:00.

Respiration rate increased during the morning as ambient temperature increased at 13:00 and then decreased again in the afternoon (Figure 20.2). Differences between breeds were the highest at 15:00 and 17:00 being higher in Holstein-Friesians in comparison to Jerseys. The respiration rate of Holstein-Friesian and Jersey was similarly affected by increasing ambient temperatures, although it was lower for Jerseys.

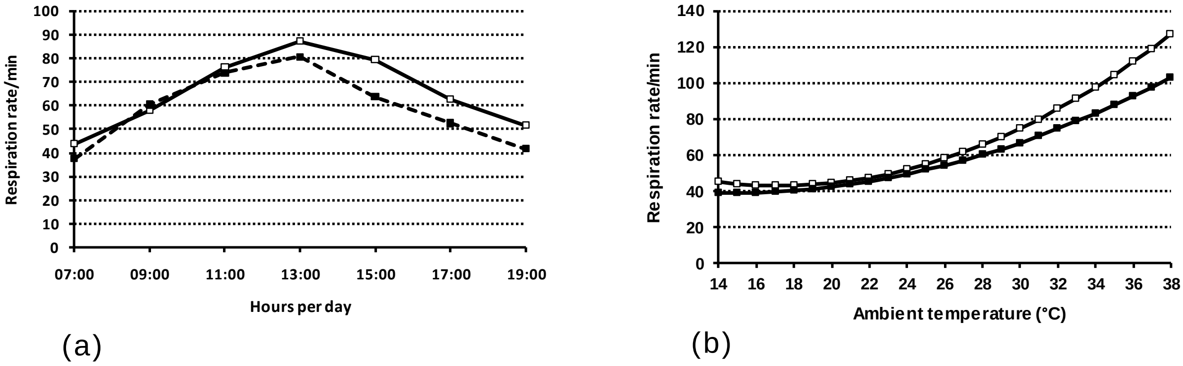


Figure 20.2. The respiration rate in Holstein (□) and Jersey (■) cows as affected by (a) time of day and (b) increasing ambient temperature

Other researchers also found peak respiration rates at 12:00 of 75 and 115 inhalations per min for cows with access or no access to shade, respectively. Research in India showed that the respiration rate of F1 Holstein x Sahiwal, F1 Jersey x Sahiwal and Sahiwal cattle was 65, 55 and 35 inhalations per min respectively showing the better adaptability of local breeds for a hot humid climate. Cattle show an increased respiratory rate because of higher ambient temperatures as this enables cows to dissipate about 30% of their heat by respiratory vaporisation. Excessive respiratory activity, however, increases internal heat production and may also lead to respiratory alkalosis. Initially it was thought that a higher respiration rate indicated a better adaptability to high temperatures. This, however, actually shows the opposite effect as a rise in respiration rate is accompanied by a fall in tidal volume. Respiration rate is therefore rather seen as an early indicator of cows experiencing heat stress.

The difference in heart rate between breeds was small, showing an increase towards midday and then decreasing again later in the day.

Factors affecting the response to heat stress in dairy cows may be related to coat colour, coat type, thickness of the hair coat, and subcutaneous fat layers, as well as milk production levels. Predominately black Holstein cows have higher rectal temperatures and respiration rates showing open-mouthed breathing (panting) more often than mainly white cows. This is probably because there is a higher reflection of thermal radiation from a white or light-coloured coat. Cattle have sweat glands at the base of each hair follicle. There is, however, according to a study in the USA, little difference in follicle density between Jersey and Holstein cows, i.e. 600-1100 vs. 50-1095, respectively. Morphological studies show that Jerseys have small, baggy sweat glands, with a skin structure characteristic of some *Bos indicus* breeds. This seems to support a hypothesis that the Jersey breed may have Zebu-type cattle among its ancestors. Jerseys also have a 20% lower metabolic rate than European temperate breeds such as the Holstein-Friesian. The higher production of Holstein-Friesian together with other anatomical factors may result in these cows showing a more pronounced effect of heat stress than Jersey cattle.

Effect of winter conditions on dairy cows

Climatic conditions in South Africa during winter are relatively mild in comparison to most European countries and parts of the USA. Cows being kept in the Western Cape in open camps during the winter experience considerable discomfort as they are often exposed to highly intensive rain showers, cold and often strong winds, and usually, extremely muddy conditions because of a lack of drainage from open camps. Almost 60% of the annual rainfall occurs during the winter from May to August. Wind and rain are significant components determining the coldness of an environment. The insulation value of an animal's hair coat is reduced by wind and rain while the surface heat exchange is increased. A study was conducted at Elsenburg during winter to determine the effect of different housing structures on the performance of Holstein-Friesian cows. Three groups of six Holstein-Friesian cows each were put in (i) an open camp without any protection against adverse weather conditions, (ii) an open camp with a shade structure and (iii) a tie-stall barn. Cows were fed the same total mixed ration and milked twice a day. The production of cows was recorded over 53 days during winter. Blood samples were collected to determine cortisol and thyroxine as stress indicators. The daily milk yield of cows on rainy days was compared to the immediate previous non-rainy day.

Typical winter conditions were experienced during the study. The average daily maximum and minimum temperatures were 18.5 and 8.7°C, respectively, which were within the thermo-neutral or comfort zone of dairy cows, being -5 to 21°C. Thermal fluctuations outside this comfort zone occurred on a short-term basis only. During the trial period, rain fell on 22 days for a total rainfall of 180 mm. While the average daily wind run was 100 km/24 hr, indicating little wind overall, on rainy days the daily wind run was higher than on non-rainy days, being 154 vs. 64 km/24 hr. These high winds would have increased the wind chill factor probably resulting in cows experiencing colder conditions than recorded ambient temperatures. The milk yield, milk composition, and stress levels, as indicated by blood cortisol and thyroxin levels of Holstein-Friesian cows in the different housing structures, did not differ. These results seem to indicate that these sheltering facilities had, under local conditions, no advantage in terms of milk production and milk composition.

It also seems that the average milk production of cows was affected negatively only on days when highly concentrated rainfall (average 21.2 mm/day over four days) occurred. On days with less rain, milk production was negatively affected in some cows only. Australian research found similar results and the lack of response was attributed to the absence of extremely cold conditions (with regard to the comfort zone of dairy cows) and relatively brief duration of really cold and wet conditions. That study showed that the magnitude of production changes between the periods before, during, and after low temperature stress periods was very small and the direction of change was also not consistent.

The lack of response is probably an indication of how well-adapted dairy cows are to withstand cold conditions while also emphasising the mild conditions normally occurring during winter. Cows tend to eat more when it is cold, resulting in an increased heat production. Cows have large muscle groups, good subcutaneous fat stores, and thick hides, while insulation is increased by growing thick winter hair coats. In the Elsenburg study, Dutch type Holstein-Friesian cows, being large-framed animals, were used. The effect of winter conditions on small-framed thin-skinned Jersey cows would probably be different.

In climatic chambers with constant cold conditions, it was found that the milk yield of Holstein-Friesian cows fed *ad libitum* declined at environmental temperatures below - 4°C. However, in this study cows did not have the benefit of a daily diurnal temperature pattern, giving them time to recover from extreme cold conditions. British researchers maintain that low air temperatures *per se* are unlikely to cause intolerable stress on dairy cows in the temperate climatic zones of the world. A primary need for dairy cows is a dry lying down area. Cows will often choose to lie in a dry area exposed to the weather rather than to lie down in a sheltered but wet area. Cows mainly require protection against excessive wind and rain. For this reason, housing systems in the Western Cape do not really need permanent walls to protect cows against prevailing winds. Closing up the side- or end-walls openings of housing structures could be done by removable cheap fabric, such as plastic sheeting. This would reduce the construction cost of buildings while increasing the ventilation especially during the summer. These openings need to be closed up only in severe winter weather.

In closing

Dairy cows are affected by the climate showing breed differences. Holstein cows seem to be more affected by heat stress than Jersey cows. This may be due to inherent breed differences and also higher milk yield levels. Protection against summer heat is required in most places in South Africa. This can be done in various ways. Housing is an expensive way of protecting cows against heat stress, although this would be preferred in some areas especially in high rainfall areas. High genetic merit cows require the best and most comfortable housing conditions to ensure high milk yields. This may even improve the lifetime performance of dairy cows. Winter conditions in the Western Cape are relatively mild and cows require mainly protection against rain and excessive wind. Housing systems should be considered when open camps do not provide such protection as well as a dry lying down area.

CHAPTER 21

HOUSING REQUIREMENTS OF DAIRY COWS

Introduction

In the Western Cape, dairy farms vary from large (more than 2500 cows in milk), mostly zero-grazing herds, to smaller dairy herds that are pasture-based. Zero-grazing herds do not make use of cultivated pastures and cows are fed on a daily basis using total mixed rations (TMR) which include the roughage and concentrate portions of the total diet. In some cases, roughage may be fed on its own while a concentrate mixture is fed inside the milking parlour or in a post-parlour concentrate feeding system. Cows are usually grouped according to milk production potential or stage of lactation. Feed is provided to them in feed troughs on a daily basis. Pasture-based dairy farms are in operation in areas where the rainfall is more evenly spread-out over the year with also the possibility of collecting runoff water for supplementary irrigation. On most pasture-based dairy farms, additional hay or silage is fed, especially during winter when pasture growth is limited. Because of economic pressure, many dairy farmers are increasing the number of cows in the herd, and, in many cases, exceeding the carrying capacity of the farm's pasture base. An expansion in this way results in a mixed production system, combining a pasture-based and a zero-grazing system. In this way, some of the problems of intensive systems are added to the overall production system.

Presently in the Swartland area of the Western Cape, most large-scale dairy farms use either an open camp system (dry lots) or intensive housing. The type of protection provided in open camps varies from no protection to at least a shaded structure. In most cases, during winter, the open camp systems become extremely wet and dirty because of the highly intensive rainfall, poor drainage, the accumulation of manure and short dry periods. In the summer, cows are exposed to high daytime temperatures because of long hot days, while wet winter conditions are usually conducive to the development of mastitis, foot rot, and other health problems. Recently, environmental pressure, due to uncontrolled manure runoff from large open camps, resulted in some dairy farms converting to intensive housing systems. Such systems, if designed correctly, also protect cows against summer heat, while a manure management system to control environmental pollution could be put in place. Although the number of dairy farms using open camps systems is decreasing, a combination of both systems is being used on some farms because of the high cost of constructing an intensive housing system. The management of an intensive housing system is also a factor to be considered as manure removal and lying down surfaces in free stalls require daily attention.

Earlier local research

The first local design of an intensive housing system for dairy cows at Elsenburg was a low-roofed (2.05 m high at the low end) structure with 1.2 m high back wall. Manure collected in the feeding passage was removed manually by scraping the concrete floor daily. Inside the building, cows had access to individual free stalls with a level (not sloped) concrete surface. To improve the comfort of the free stall surface for lying down, wheat straw was used as bedding inside each free stall. Soiled bedding material was removed every day and fresh straw added to maintain a soft dry surface to lie on. The orientation of the building was such that the structure was open to the north-east with a feed trough under the open end. Although the design provided protection against winter conditions, during summer, the low roof and 1.2 m back wall created very hot conditions inside the building. Because the feed trough was on the north-eastern side of the building, cows, when eating, were exposed to rain in winter and direct sunlight during the morning feeding period. The wooden pole structure also reduced the feet movement of cows when getting up and lying down, as the back wall of the structure reduced the forward lunging movement of cows. At the time little effort was put into determining the housing requirements of dairy cows as the expectation was that cows would use the building regardless of its design. In a later study conducted during the winter employing a two-choice preferential test, cows were given a choice between either using an open camp and the intensive housing system. This study showed that cows, after feeding, preferred to stand around or to lie down in the open camp to rest and ruminate. Presumably, the soil surface in the open camp provided a softer lying down surface than the concrete floors of the free stalls while it was easier for cows to lie down or get up in comparison to the restricted space of the free stalls. Cows only used the protection of the housing structure during heavy rainstorms, even though minimum temperatures reached well below 10°C on non-rainy days; this shows their ability to cope with cold conditions.

In contrast to this, buildings for dairy housing in other parts of the world with similar climatic conditions as the Western Cape, i.e. California in the USA and Israel, have high roofs (3.5 to 5 m high) and open sides (no walls) with central feeding troughs, resulting in cows being exposed to minimal sunshine underneath the roof. Free stalls inside these buildings have sloped floors to accommodate the natural tendency for cows to lie on an uphill slope.

This trial building showed that a costly intensive housing structure may not always result in a comfortable environment for dairy cows. This is because the design of the structure did not consider the natural behaviour of dairy cows. Disregarding this aspect may, in the medium to long term, result in problems for cows, which could affect their performance. Dairy cows have the following essential housing requirements:

1. Dry and clean lying down area

Dairy cows spend 8 to 12 hours per day lying down to ruminate and/or to sleep and therefore need a clean, dry and comfortable (level) lying down area. The bedding area has to be soft as cows have a large and heavy conformation. Pasture, soil or sand provides the most comfortable surface for cows to lie on. A cow will normally lie on her one side for a while after which she will get up to lie down again in the same place, although usually on her other side. The number of times that cows get up and lie down is often an indication of the comfort of the resting place. When it is difficult for cows to get up or lie down because of incorrect free stall design, they will often stand for extended periods inside the stall or with their front feet inside the stall and back feet in the manure passage way (perching). Poor management often creates uneven surfaces, which also reduces the occupancy rate of free stalls.

2. Concrete surfaces

Dairy cows stand around for about 12 to 16 hours per day to eat, during rumination and milking. They have to move around daily between the feeding area and milking parlour holding areas. They often have to stand for a number of hours waiting to be milked or after milking before going back to the feeding area. A concrete surface is an unnatural surface for cows to use. Concrete often becomes slippery because of a manure build-up, while the hoofs of cows are constantly wet as the feed alleys are also used as manure and urine collection points. Cows feeling unsafe on slippery floors reduce their walking speed and would not show natural behaviour with regards to heat detection. Uneven and very slippery surfaces often cause feet and leg injuries.

3. Shelter

Cows require protection against adverse climatic conditions. The ambient temperature is the most important climatic factor affecting the production of dairy cows. The ideal temperature for milk production is between 10 and 18°C. However, the production performance of dairy cows is little affected within their temperature comfort zone of between 4 and 24°C. The design of an intensive housing system for dairy cows should therefore consider the long-term weather pattern of an area. Meteorological records show that maximum temperatures in the Western Cape exceed 24°C on almost 60% of the days between November and April. As meteorological temperatures are normally measured in the shade, thereby excluding radiation heat, the necessity of providing shelter against high temperatures is further emphasised. On the other hand, temperatures recorded during the winter are relatively mild, being actually within the comfort range of dairy cows. However, almost 60% of the annual rainfall occurs between May and August. Rain is usually accompanied by strong, cold winds. Due to the wind chill factor, the effective temperatures to which cows are exposed would be lower than recorded temperatures Rain and wind also reduce the insulating ability of the hair cover of dairy cows. The cold conditions will increase the energy requirement of cows.

For the Western Cape, an intensive housing system should mainly provide protection against summer as winter conditions are relatively mild. Cows require only protection against wind and rain, which should be considered in the layout of the housing system. The effect of high temperatures on the performance of dairy cows is shown in Table 21.1.

Table 21.1. The reaction and performance of Holstein cows recorded at a comfortable (18°C) and hot (30°C) environmental temperature

Parameters	Environmental temperature	
	18°C	30°C
Body temperature (°C)	38.6	39.9
Respiration rate/min	32	94
Metabolic heat production (MJ/h)	3.521	2.633
Water intake per day (l)	58	75
Concentrate intake per day (kg)	9.7	9.2
Hay intake per day (kg)	5.8	4.5
Milk production per day (kg)	18.4	15.7
Fat (%)	3.42	2.42
Fat production per day (kg)	0.63	0.38

4. Ventilation

Toxic gases adversely affect the feed intake and milk production of dairy cows. The inhalation of gases also reduces their resistance to pathogens. Since large amounts of carbon dioxide and methane are produced by cows, through normal breathing and manure build-up, good ventilation is essential at all times to supply clean and fresh air inside a housing system. For this reason the orientation of housing structures with regards to the prevailing wind direction should be considered as well as the possible obstruction of other buildings and trees. Roofs of structures should be high being open to the eaves. At most protection against cold draughts could be provided at cow level using movable plastic sheeting.

5. Behaviour of cows

Dairy cows get used to a specific daily routine very easily. They are generally very sensitive to a sudden change in routine. The daily feeding and milking routine of dairy cows, as well as management procedures, like manure removal and cleaning of free stalls, should therefore vary as little as possible from day to day. Within any group of dairy cows, there is always a distinct social order of dominant and subordinate (lower ranking) cows. Determination of the social order is influenced by the following factors:

- **Group size.** It is difficult for cows to recognise each other in large groups. For this reason, groups of cows should preferably not be more than 60 cows.
- **Space.** Competition for feed and water is increased with a greater number of cows per unit area. Adequate feeding and drinking space should be provided to ensure that the production of lower ranking cows is not affected.
- **Age.** Groups of young cows are slower than older cows in establishing a social order.

Type of housing system

The intensive housing of dairy cows can broadly be divided into (i) free stall or cubicle housing and (ii) loose housing. Loose housing means that cows have access to a bedded pack of bedding consisting of wheat straw or a dirt mound underneath a high roofed structure. Because of the cost of bedding material and labour to remove the bedding once or twice a year, this system is not very popular any more. In the dry climate of Israel, a dirt mound is being used because of a lack of suitable bedding material. Fans are also being used to aid the drying of manure and urine collecting on the dirt mound, while at the same time increasing the ventilation inside the building. One of the latest developments includes a louvered roof structure that is open on the western side in the morning to aid drying the surface of the dirt mound, with the louvers closing as the sun moves overhead to the west, and in so doing opening the louvers on the eastern side of the roof.

Although cubicle or free stall housing systems are not without problems, it is regarded as the most effective way of housing dairy cows. In these buildings, cows have access to a separate cubicle which should provide a clean and dry lying-down surface as a bedding area. Cubicle floors or surfaces may consist of sand, soil, wood or concrete. Each of these surfaces requires a specific management system. Concrete floors should be covered with a 50 to 75 mm layer of some bedding material. This may consist of chopped wheat straw, wood shavings, or dry manure. In some cases, shredded newspaper material has also been used. Wooden floors require less bedding material although the life expectancy of such surfaces are shorter than that of concrete. Rubber mats may also be considered although some types of rubber also require a thin layer of bedding material to reduce chafing of the skin. Recently, water-filled mattresses have also been installed in housing systems. A neck rail is installed towards the front of the free stall, which encourages cows to stand towards the back-end of the free stall which allows their urine and manure to fall in the manure alley and not on the free stall floor. However, incorrect positioning of the neck rail, e.g. being too far back, reduces the movement of cows when lying down or getting up resulting in injuries to their backs or cows not using the free stalls fully. Free stalls floors should also have a slope of 2 to 4% from the front to the rear end, because cows prefer to lie on a slope with their heads higher to improve the continuous eructation of rumen gasses.

Design buildings to protect cows against heat

As dairy cows are more sensitive to heat than cold, the design of housing systems in the Western Cape should provide protection mainly against high temperatures and mostly protection against cold winter drafts. Buildings should provide a cool micro-climate. For this reason, the roof should be high to reduce the heat load from the roof onto cows inside the building. The lowest end of a pitched roof should be at least 3.5 m high, sloping upwards to a height of 5.0 m at the pitch of the roof. An opening of at least 600 mm should be left on the ridge. A steep slope ensures a fast removal of rising hot air caused by body heat, and methane and carbon dioxide contaminated air from the floor. The natural airflow of prevailing winds should be used to improve the ventilation and cooling of cows. For this reason, permanent walls are not required, although removable fabric, like plastic sheeting, may be used to protect cows against draughts, from prevailing winds and possibly rain.

The direction of the prevailing summer and winter winds determines the orientation of a housing system. Flat roof structures are normally put up with the lower end of the roof towards the prevailing summer wind for efficient ventilation and cooling down of cows. Structures should also be put up away from other farm buildings, structures and trees as these normally deflect prevailing winds. In the Western Cape, orienting livestock buildings is particularly difficult as the prevailing winter winds, bringing rain and cold air, and prevailing summer winds are from opposite directions. As dairy cows require greater protection against summer heat in comparison to winter cold, the orientation of buildings should aim to protect cows as much as possible against direct sunlight. It is therefore important to position the feeding area, i.e. trough and passage way, and free stalls inside the building, in relation to the movement of the sun. In South Africa, the sun moves from east to west along the northern horizon. The long axis of the building should therefore preferably be north to south with the feeding area in the center of the building and the free stalls at least 3 m from the outer sides of the building. A roof overhang could be used to minimise direct sun shining into free stalls. This should ensure that cows, when feeding or lying down, will be in shade for most of the day except during the early morning and late afternoon, i.e. before 09:00 and after 17:00 when the angle of the sun is low. Normally, at this time of the day, ambient temperatures are close to the comfort zone of dairy cows.

Cows normally have a specific behavioural pattern every day. After milking, they eat for about 1 to 2 hours after which they stand around or lie down to rest and ruminate. When it is hot, cows not lying down, tend to converge in groups in the coolest part of the building, usually where natural air movement occurs. Cows, however, prefer to lie down to rest and ruminate, especially after milking and feeding. The occupancy rate of free stalls, or percentage of cows lying down, can therefore be used to determine the comfort level of free stalls specifically with regards to stall design and management of the free stall surface. Continuous observation of cows is time consuming and difficult; however, by counting the number of cows lying down in free stalls at specific times during the day, an indication of occupancy rate can be obtained. The occupancy rate of free stalls is estimated by the sum of all occupied stalls at all counts divided by the total number of stalls available at all counts.

An observation study was conducted to determine the occupancy rate of free stalls as affected by the orientation of an intensive housing system. The long axis of the building was in a north-west to south-east direction to protect cows against winter rain. A single row of free stalls were along the outer north-east and south-west walls of the building being exposed to direct sunshine in the morning and afternoon. Figure 21.1 shows the difference in the percentage of cows lying down from 07:00 to 15:30 along the eastern and western side of the building.

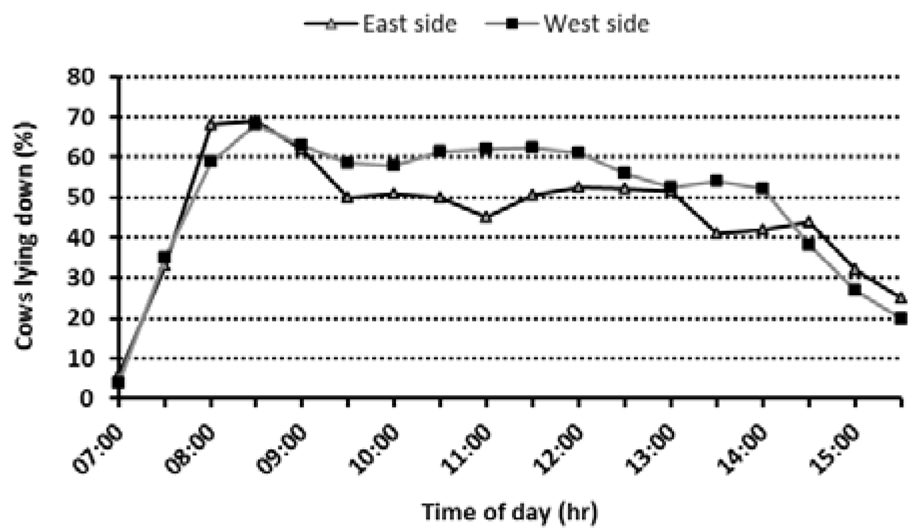


Figure 21.1. The percentage of cows lying down during the day in free stalls along the north-eastern (East) and south-western (West) side of an intensive housing system

By 08:00 about 68% of free stalls were occupied, i.e. cows were lying down, on the north-eastern side of the building; however, from 09:00, fewer cows were lying down in these free stalls as the sun was shining directly into the free stalls. This resulted in a lower occupancy rate of free stalls in the morning along the north-eastern side of the building in comparison to the south-western side which was in shade at that time, i.e. 42.3 vs. 47.5%. It therefore seems that cows preferred to stand in the shade in the central part of the building rather than to lie down in free stalls, which were in direct sunlight. The same pattern was observed during winter even though daytime temperatures were lower than summer temperatures, i.e. 17°C vs. 30°C. This seems to indicate that cows will avoid direct sunshine if they have a choice. Overall, the occupancy rate in this commercial housing system was not very high, being 60% at best. This could indicate free stall design and/or management problems. Additional protection against morning and afternoon sunshine should be provided to increase the occupancy rate of free stalls giving cows more time to lie down to rest and ruminate. This can be done by extending the roof overhang to reduce the extent of the sun’s penetration into the building, thereby increasing the size of the shade inside the building. Putting up shade netting from the roof to the floor is not a good option as this would reduce the natural airflow through the building, specifically at cow level.

Free stalls

Cows require at least 10 to 12 hours resting time per day. When cows are not being milked or feeding, they should lie down to rest and ruminate. Cows stand around to ruminate and for socialising. In an intensive housing system, they often stand in the manure alley or inside the free stalls. However, when these standing bouts are too long, it is usually an indication of poor free stall design or because of poor free stall management. Another indicator of poor free stall occupation is when cows are standing halfway into the stalls with their hind feet in the manure alley. This standing position is called perching. The number of cows perching can be used as an indicator of free stall comfort. When the design of free stalls is incorrect, i.e. being too narrow or short, or the lying down surface of the free stalls is uncomfortable being uneven or hard, then cows are reluctant to lie down. Uncomfortable free stalls result in fewer cows lying down or they lie down for shorter periods, getting up more regularly. Filming the movement of cows showed that cows require a forward-lunging movement to lie down or to get up. This means that free stalls have to be longer than their total body length when lying down. Therefore, obstructions, like a wall at the front-end of free stalls, would cause cows to be hesitant to lie down or having to move sideways when lying down or getting up.

An observational study was conducted at Elsenburg to determine the effect of lunging space as affected by the presence or absence of a permanent wall at the front-end of free stalls on the behaviour of dairy cows (Table 21.2).

Table 21.2. The behaviour of Holstein cows as affected by lunging space at the front-end of free stalls (lunging space was created by the removal of a permanent wall)

Parameters	With a wall	Without a wall	*P*
Total lying down time (min)	646	758	*
Total standing time (min)	380	254	*
Time standing in the manure alley (min)	174	107	*
Standing – perching (min)	156	113	ns
Standing in free stalls (min)	50	34	*
Total feeding time (min)	319	311	ns

P = significance; * = $P < 0.05$; ns = not significant ($P > 0.05$)

Cows used free stalls with a permanent wall at the front-end of the free stalls almost 2 hours less than cows using stalls without a wall, i.e. 12.6 vs. 10.8 h/day. Cows with a permanent wall at the front-end of the free stalls also had a longer overall standing time, i.e. 6.3 vs. 2.3 h/day. For both types of stalls, more than 40% of the time spent standing was in the perching position, while the actual time perching was longer in stalls with a wall at the front-end of stalls. The total feeding time was the same for cows with access to free stalls with or without a wall. The longer time standing in the manure alley, inside the free stalls and in the perching position, showed that cows were more reluctant to use free stalls with a wall in the front. Cows using free stalls with a wall at the front-end were also lying down for shorter periods. They also got up more regularly to move to another stall. They also seemed to struggle to get up as they had to lunge sideways in order to rise. This forward lunging movement was obstructed by the side barriers between the individual stalls. When lying down, cows had to keep their heads sideways to avoid touching the wall.

In closing

The behaviour of cows gives a good indication of the way they perceive housing conditions. Farmers should be more observant of behavioural indicators as poor free stall design and management are difficult to identify. The negative effect of such conditions will result in poor performance in the long term.

CHAPTER 22

SHADING FOR DAIRY COWS

Introduction

It is well established that dairy cows are well-adapted to cold conditions because of specific inherent characteristics. However, these traits make them very sensitive to heat. Because of solar radiation, air temperatures do not have to be very high for cows to seek shade. Protecting cows against heat stress improves their welfare and production. Heat stress occurs when the ambient temperature rises above the comfort zone of dairy cows. This can vary from 21°C for Holstein cows to 24°C for Jersey cows. Ambient temperature increases because of solar radiation. The effect of high temperatures is aggravated by high relative humidity levels. In the Western Cape, relative humidity levels decrease during the day, though still reaching temperature-humidity index values above 72, which is the lower level indicating heat stress. Cool nights give cows the opportunity to recover from daytime heat stress. As the daily maximum temperature exceeds 24°C on more than 60% of all days in most parts of South Africa, it is clear that cows need some protection against summer heat. Each summer, cows suffer major losses in milk yield because of heat stress reducing farm income. As ambient temperatures are measured in the shade, it means that radiation heat from the sun is not included. Consequently, at an air temperature of 24°C, the ambient temperature (what the cow feels) would be much higher because of radiation heat.

A shade structure (Figure 22.1) is the simplest and most cost effective way to protect dairy cows against heat stress. Due to a reduction of the direct radiation from the sun, the heat load on cows is reduced by 30 to 50%. Studies also show that dairy cows with free access to shade have a higher feed intake and produce more milk than cows without access to shade. Fewer inseminations per conception are required for cows provided with shade, resulting in a shorter calving interval.

Figure 22.1. Cows using a shade structure in an open camp system in the Western Cape

Natural shade

The most comfortable natural environment for cows on a warm day would be in the shade of trees in a pasture field. The trees would protect cows against the sun's radiation, while cows would benefit from the cool environment created by the transpiring vegetation of the trees and grass. Natural air movement would further aid cooling. A large tree with dense foliage is generally described as a biological shed. However, such an environment is possible only for a small number of cows and would generally not be attainable on a large-scale dairy farm. Pasture-based dairy farmers do not plant trees as they would be in the way of equipment used in pasture management nor do they put up artificial shade structures for cow comfort because a specific field is used only once in a 25 to 30-day rotation period. Furthermore, a large number of cows seeking shade underneath trees on a daily basis would result in trees dying because of being ring-barked and from pollution caused by manure building up in the soil. In some incidences farmers have erected shade structures on the edge of fields, although a wet and dirty area for lying down is created very quickly similar to an intensive open camp system.

Artificial shade

Cows being kept in open camps during the day need to be protected against summer heat. It is required for cows that are usually on pasture at night to be fed additional hay or silage during the day and also for cows that are being fed a total mixed ration in open camps. The best shade structure for cows is a solid sheet high above the ground with enough space around the structure for cows to use the shade pattern that moves as the sun moves through the sky from east to west. On a hot day, cows converge in the shade, which is not specifically underneath the shade structure. The shade pattern is directly underneath the structure only at midday while for the rest of the day it is related to the position of the sun. A shade structure protects cows against solar radiation while body heat is radiated away to the clear and cooler sky.

A shade structure should be high enough to protect cows against heat radiating down from the roof. In temperate regions, a shade structure should be at least 3.5 to 4.0 m high while higher shades are used in very hot and desert-like regions. The length to width ratio may vary from 2:1 to 10:1. The structure should not be wider than 12 m as air movement underneath the structure is then greatly reduced. The best thermal comfort is provided with long narrow shades (5 – 8 m wide) with the long axis orientated east to west. With this orientation, the shade pattern is mostly to the south of the structure where cows are protected against the sun, but exposed to the cooler part of the sky to the south. As the shade pattern moves very little on the ground, the ground becomes a little cooler. However, because the shade pattern moves very little with this orientation, the ground underneath the structure is not fully exposed to the sun and with cows standing and lying down in this one area, the ground becomes wet and dirty very quickly. This is caused by a build-up of manure and urine, resulting in dirty cows. Dirty udders and teats add to milking times because of the time spent washing teats while milk quality is reduced because of a higher incidence of mastitis and sediment in milk. Therefore, it is recommended that shade structures be put up in a north-south orientation as this creates more favourable ground conditions for cows to lie down on. With the north-south orientation, the shade pattern moves quickly over the ground covering an area during the day about three times the size of the shade. This means that because cows are using a larger area, manure deposits are spread out more evenly, while the soil around the shade structure is exposed longer to the sun drying out manure and urine deposits better.

In the past, partial shade, i.e. using slats or corrugated metal sheets supported between steel cables and spaced 5 to 10 cm apart, was considered because of the drying out effect of the soil. However, results were not very positive as with a slatted roof orientated east to west, the ground underneath the shade structure would be covered by cows lying down or standing around, resulting in the sun not reaching the ground. The effectiveness of a slatted roof is directly proportional to the percentage of coverage. A roof with a 50% covering using slats is only 50% as effective as a solid shade. Shade netting is very popular because of the lower setting up costs. However, its effectiveness is also less than that of a solid shade. This is because, similar to a slatted roof, some sun is let through the netting. The maximum ambient temperature underneath a shade structure at Elsenburg was 10°C lower than in direct sunlight, whereas underneath a double-layer of 80% shade netting, the temperature difference was only 6°C.

Local research results

A study was conducted at Elsenburg comparing the production performance, stress levels and behaviour of Holstein-Friesian cows with and without access to a shade structure during summer. Cows with access to an asbestos-roofed structure 3.65 m high, orientated lengthwise north to south, providing at least 4 m² of roof space per cow, in an open camp were compared to cows in a similarly sized open camp without any protection against the sun. During the study, days were characterised by high day-time temperatures, on average about 28°C, and cool nights, with minimum temperatures of about 14°C. Maximum temperatures were higher than 25°C on 74% of all days while the ambient temperature was higher than 25°C, i.e. exceeding the upper comfort level of cows, for more than 7 hours per day. The highest ambient temperatures were recorded at 14:00 and 25°C was exceeded from about 10:30 to 18:00. The number of stress hours per day was closely related to maximum temperatures. As ambient temperatures do not include solar radiation, black globe temperatures should actually be used to indicate an area's heat stress levels. Black globe temperatures integrate the effects of net radiation, i.e. from the sun, horizon, ground surface and other objects close-by. The difference between black globe temperatures underneath the shade structure and in the sun was 10°C, being 30 and 40°C respectively.

Cows with access to shade had higher feed intakes, both during the day and at night. The daily free-water intake of cows without shade was higher than that of cows with access to shade, being 114 vs. 97 litres per cow per day, respectively. The overall response in milk yield over three summer seasons was a 5.5% higher milk yield for cows with shade. Based on linear regression analyses the average daily milk production of cows was not affected by increasing maximum temperatures. This result was unexpected but could be explained by the fact that feed intake was not affected by high daytime temperatures because cows had adapted their feed intake towards the cool times of the day. About 55% of the total daily feed intake was at night. Most cows would also complete most of their daytime feed intake before 09:00 in the morning. Only a small number of cows would eat again during the hot time of the morning, i.e. around 11:00 to 13:00. During the evenings and nights, a normal feed intake was maintained, because of cool conditions, i.e. ambient temperatures below 24°C.

Providing shade resulted in reduced stress levels as observed in lower blood thyroxine and cortisol levels. The rectal temperatures and respiration rates of cows using shade was lower than that of cows without shade. In Figure 22.2, the mean respiration rate and rectal temperatures of Holstein-Friesian cows with access to and without shade on days when the maximum temperature exceeded 25°C, is presented. The respiration rate of cows increased during the day because of an increase in ambient temperature from about 17°C at 07:00 to 28°C at 14:00. The respiration rate of cows with access to shade was significantly lower than that of cows without shade, being 63 and 81 inhalations per min for shade and no shade cows, respectively. Rectal temperatures similarly increased during the day for both shade and no shade cows, though being lower for shade cows. The rectal temperature of shaded cows was higher at 17:00 probably because of the activity associated with the afternoon milking process. It is for this reason that it is generally recommended that, during summer, the afternoon milking session be moved closer towards the evening when ambient temperatures are expected to be lower than at 15:00.

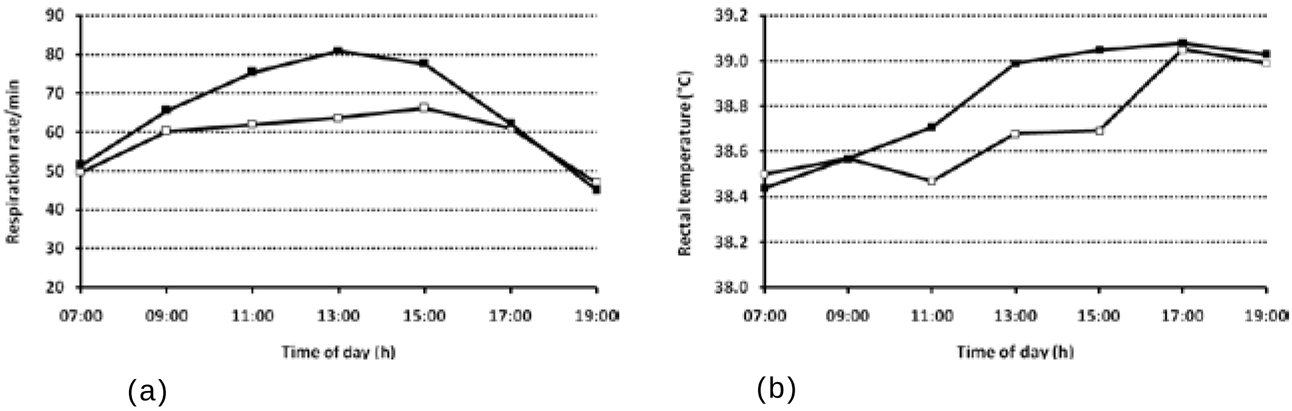


Figure 22.2. The average (a) respiration rate and (b) rectal temperature of Holstein-Friesian cows with access to shade (□) and without shade (■) on hot days (day-time maximum temperature >25.0°C)

On cool days, i.e. days when the maximum temperature is below 25°C, the difference in respiration rate and rectal temperature between cows with and without shade did not differ significantly, while the diurnal pattern for both heat stress indicators was the same.

Cows without shade also adapted their daily behaviour to cope with heat stress. They converged at the water trough, with some cows standing with their front feet inside the trough while other cows would use another cow's body to shield their heads from the sun. Even at a modest increase of 5% in milk yield, the construction cost of putting up a shade structure was paid within two summers.

In the Elsenburg study, the response to shade was relatively small when compared to studies conducted in other parts of the world. This is probably because environmental conditions at Elsenburg at night during summer are generally cool, as indicated by average minimum temperatures of about 14 to 15°C. This cooler period would allow cows to recover from the day-time heat stress. In areas with higher maximum temperatures and higher relative humidity levels than at Elsenburg, the negative effect of heat stress on milk yield would be greater, resulting in a faster pay-back period.

Different materials to be used as shade

There are measurable differences in the effectiveness of various solid materials that could be used for a shade structure. In the early years, a layer of straw was used as roofing material. A 15 cm layer of loose bulky material, such as hay or straw, is about 20% more effective than galvanised steel sheets. This is because the layer of loose straw does not heat up while heat is not radiated away from the underside onto cows using the shade. Such shades are, at present, not being used anymore because of the difficulty of maintaining a good layer of straw as a roof. Solid wood could also be used as roof material and is also slightly more effective than steel for the same reasons mentioned above regarding a layer of straw. However, wood would not last as long as steel sheets, especially in a humid climate. Other roofing material includes asbestos, aluminum or galvanised sheeting. The nature of the metal surfaces being used as roofing material affects their effectiveness. New galvanised steel and aluminum, which are still bright, are similar in effectiveness. This is reduced as the surfaces of the sheets become dull. The effectiveness of these materials can be improved by about 10% by painting the top white and the undersurface black. The white colour would reflect a portion of direct solar radiation, while the black colour reduces the radiation and reflective heat from the roof onto the animals underneath the shade. However, in a dusty environment and with flies and fly sprays, these surfaces quickly become gray, losing its effectiveness. Insulating the underside of a metal roof will improve its effectiveness, though only to the level of a shade made from a layer of hay. Usually, considering the cost, durability and effectiveness, corrugated steel sheets on top of steel frames are recommended.

Shade size and location

Shade structures should provide at least 4 to 5 m² shade space per cow. For young calves (2 to 5 months of age) and growing heifers shade space of 2 to 3 m² per animal should be provided. A smaller structure for dairy cows would cause crowding underneath the structure often preventing cows from lying down to rest. Airflow over the animals is also reduced causing heat to build up underneath the shade structure while the soil becomes wet, muddy and dirty from manure buildup. This increases the possibility of mastitis for cows when lying down. The shade structure should be erected in the middle of the open camp or at a convenient distance from the feed and water troughs. There should be enough space around the shade structure to accommodate the movement of the sun. Because of the low angle of the sun early in the morning and late afternoon a shade structure erected closer than 4 m from the fence on the west and east side of the structure will project a shade pattern outside the open camp in the morning and afternoon. A continuous line of shade structures extending over fences covering a number of open camps is cheaper to build, although cows tend to converge along the common fence line resulting in poor shade space utilisation. Putting up a shade structure over a fence line feeding trough is not generally recommended as it is not used fully during the day which results in poor ground space utilisation in the open camp. Usually poor soil conditions are created because of cows converging at the feed trough. At night, the shade will reduce the radiant exchange from the cows to the cool night sky which may discourage cows from eating at night. Often, depending on the layout of the open camps, the shade pattern is sometimes out of the reach of the cows. Furthermore, if no other shade is available in an open camp, cows will converge at the feed trough causing a disruption and preventing other cows' access to the feed. Cows will sometimes lie down on the concrete apron at the feed trough, causing further feeding disruptions. This area is also usually very dirty because of manure buildup, again increasing the possibility of mastitis.

Natural air movement

Natural air movement in the open camps and underneath the shade structure would contribute to animal comfort on hot days. The natural movement of air currents caused by prevailing winds should be used as much as possible. Fence lines should consist of only a few strands while netted fences would reduce airflow. Obstructions, like large stacks of hay or buildings near the open camps, would reduce air movement, while also reflecting heat onto cows.

In closing

The necessity for shade for dairy cows is evident from the fact that during the summer the daily maximum temperature exceeds 24°C on more than 60% of all days in most parts of South Africa. It should be kept in mind that air temperatures are generally recorded measured in the shade, which does not include the direct radiation from the sun. This means that at an air temperature of 24°C, ambient temperature (what the cow feels) would be much higher because of radiation heat. A shade structure is the simplest and most cost effective way to protect dairy cows against heat stress. Due to a reduction of the direct radiation from the sun, the heat load on cows is reduced by 30 to 50%. Local research has shown that Holstein-Friesian cows with free access to shade have a higher daily feed intake and produced 5% more milk than cows without access to shade. This study also showed that the difference between the accumulative milk yield of cows with shade and no shade increased as the summer progressed. This indicated that as the summer progressed and cows experience heat stress for a longer period, the negative effect on milk yield became greater. A well-built shade structure may last for more than 30 years, improving the milk yield and welfare of cows having access to it.

CHAPTER 23

MANURE MANAGEMENT ON DAIRY FARMS

Introduction

Manure management is a critical aspect of a dairy farm. On many dairy farms in South Africa, it is obvious that the layout of the farm was not planned to accommodate managing the large amounts of manure produced on farms. This is obvious in the lack of manure ponds, poorly managed lagoons, or no control management of the runoff of wastewater from holding pens and the milking parlour. Sometimes large or small ditches are observed channeling wastewater away from the milking parlour, while open camps often have no clear manure management facilities. Manure management usually only becomes a problem when it rains. Rain runoff from holding pens, falling on manure collection areas, becomes contaminated and when such water ends up in natural waterways pollution is caused, which is in essence a criminal act under the National Environment Management Waste Act no 59 of 2008.

Each dairy cow produces, on a daily basis, about 50 kg of manure and urine. Added to this are large amounts of bedding material that is usually used for housing small calves and heifers. Wastewater from the milking parlour also contains a significant amount of manure and urine in addition to discarded milk from cows suffering from mastitis and cows being treated for various diseases. The manure and urine produced by each cow amounts to more than 18 tons of wet material per year. A large amount of waste material can thus quickly accumulate on a dairy farm. The liquid content of the combined waste products is usually higher than 80%. This means that handling such material is difficult, requiring specific housing designs to collect and keep manure and urine in storage. Manure management is a daily process on dairy farms and some measures should be taken to reduce the physical inputs of this process. On concrete surfaces, the build-up of manure is very obvious while in open camps the build-up is initially not so obvious because manure gets trampled into the earth with urine being absorbed. It is only when it rains that the manure in the soil is shown, specifically in high-traffic areas such as near feed and water troughs, shade structures and gates.

There is also currently an increasing emphasis on protecting the environment. For this reason when developing new dairies, farmers have to provide an environmental impact assessment to comply with the Environmental Impact Assessment and Waste Management Act or risk the chance of not being allowed to develop the farm. In other parts of the world, environmental protection agencies have a tight rein on farmers' management systems ensuring good farming practices. Locally farmers are put under pressure often from a welfare point of view while no strong action has been taken against poor environmental conditions. Innovations regarding manure management are presently emphasising the utilisation of manure and not really towards how manure should be managed. Fortunately, there are a number of ways to manage manure and to protect the environment. This includes the following:

1. Separating clean and contaminated water

One way of reducing pollution is to reduce the amount of water entering the area where most activities of the farm take place. The general principle that applies here is that of a so-called environmental eye, i.e. the upper lid being the diversion of clean water flowing over the dairy and the bottom lid collecting the polluted water below the dairy. To reduce environmental contamination involves two strategies, i.e.

(i) preventing clean water (rain water) from flowing across manure covered areas, and
(ii) filtering polluted water being collected in holdings pens, etc.

One way of realising the first strategy is by including fitting rain gutters, with downpipes with outlets from the gutters, which can divert rainwater away from where cows are being kept. It is possibly a good option to connect downpipes to an underground outlet to carry water away from the heavy cow traffic areas. This is a low cost to existing buildings and can be custom fitted to most buildings. This will result in a drier, cleaner dairy environment. Gutters, however, must be kept clean and regular maintenance is required. Another option is to divert clean water with an earthen ridge or channel across the slope of yards or open camps where cows are kept. The second strategy is to include a settling basin to collect the runoff from areas where cows are being kept. This may be a concrete basin or a filter or buffer strip of grass or wetland type of plants to trap nutrients and suspended organic matter. A concrete basin should be large enough to store contaminated water for the separation of water and solids. The solids could be removed on a daily basis with a front-end loader; alternatively, the system must include a system to pump wastewater into holding ponds for the anaerobic digestion of organic matter. When using a filter strip, the area should be large enough to contain the runoff. It may even be useful to install a spreader at the top end of the filter strip to distribute water evenly over the whole filter strip area. The type of soil, however, determines the success of a filtering system, as some soils have little or too much permeability causing pollution.

2. Intensive housing

This system allows for an easy way to collect manure as cows are kept on concrete, making it possible to scrape the manure collecting in feed and manure passage ways into a manure sump. These passage ways could also be washed down using a manual or automatic flushing system. In this way, manure and urine are removed usually twice a day into a collection sump. This wastewater could be channeled over a sieve or pumped through a press pump, to separate organic matter and water. The organic matter collected could be put through a composting process. This can be done on a concrete floor preventing the breeding of flies, as the larvae need soil to pupate before emerging as mature flies. Reducing the organic matter content of the wastewater increases the further use of this water for irrigation purposes. Such wastewater is usually collected in holding ponds where the organic matter is digested by anaerobic bacteria. By covering these ponds with plastic sheeting, it is possible to collect methane gas produced under these anaerobic conditions. As methane gas is one of the important greenhouse gasses, the release of this gas into the atmosphere is to be prevented. Methane gas could be used to produce on-farm electricity.

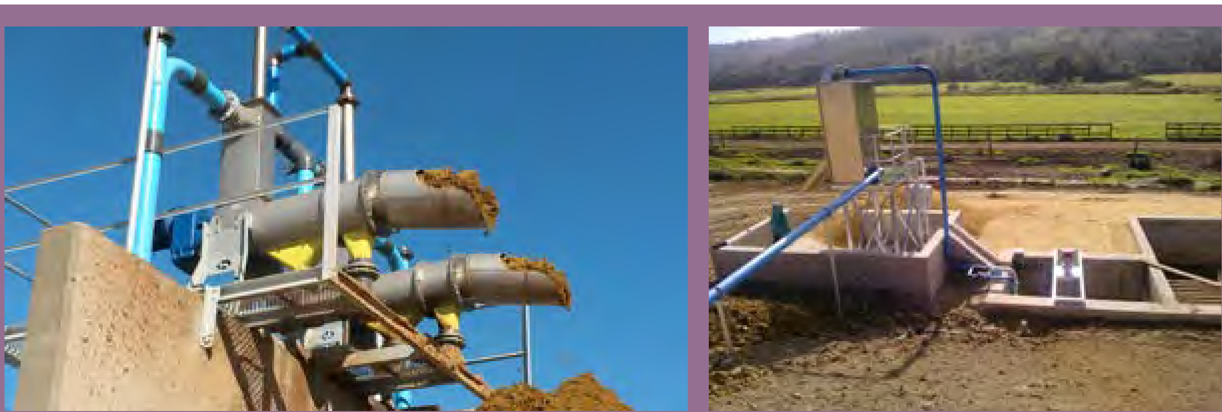


Figure 23.1. Different systems of separating solid material from waste water flushed from dairy housing systems being (a) using a high pressure press and (b) a run-over sieve

3. Cows on pasture

Cows on pasture-based dairy farms distribute manure and urine all over the farm with some critical areas becoming pollution source points as manure builds up around water troughs, shaded areas and on the pathways to and from the pasture camps. Runoff control from such areas is important as sudden rain downpours could result in manure ending up in waterways. In a pasture-based system, only about 20% of the herd's total manure and urine can be collected on concreted areas around the milking parlour. When cows are fed supplementary hay or silage on a feed pad, a larger amount of manure can be collected in a similar way as for an intensive housing system. The same principles apply for these areas as for intensive housing.

4. Holding ponds

The management of holdings ponds (Figure 23.2) is very important as this could create a further pollution source. Well-managed holding ponds could be sources of water for irrigation, as well as methane gas for electricity production.

Figure 23.2. A recently constructed holding pond for a dairy herd of 200 cows in milk

Figure 23.3. A poorly managed holding pond because of a heavy load of organic matter showing little anaerobic digestion

In closing

The value of manure is known by farmers and it has been used in the past as fertilisers. The same qualities, however, could cause serious pollution of waterways. For this reason, some runoff-control system should be in place on all dairies. The number of animals and the type of feeding system on the farm determine the manure management system. The value of manure is currently being investigated as a way to improve soil quality and for energy production.

CHAPTER 24

FEED TROUGHS – A BASIC REQUIREMENT ON DAIRY FARMS

Introduction

The feeding of dairy cows today has become highly scientific. The chemical composition of feeds and feeding requirements of cows are known and least cost feed formulation programmes are used to formulate diets. In spite of all this information, the feeding management of dairy cows is often sub-optimal, resulting in lower than expected milk yields, milk composition, reproduction, and farm profitability. Many farmers do not realise the importance of properly designed and well-built feed troughs and feed trough management. On some farms, feed troughs are in a poor state being broken, filled with several days old moldy and dirty feed. In some cases, feed troughs are unsafe to use because of broken feed barriers and wet, dirty and slippery manure walkways. Notwithstanding the poor conditions of some troughs, they are being used on a daily basis, continually exposing cows to risks and poor environmental conditions. It is of little help having correctly formulated and mixed diets, but the feed troughs to be used are in a poor condition negatively affecting voluntary feed intake. Cows require sufficient amounts of feed on a daily basis to ensure high milk yield levels, good body condition scores, and high fertility. Large amounts of feed can be lost when troughs are broken or not well maintained. The amount of wasted feed adds to the production cost of milk, thereby reducing the efficiency of production. The cost of constructing proper facilities should be weighed up against the cost of feed wasted from broken troughs.

Dairy cows require large feed troughs

Dairy cows consume large amounts of feed on a daily basis, e.g. 20 to 26 kg dry matter (DM) per day for Holstein cows while Jersey cows eat about 14 to 18 kg DM per day. Because cows are ruminants, their feed has to contain a large minimum amount of roughage, which makes the total daily feed mixture very bulky. Feed troughs must therefore be large enough to hold, at least, the amount of feed required for one day. Usually, to ensure that feed is fresh, daily feeding should be done at least twice a day. Cows could also be fed more times per day. This, however, will increase the daily labour and machine cost. Many producers milking from pastures also feed cows additional hay or silage, especially during the night. Although the amount should be less than when a full day's amount of feed is to be fed, the same principles apply with regards to the design of feed troughs.

The dimensions of feed troughs should be such to prevent cows being injured while eating. Cows have a relatively long feeding reach. They can easily reach feed up to 900 mm in front of them. However, to reduce the impact of cows on the feed trough barriers, feed troughs should be less than 850 mm wide. When feed is further away, a large amount of forward horizontal pressure is exerted on the feed barriers, which may lead to injuries or breaking barriers. When dairy cows have to eat from both sides, the feed trough should be at least 1.2 m wide to ensure sufficient headspace for cows.

When eating from one side, feed troughs should also not be too narrow, as this will restrict the cows' natural head movement while eating. Usually cows will collect their feed with the tongue pushing it into their mouths after which the head is lifted up for the chewing movement to begin. When finely ground feed is fed, some feed will fall from the cow's mouth while she is chewing. When a narrow feed trough is used, some feed will fall behind the back barrier of the trough; this is out of the cow's reach and is wasted. A narrow feed trough will also cause cows to stand back for the forward-upward movement of the head. Cows may also stand sideways to the trough for the forward-and-upward swinging movement of the head.

The volume of the feed trough is determined by its width, the height of the floor and the height of the partitions at the back and front of the trough. A higher partition at the front means a larger trough volume for more feed; however, when this partition is too high, cows cannot easily reach the feed at the floor of the trough increasing the pressure on the throat rail. A higher trough floor makes feeding from the floor easier, although it reduces the volume of the trough. The pressure on the throat rail is also increased when the feed trough floor is on the same level as the feet of cows. Cows seem to prefer a level about 10 cm above the manure passage way, i.e. the usual height of pasture.

A neck rail is usually put at the front of the feed trough. The neck rail should be about 650 – 700 mm above the throat rail. This is to prevent cows walking through the trough and to reduce their head movements while feeding. This is especially required when eating coarse, unground feed, such as long hay, and low quality roughages, like wheat straw. Cows will often shake such feed to separate the smaller parts like leaves from the stems, as the leaves taste better and have a higher feeding value than the stems. A very low neck rail will reduce the head movement of cows, though cows can be injured when they have to stretch to reach the feed. The forward pressure on the neck rail is also reduced when it is installed about 15 to 20 cm forward from the throat rail. For this reason, vertical partitions to separate feeding spaces of cows, should be installed angling forward. Vertical partitions should be far apart to allow sufficient feeding space per cow feeding either as groups or single cows. Holstein and Jersey cows require at least 700 to 750 and 550 to 650 mm feeding space per cow respectively. Vertical partitions should, therefore, be put up using these requirements as guidelines. The feeding space of cows is determined by their body width and not the space through which the head is put.

Feed trough dimensions

Feed trough dimensions for Holstein cows and heifers are presented in Table 24.1. For Jerseys, the dimensions should be about 50 to 100 mm less.

Table 24.1. Feed trough dimensions for Holstein cows and heifers

Feed barrier	Animals	Measurement (mm)
Throat rail	Calves Heifers Mature cows	400 500 600
Neck rail	Calves Heifers Mature cows	400 500 – 600 600 – 700
Feeding space	Calves Heifers Mature cows	500 600 650 – 750

The dimensions of a feed trough for cows weighing between 450 and 700 kg are presented in Figure 24.1. For Jersey cows dimensions should be slightly smaller.

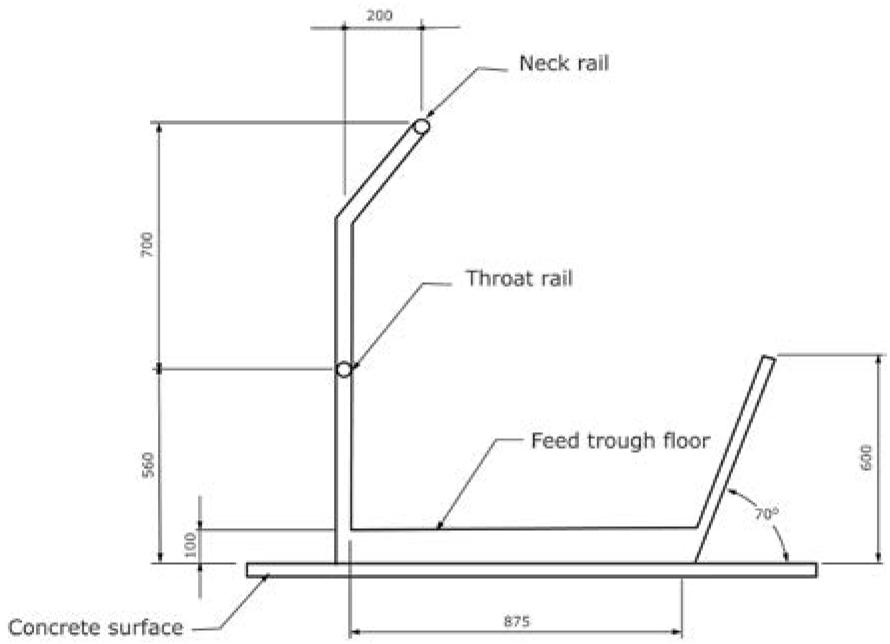


Figure 24.1. Dimensions of a feed trough for cows weighing between 450 and 700 kg

The design of feed troughs should include their being cleaned easily. Feed leftovers must be removed at least weekly, although daily cleaning is preferred. The reason for this is that cows produce a large amount of saliva while they are eating. Total mixed rations usually contain large quantities of concentrates such as starch. The saliva that cows produce will contaminate feed, causing the residue to become moldy or acidic. Fresh feed put on top of old feed residues will become contaminated, negatively affecting voluntary feed intake. When diets containing silage is being fed, it is especially important that feed troughs be cleaned on a daily basis, as the high moisture content of silage will result in feed becoming moldy quicker than feeds containing hay.

In closing

Correctly-designed and well-built feed troughs are a good investment for a dairy farm. At Elsenburg, dairy cows used relatively cheap wooden feed troughs with the correct measurements for more than 20 years. When planning new feed troughs, the size of cows, based on their live weights and their natural behaviour should be considered. The decision to build or not to build new troughs should be based on the amount of feed that is wasted on a daily basis. Silage bunkers could in some cases also be used as a feeding pad. Specifically designed feed barriers are required to prevent silage wastage. For this, cows need free access to the silage bunker as this reduces the feeding space to 250 mm per cow. To ensure an *ad libitum* daily feed intake, sufficient amounts of silage should be loosened from the silage face.

CHAPTER 25

HOUSING OF YOUNG CALVES AND HEIFERS

Introduction

Dairy cows have to calve down to start a new lactation. From this, heifers and bull calves are born. As the bull calves on most farms are sold at an early age, unless the farmer is a breeder, most housing for young calves is aimed at heifer calves. Heifer calves are the future dairy herd as they, at first calving, replaces cows that have been culled from the herd. As newly born heifers are literally babies, they should be well looked after otherwise a high mortality rate could occur. A management plan for heifers should include their housing facilities. Calves with similar characteristics and requirements should be grouped together into management groups. This is specifically important in modern-day dairies where animals are managed in groups rather than individually to reduce the cost of labour. The goal of housing facilities is to serve as tools in supporting the overall management plan.

Management groups

For the rearing of dairy heifers, three distinct management groups can be identified: the newborn group, the transition group, and the adolescent group. The newborn group consists of calves from birth to about 10 days after weaning. Weaning of young calves can take place at 6 weeks to 3 months of age. Usually, weaning is done when the intake of dry feed (a calf starter meal) reaches 0.75 to 1.0 kg per day. This would supply sufficient protein and energy to provide for the growing requirements of heifers. From a health aspect, general recommendations are that newborn calves receive individual attention. They are therefore kept in individual stalls to minimise the potential of disease spreading and that access to water and feed takes place without competition. To keep calves for at least 10 days after weaning in this group allows for close observation to reduce the risk of weaning.

The transition group includes heifer calves from weaning to about 5 to 6 months of age. Heifers are kept in small groups of about 5 to 10 calves each. They can be fed a growth meal providing at least 16% crude protein (CP) and 10 Mega Joules (MJ) Metabolizable Energy (ME) per kg dry matter. Fresh feed and clean drinking water must be provided daily. Stalls must be cleaned daily. Sick calves should be removed from the group and put into individual stalls for veterinary treatment.

Figure 25.1. Group housing of heifers inside an open building with wood shavings as bedding

The adolescent group of heifers includes all heifers from about 6 months of age to just before first calving at about 24 months of age. This group could be divided into a pre-breeding group, i.e. up to 12 to 13 months of age, a breeding group from 13 to 18 months of age, a pregnant heifer group, and steam-up heifer group. This group of heifers is usually put with the dry cows during which time they are introduced to the milking parlour environment.

Feeding of heifers over these age groups can vary from total mixed rations formulated for the age group's specific feeding requirements to heifers receiving mainly roughage supplemented with a suitable concentrate mixture. On pasture-based dairy farms, heifers from about 12 months of age are kept on pasture only. All heifers should receive a pre-calving steam-up concentrate to prevent milk fever after calving.

Environmental requirements for young calves

As young calves are sensitive to cold conditions, housing should provide protection against cold and wet conditions. Adequate ventilation is important while cold draughts must be prevented. Older heifer calves are less sensitive to poor environmental conditions, though they do need a clean, dry and comfortable resting area with sufficient ventilation with easy access to clean feed and water to ensure efficient growth year-round. For a start, pre-weaned calves should be kept separated from older calves to prevent calf-to-calf contact for spreading of diseases.

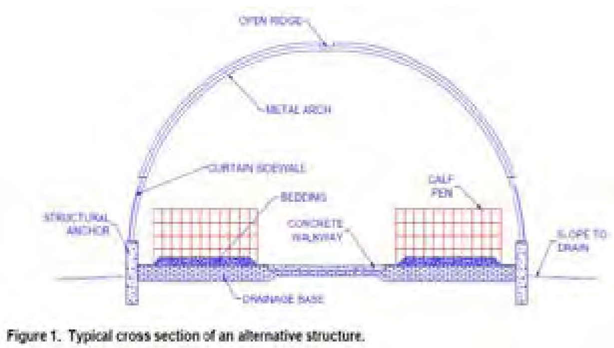
Air quality within a calf housing system must be similar to the air outside. With sufficient ventilation, the relative humidity should be about the same as outside and the concentration of manure gases, dust and pathogens would be low. Air exchange is the process of using outside, fresh air to replace the contaminated air within the housing structure. Poor ventilation can cause respiratory problems, reduced feed intake, and slower growth rates. Shelters for calves should be orientated to take advantage of prevailing winds in the summer and to allow sunlight penetration in the winter. Cold draughts in winter should be blocked. In the Western Cape, the open side of shelters should be orientated towards the north-east to allow sunshine in during the winter and to provide protection in winter against cold winds from the north-west and south. Shelters should not be wide to ensure that sunshine penetrates to the second row of individual stalls. During summer, removable fabric can be used to protect the front row of stalls against early morning to midday direct sunshine.

Young calves need unrestricted access to clean feed and water every day to achieve a sufficient growth rate. This should be provided individually with feed and water bins preferably located outside the pens to prevent contamination by urine and manure and to prevent liquid feed and water spilling on bedding material. Having feed bins outside the stalls make it easier to deliver feed and water and for removing containers to be cleaned and sanitised.

Calf hutches

The preferred way of housing young calves is with individual calf hutches (Figure 25.2) as this allows for all the requirements mentioned above. In this way young calves are separated from older calves and good ventilation is possible because hutches can be kept outside. Each hutch is provided with a separate feed and water bin on the outside, which allows for easy delivery of feed and water and removal of bins to be cleaned. Rows of calf hutches also makes for easy observation by caretakers as each calf can be observed within the hutch one at a time. On some dairy farms, hutches are covered with a roof to improve operator comfort. This increases the cost of construction, while the advantages of hutches may be compromised as ventilation for instance could be poorer, while the sterilising effect of the sun is removed

(a)



(b)

Figure 25.2. Housing for young calves (a) individual calf hutches on a concrete surface and (b) a cross section of a plastic covered arch-framed structure for housing young calves in hutches

Plastic covered arch-framed structures for young calves

Plastic or fabric covered arch-frame structures, also known as greenhouses, are a new trend of housing dairy calves. These structures may be put up on a temporary or semi-permanent basis by dairy farms using a designated calf manager for the replacement herd. The construction cost of arch-frame structures is lower than for more permanent structures. The design of the structures allows for natural ventilation as the sidewalls, usually consisting of sheets, can be rolled up or down as required by the present weather conditions. The transmission of light through the translucent covering material may result in enhanced calf health. However, if the structural advantages of a plastic covered arch-frame structure are disregarded, then they should still provide a clean, dry and comfortable resting area for calves with adequate ventilation. This is attainable through sufficient floor space and drainage from the pens, while pens should not be too close to the outside walls where rain could fall in the resting area. Structures should have vertical or nearly vertical walls to prevent runoff dropping into the shelter. Curtain sidewalls that drop down to open should be installed. In structures with curved sidewalls, individual pens should be moved further away from the sidewalls, specifically on the rain-wind side of the structure. For drainage, a thick stone base should be used, preferably with no fine material among the crushed stone.

Adequate ventilation is achieved through opening sidewalls, end-walls, and peak openings at the right times. This is especially important for structures with transparent or translucent covers as the radiation heat from the sun quickly heats up the air within the structure. Clear plastic coverings transmit about 87% of light while white plastic coverings transmit about 30%. Warmer air inside structures will increase the evaporation of free moisture, increases the production of methane from manure and increases the air moisture from calf respiration. It is important that the moisture evaporated during the day escapes, i.e. for the air to become drier, as at night moisture in the air will condense because of the air temperature falling reaching dew-point temperatures specifically along the outer perimeter of the structures resulting in droplets falling from the roof of the structure wetting the bedding.

Open front structures with individual pens

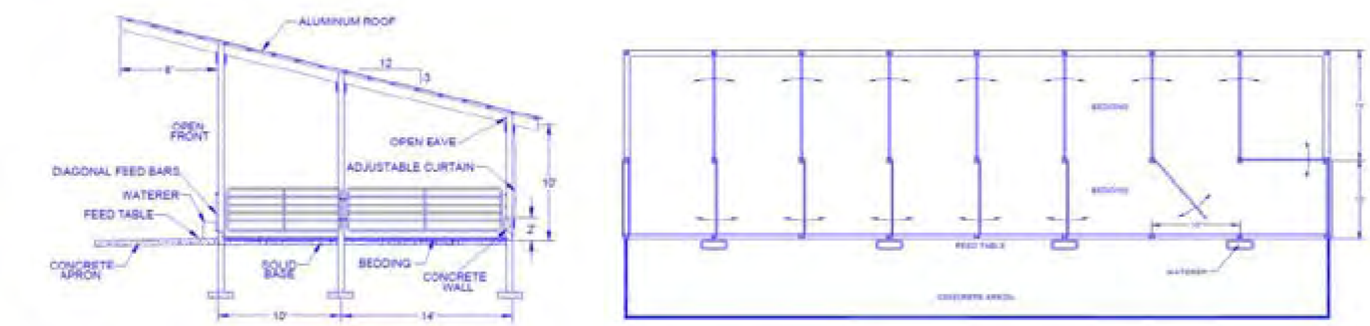
Open front structures with individual pens can be used with success for rearing young calves (Figure 25.3). These structures require less land space than individual calf hutches while also providing protection for the caretaker from rain and winter conditions. Each individual pen is 1.2 m wide and 2.1 to 2.4 m long. The backside of the structure can be closed during the winter to reduce draughts and to preserve heat produced by the calf. In hot weather, this opening is removed to improve air exchange by an inflow of cool air. Installing adjustable curtains along the sidewalls improves ventilation and reducing construction cost. The roof at the low end should be at least 1.8 m high with a 25% slope rising to about 3.0 m.

(a) (b)

Figure 25.3. Individual pens for young calves (a) within a closed building and (b) outside on a concrete surface underneath a roof

Housing for transition heifers

After weaning, heifers from 10 days after weaning to about 5 to 6 months of age, can be grouped according to similar size and age. Group housing should enable continued live weight growth and body development while being labour efficient. The housing requirements of transition heifers are basically the same as for young heifers, i.e. a clean, dry and comfortable resting area, adequate ventilation, and easy access to food and water. The super hutch consists of a number of smaller hutches 3 m wide x 7.5 m long underneath a roof with an open end. At the back, the roof should be at least 3 m high. In front of the bedding area, a 3 m wide concrete base feeding and manure passage is also included under the roof. To contain the bedding material, a concrete curb 0.6 m high is used at the back and front of the hutch. To ensure adequate ventilation, an adjustable curtain is used to close up the back end of the hutch. Curtains should be rolled up from the top of the concrete curb to protect heifers against draughts while enabling normal ventilation to take place. The recommended materials for roofing are aluminum or galvanised iron sheets. Insulation of the roofing material is not required as natural ventilation would prevent excessive radiant heat causing heat stress. Hutches are divided with swinging gates, which could also be used to close up the bedding area to enable cleaning the manure passage. Groups of heifers are moved to the next hutch. Once heifers have moved on, the hutch is cleaned by removing bedding material after which the floor is sanitised before the next group of heifers is moved in. Feed and water troughs are provided on the outside of the manure passage to facilitate feeding from a feeder wagon if required. Heifers can be fed a total mixed ration as pellets. Adequate feeding space should be provided, i.e. 350 mm per calf for 2 to 4 month old calves and 450 mm per calf for heifers 4 to 6 months of age. The feeding surface should be smooth to enable easy removal of feed residue and cleaning of the surface. For a smooth surface plastic liners or ceramic tiles can be used. The feeding floor should have a 2% slope away from the feed barrier to provide drainage away from the feed.



(a) (b)

Figure 25.4. Housing for transition heifers (a) cross section for an open shelter with bedded pack and (b) a floor plan of group housing using gates for division

Adolescent heifer housing

The adolescent group of heifers includes all heifers from 6 months of age to pre-calving. These heifers are grouped according to age or live weight and reproductive state. Live weight groups could be from 180 - 270 kg, 271 - 360 kg, 361 - 450 kg and 451 - 550 kg. Housing options for heifers that are not on pasture include super hutches or an open camp system providing the same facilities as for mature cows, i.e. protection against heat and cold, large area for heifers to move around in, feed troughs with adequate feeding space and a dry, clean and comfortable bedding area. Heifers in these age groups have to get used to increased competition for feed and water.

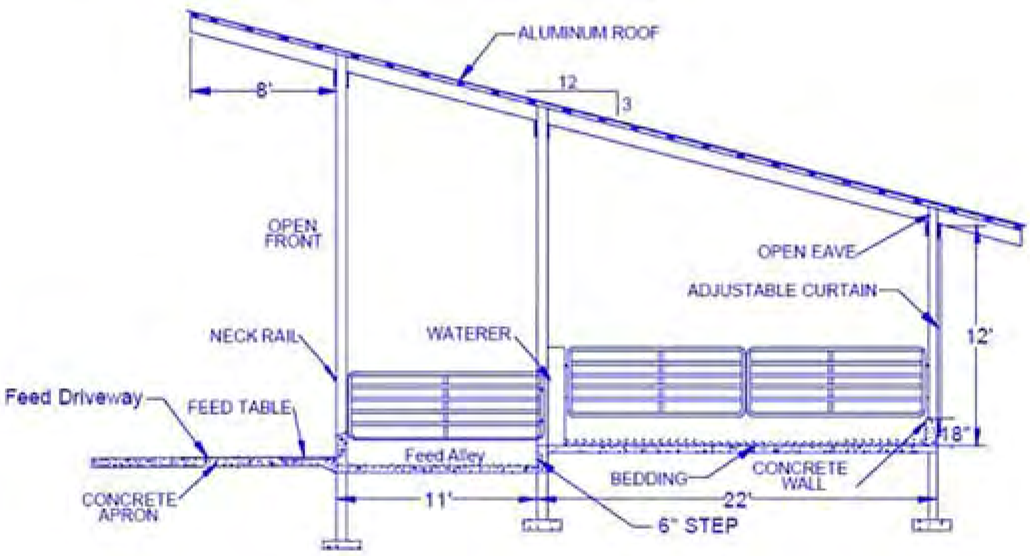


Figure 25.5. Cross section of a gated bedded-pack group housing for adolescent heifers

Instead of using a bedded-pack, free stalls could be used for housing adolescent dairy heifers. Heifers experiencing such a housing facility at an early age should be well adapted in a free stall housing system after first calving. Free stall housing require less bedding than a bedded-pack while cleaning out a manure passageway is also easier. Free stall shelters, however, require more total area per heifer increasing the construction cost of heifer housing. For a bedded-pack 5.5 m² are required per heifer while for a free stall structure at least 7.0 m² are required. Free stalls should preferably be used by heifers older than 10 - 12 months of age.

In closing

Dairy heifers can be housed in different facilities. This may vary from an extensive system with calves kept outside in hutches or with hutches inside an intensive housing system with an open end towards the north or north-east depending on the prevailing wind during winter. Heifer housing should be designed for labour efficiency. Older calves could be housed in groups according to age or size to reduce competition. Sick calves should be removed from group housing to a hospital pen to prevent transferring of diseases. The first two months of a calf's life is critical to their growth performance, as during this time they are weaned and learning to eat dry feed. The housing of calves during this period is important, as they are sensitive to specific cold conditions while a dirty environment will expose them to diseases.

SECTION 3

REPRODUCTION MANAGEMENT IN DAIRY HERDS

CHAPTER 26

THE REPRODUCTIVE SYSTEM OF DAIRY COWS: ANATOMY AND PHYSIOLOGY

Introduction

The reproductive ability of dairy cows affects the overall profitability of a dairy herd. Cows must calve down to initiate a new lactation period and the more regularly they calve down, the more profitable the dairy herd becomes. Cows also need to live long to reduce the cost of rearing a large number of replacement heifers. Cows should calve down at least every 12 to 13 months. To maintain a high standard of reproduction management, farmers require in-depth knowledge of the basic principles involved with the reproductive ability of dairy cows, specifically with regards to the anatomy and normal functions of the reproductive system of a dairy cow. The anatomy and the physiology of the reproductive system of dairy cows will be discussed briefly in this chapter.

Anatomy of the reproductive system

In Figure 26.1, a schematic description of the side view of the anatomy of the reproductive system of a dairy cow and a radiograph of the top view of the cervix, uterine body and uterine horns is shown (O'Connor & Peters, 2003).

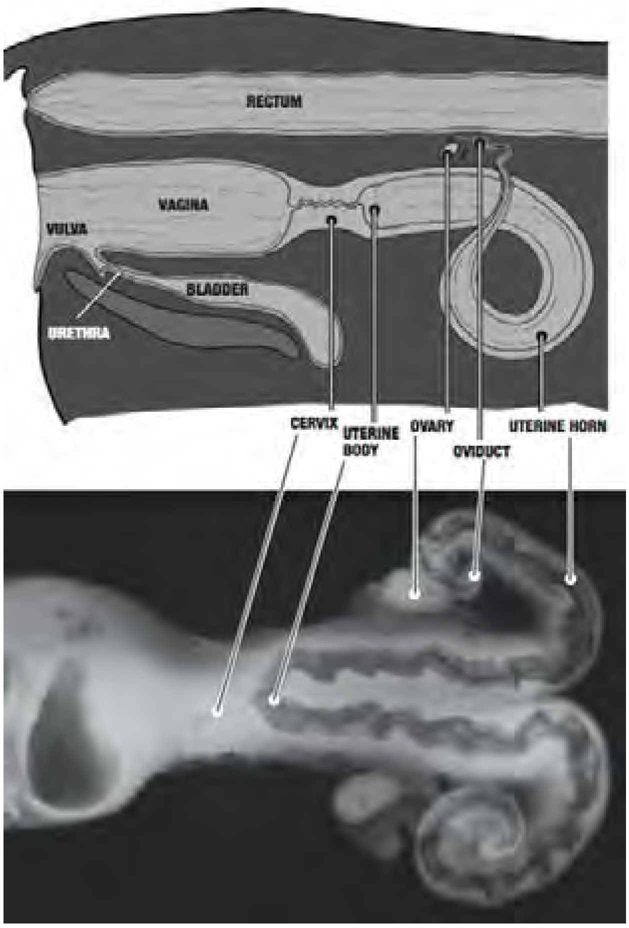


Figure 26.1. A schematic description of the anatomy of the reproductive system of a dairy cow

The reproductive system of dairy cows consist of two ovaries, two Fallopian tubes, a uterus consisting of two uterus horns, two uterus bodies, a cervix, a vagina, and a vulva. The ovaries and Fallopian tubes are kept in position in the abdominal cavity by ligaments.

Ovaries

The ovaries, although differing in size depending largely on the age of the cow and the degree of activity taking place in the ovary, are usually 32 to 42 mm long, 19 to 32 mm thick, and 13 to 19 mm wide. The follicles develop in the ovaries. The wall of the developing follicle secretes the estrogen hormone responsible for the typical estrus signs cows show when they are in heat. When the follicle is mature, it bursts open, releasing the egg (ovum) into the Fallopian tube. This process is referred to as ovulation. After ovulation, the corpus luteum develops where the follicle was. The corpus luteum produces progesterone.

Fallopian tubes

The Fallopian tubes, or oviducts, are two thin tortuous tubes, 20 to 25 cm in length, stretching from the end of the uterus horn to the ovaries, where they end in the funnel-like infundibulum. The function of this structure is to fold around the follicle at ovulation to collect the released ovum into the Fallopian tube through which it moves down to the uterus horn. Cysts or any abnormalities in the Fallopian tubes will prevent the downward movement of the ovum to the uterus.

Uterus

The uterus consists of two uterus horns (cornua) stretching from the Fallopian tubes and the uterus body. The uterus ends in the cervix. The uterus body of a non-pregnant cow is about 9 to 12 cm wide and 4 to 5 cm long, after which it divides into the two horns. At this point, the uterus horns are about 3 to 4 cm wide and 20 to 35 cm in length. The uterus wall consists of three types of tissue, i.e. a thin serous membrane (peritoneum) on the outside, muscle layers in the middle, and a soft mucus membrane lining the inside. The inside layer of cells, known as the endometrium, contains a number of small glands that secrete a fluid, called uterine milk, that helps nourish the developing embryo during pregnancy and also a number of elevations, or cotyledons, to which the placenta attaches during pregnancy. There are about 80 to 120 cotyledons in the uterus of a cow. The cotyledons in a non-pregnant cow are about 15 to 17 mm long, 6 to 9 mm wide, and 2 to 4 mm high.

Cervix

The cervix (or neck) is a thick-walled structure situated between the vagina and the uterus body. In some instances, it is regarded as the posterior portion of the uterus. On rectal palpation, the cervix can easily be distinguished from the other structures, because its inside wall consists of dense and firm muscular tissue, forming folds or rings overlapping each other. It usually feels like a thick firm cord about 5 to 10 cm long and 3 to 4 cm in diameter. This ensures that the cervix is tightly closed during pregnancy. The posterior opening (*os uteri externa*) of the cervix protrudes out into the vagina. It is normally tightly closed, except during estrus, when it is open to allow the entry of the sperm cells following natural service or access for the pipette during artificial insemination.

Vagina

This forms the posterior portion of the reproductive organs of the dairy cow. It is regarded as a passage for both the urinary and genital systems as the urine from the bladder is excreted through its posterior part, and, during mating, the semen of the bull is deposited in the anterior half near the opening of the cervix for access into the uterus. The length of the vagina is approximately 22 cm. At the back the vagina opens through the vulva which lies below the anus. Signs of the cow being in heat are usually observed as the appearance of the vulva changes, often becoming reddish and swollen. On the floor of the vagina is the opening of the urethra, leading to the bladder. During artificial insemination, this opening should be avoided by pointing the pipette upwards when entering the vagina. Because of the protruding opening of the cervix into the vagina, a blind pocket is formed. It is for this reason that, during artificial insemination, the cervix has to be located and held through the rectum wall to guide the pipette towards the protruding opening of the cervix.

Reproductive hormones affecting the estrus cycle

The estrus cycle is controlled by a number of reproduction hormones which include the gonadotrophin-releasing hormones from the hypothalamus. This stimulates the secretion of the follicle stimulating hormone (FSH) and luteinizing hormone (LH) from the anterior pituatary. In Figure 26.2 the hormones controlling the estrus cycle is shown schematically.

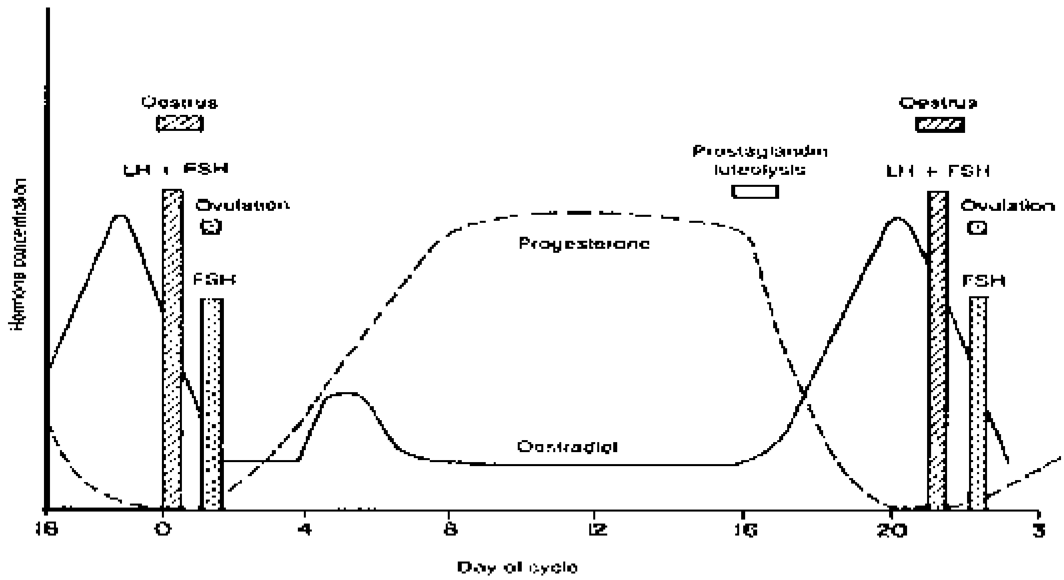


Figure 26.2. A schematic representation of the relative changes in plasm hormone concentrations during the estrus cycle of dairy cows (Pellisier & Cupps, 1980)

FSH stimulates the growth of the follicle inside the ovarium. Under the influence of FSH, one or two of the follicles grows bigger, jutting out above the surface of the ovarium. The wall of the enlarged follicle starts secreting the hormone estrogen. Estrogen is responsible for the signs usually associated with estrus, which include cows standing still to be serviced by a bull. This is commonly referred to as standing heat.

Ovulation takes place about 25 to 30 hours after the start of estrus. The release of the ovum or ovulation takes place under the influence of LH, which further stimulates the growth of the luteal tissue, creating the corpus luteum to fill the space of the ovulated follicle. The corpus luteum starts producing the hormone progesterone about 24 to 48 hours after ovulation. Progesterone suppresses the production and secretion of FSH and LH and further follicular growth. Under the influence of progesterone, the uterus is prepared to receive and maintain the fertilised ovum if fertilisation had taken place. When no fertilisation had taken place, the *corpus luteum* is active for a further 17 to 19 days after which the uterus produces prostaglandin, thereby destroying the corpus luteum. This stops the inhibiting effect of progesterone on the production and secretion of FSH and LH after which the cycle starts again. The estrus cycle of dairy cows varies between 18 to 25 days, with an average of 21 days.

Estrus and ovulation

At estrus, the vulva is slightly swollen with a reddish appearance. At, or just before estrus, strings of thin watery mucus may flow from the vulva. Sometimes the mucus may contain spots of blood. Between estrus events, the mucus becomes thick and sticky, forming a plug in the cervix protecting the uterus against environmental infections from outside. The mucus is secreted by the walls of the cervix and vagina. Estrus last about 6 to 30 hours with an average of 18 hours. It may last 19 hours in mature cows and 16 hours in heifers. Ovulation takes place 25 to 30 hours after the start of estrus which is about 10 to 12 hours after estrus has ended.

The movement of sperm cells in the female reproductive system

Sperm cells are unique in the sense that they have to move through a number of fluids, e.g. testicular fluid, seminal plasma, vaginal fluid, cervical fluid, to eventually fertilise the ovum. Each of these fluids has different physiological and biochemical characteristics. Following natural service, most of the sperm cells move through the cervix within 2 to 10 minutes. A large number of the sperm cells get trapped in the folds of the cervix. In the Fallopian tubes, sperm cells move upwards, while the ovum moves downwards. This is possible through a range of integrated peristaltic movements

It takes about eight hours for the sperm cells to reach the ovum for fertilisation to take place. The survival of the ovum and sperm cells depends on a number of factors which includes the hormonal status of the cow or heifer. Because of this, it is difficult to determine the actual time of survival of sperm cells and the ovum. It has been found that sperm cells could survive in the female genital tract for 30 to 48 hours, while the ovum may survive between 12 to 24 hours. However, this fertile period progressively decreases with time.

Pregnancy and calving down

Pregnancy starts with the fertilisation of the ovum by a sperm cell and ends at calving. It is a continuing process of cell division and cell growth. Pregnancy can be divided into three stages, i.e. stage of the ovum, the stage of the embryo, and the stage of the foetus.

The stage of the ovum stretches from fertilisation to day 12. During the first four days, when cell division takes place, the ovum moves down to the uterus where it drifts around freely for a further 8 to 9 days. On day 8, the cell wall of the fertilised ovum bursts open and further cell division takes place.

The stage of the embryo stretches from about day 13 to day 45. During this time all the organs are formed within the embryo. From day 30 to day 35, the placenta starts to attach itself to the cotyledons on the walls of the uterus. Before this period, the embryo gets its nutrition from the yolk bag. After the placenta has attached itself to the cotyledons, all the nutrition for the embryo comes from the mother. The exchange between the foetus and the mother takes place through diffusion. The blood of the foetus does not come into contact with the blood of the mother. The attachment of the placenta to the cotyledons takes place through the placental caruncles with fingerlike bulges fitting into the sponge-like cotyledons of the uterus. At calving, the caruncles release the attachments of the placenta, thereby ensuring that the placenta is not ruptured.

The stage of the foetus stretches from day 46 to calving. During this stage differential growth takes place, forming the different body components, like the bones, hair growth, etc. During pregnancy the uterus and its contents could increase in weight by up to 70 kg, depending on the breed, age and size of the dam. The foetus comprises about 60% of this weight. About half of the weight gain takes place during the last two months of the pregnancy period.

An important part of the calving down process is the complete release and expulsion of the placenta. Under normal conditions, this takes place about one to eight hours after calving. When this does not happen after calving, veterinary assistance should be obtained. About 24 to 36 hours after calving, the cervix closes to such an extent that it becomes difficult to put something through it. The actual physical removal of the placenta from the uterus by hand should be done with great care, as leaving any material in the uterus could cause serious infections. The normal pregnancy period in dairy cows vary between 278 and 284 days. Usually pregnancy is one day longer with bull calves, while for twins, pregnancy may be 5 to 10 days less.

Recovery of the uterus

After calving it is important that reconception takes place as soon as possible. However, before this can happen, the uterus should fully recover after calving. Firstly, the cotyledons must become smaller after which the endometrium recovers. This recovery period or uterus involution may take 26 to 52 days. This interval is also referred to as the voluntary waiting period. Cows are usually not inseminated during this period because the conception rate is poor, which may also result in a subsequently short lactation period. In Figure 26.3, the recovery period of the uterus and the start of the estrus cycle after calving are shown schematically.

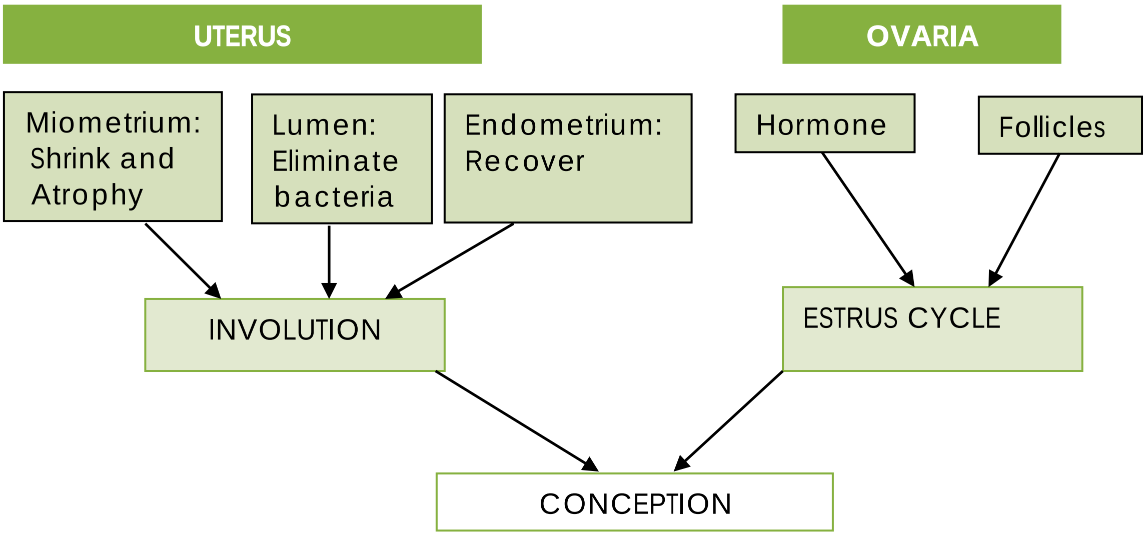


Figure 26.3. A schematic description of the post partum involution of the uterus and the recovery of the estrus cycle

The ovaries of cows start functioning relatively soon after calving. First ovulation often occurs as early as 13 to 20 days after calving; although, in most cases, no outward estrus signs are shown. For this reason, these estrus cycles are called silent heats. Because the uterus has not recovered fully at this stage, cows usually do not conceive from such early inseminations. Most cows are only ready to be inseminated at 32 days after calving. However, in practice cows are not inseminated this early. Cows that have had one visible heat cycle before insemination are more prone to conceive. Acceptable conception rates are achieved when first insemination is done at 50 to 60 days after calving. Reproductive targets should include a large proportion of cows conceiving by 90 days after calving.

In closing

The reproductive ability of dairy cows affects the profitability of a dairy herd. Cows must calve down to initiate a new lactation period and the more regularly they calve down, the more profitable the dairy becomes. Knowing the anatomy and physiology of the reproductive system of dairy cows helps towards improving the standard of reproductive management. After calving, the uterus of cows should recover fully and normal heat cycles should start before first insemination. Cows should be checked after calving to determine whether the placenta has been removed fully and whether no infection has taken place.

CHAPTER 27

MANAGING DAIRY COWS POST-PARTUM TO FIRST SERVICE

Introduction

The interval from just before calving up to conception after calving has a major effect on the profitability of milk production. Cows have to calve down to start a new lactation period, and the interval from calving to conception and the success rate of first insemination affects the calving interval of cows. Cows have to calve down regularly, at least every 12 to 14 months, and they should have a long lifetime. The lifetime efficiency of cows increases when the calving interval is short and with cows having more early lactation periods in their lifetimes. There are a number of management aspects during this period that could affect efficient reproduction management and profitability. This specific period in a cow's lifetime is known as the peripartum period.

Calving down management
At calving the following aspects should receive attention:

1. Hygiene

At calving, hygiene is of extreme importance. Cows should have access to a clean calving down area, which could be a small pasture-based camp with a well-drained, level surface. The camp should also be protected against adverse climatic conditions, like cold winds and hot summer temperatures. Such a calving down area should preferably be separate from the rest of the herd. It should have sufficient space to prevent the building up of pathogenic bacteria or alternatively camps should be rotated. For zero-grazing systems, cows should have access to calving pens. A few days before their expected calving dates, cows are brought to the calving down area where they receive feed and clean drinking water. Calving pens should be washed and cleaned after each calving event. This is important especially when the calving down area is not exposed to direct sunlight, which sterilises soil and concrete surfaces. Calving pens should be about 6 m^2 in size. When cows are helped during the calving down process, it is important that hygienic principles are applied. Hands should be washed beforehand, using clean, warm water and soap. In all situations, contamination of the calf and reproductive organs by manure should be prevented.

2. Calving down difficulties (Dystocia)

Only managers with the required skills should provide help when calving down problems are encountered. Such a person should know when, for the sake of the cow and calf, to call in a veterinarian.

Factors affecting calving ease:

- Size of the calf: It is not only the birth weight of calves that affects the ease of calving, but also the conformation (shape) of the calf. Fewer calving problems are seen with thin, long calves in comparison to wide, short, and bulky calves. Calving ease should be considered when bulls are selected for Holstein heifers. Birth weight has a medium heritability and bulls that were heavy at birth should not be used on heifers.

- The size of the pelvic opening: The single most major cause of dystocia at calving is the disproportion between the size of the calf at birth (as indicated by birth weight) and the cow's birth canal (pelvic opening). Differences in pelvic area are generally due to pelvic height rather than width measurements. Pelvic size, independent of cow live weight, affects calving difficulty. Larger heifers at first calving tend to have a larger pelvic opening although they may also have heavier calves. Both heifer live weight and heifer age has a positive relationship with pelvic area, although live weight may not be a good indicator. External dimensions such as width of hooks and rump length are good indicators of pelvic area and the possibility of calving difficulty. For this reason pelvic measurements can be a useful management tool to eliminate heifers for calving difficulty.

- The feeding of heifers during pregnancy: The correct feeding of heifers before calving down is under the control of the manager, which could ensure ease of calving. Heifers that are fat and not fit usually have a difficult calving down process. Calving down difficulties in heifers could be reduced by feeding a diet that ensures good skeletal development from birth to first calving.

- Presentation of the calf: This aspect is usually outside human control, but could be fixed by a skilled manager. At calving, calves usually present themselves in two ways, i.e. in the normal position with the front feet and head showing or with the back feet showing. To pull on a calf that is not in one of these positions could be dangerous and could lead to the death of, or major injury to, the calf and cow.

3. Disinfecting the uterus

The most common problem in reproduction management is the lack of proper disinfection of the uterus after calving. This is usually a problem following a difficult calving down process or an abortion, specifically after a pregnancy of about six months. Both these problems usually result in an infection inside the uterus, metritis, which results in an increase in the interval from calving to conception.

Metritis can be reduced by putting in a set pill into the uterus immediately after the removal of the placenta after calving. For cows that have had a normal calving down process under hygienic conditions, inserting a set pill is usually not required. However, when the calving down process was difficult or the calving down area was dirty, a set pill would be required. Set pills that are effervescent (foam) are preferred as this ensures the distribution of the antibiotic throughout the enlarged uterus. It is also very important that this action is done under hygienic conditions and that the set pill should be inserted into the uterus through the cervix.

The treatment of cows with systemic antibiotics is sometimes required, especially for cows that have had a difficult calving down process or when a calf that had died inside the uterus had started to decompose. Long-acting tetracyclines are the most suitable antibiotic treatment because cows only need one injection. The correct dosage should be applied and is usually 10 mℓ per 100 kg live weight. A lower dosage is not recommended as not enough therapeutics is provided through the blood. It is also important that managers are aware of the withdrawal period of the milk of cows under treatment, because this differs between treatments.

4. Retained placenta

A retained placenta occurs when the expulsion of the placenta is not complete or is still attached 12 hours after calving. In some herds, it is a common incidence which affects the fertility of dairy cows and reproduction management. This adds to the stress that cows experience after calving. This could also lead to injuries to the uterus which could affect their reproductive ability.

This problem is nutrition related and is usually caused by an energy deficient diet resulting in cows being in poor condition at calving down. Furthermore, deficiencies in Vitamins A and E, as well as imbalances in the calcium to phosphorus ratio, may also cause this problem. Usually an improvement is observed by adding selenium and Vitamins A and E into the diet, even though the mineral levels in the blood may seem normal. Stress conditions, like bad weather, transporting cows close to calving down, and/or drastic feed changes during the dry period, could also lead to such problems.

5. Prolapse of the uterus

This condition occurs sporadically and usually happens when cows keep on pushing after the calving process has been completed. The prolapse of the uterus is when the uterus hangs outside the body. It is usually associated with a ruptured cervix. Treatment includes putting the uterus back into the body cavity after it has been washed clean and disinfected. The vagina could be closed up by one or two stitches. This condition sometime occurs when cows are in a very good or poor condition at calving.

In closing

The interval from just before calving up to conception after calving has a major effect on the profitability of milk production. Cows have to calve down to start a new lactation period and the interval from calving to conception and success rate of first insemination affects the calving interval of cows. A number of management aspects during this period may affect efficient reproduction management and profitability. These include getting cows to calve down under hygienic conditions, helping cows early and correctly when they experience dystocia problems, helping to disinfect the uterus after calving to prevent metritis, correctly removing the placenta, and correctly treating a prolapsed uterus when it occurs. Cows should be treated with care at or around calving as during this period they are very susceptible to injury and infection which may affect their lifetime production.

CHAPTER 28

HEAT DETECTION IN DAIRY COWS

Introduction

The artificial insemination (AI) of dairy cows has become a standard practice in most dairy herds. Through this process, dairy farmers have access to high genetic merit bulls from different countries at a fraction of the cost of keeping a bull. Through AI, a larger range of bulls can also be used than is usually available for natural service. The genetic merit of dairy bulls for AI is estimated through standard progeny testing programmes, using the production performance and conformation traits of their daughters. Initially, in many countries the demand for AI was to overcome the spreading of reproductive diseases in dairy cows being transmitted by natural service. However, after the Second World War, there was also a strong demand for a faster improvement in the genetic merit of dairy cows towards increasing the national milk yield in many countries. In Britain, the first AI centre was established in 1942, while in South Africa the spread of venereal disease in dairy cows in the early 1950's also resulted in the development and growth of the local AI industry. However, the reproductive success of AI is dependent on the ability of people, instead of the bull, to detect cows in heat. This is essential as through AI a smaller number of sperm cells are put into the uterus than by natural service. Cows show specific signs indicating estrus which can be used in the breeding programme as an indication that they will be receptive to impregnation by AI.

The interval from calving to first service

After calving, the uterus shrinks and normal heat cycles return in cows. The voluntary waiting period refers to the interval from calving to the first possible insemination. During this time the uterus recovers and cows are not usually inseminated then. Although the interval from calving to the return of normal heat cycles may differ among cows, usually more than 90% of cows show heat by about 50 days postpartum. The fertility of dairy cows is defined in three ways, i.e. an early return to a normal estrus cycle after calving, becoming pregnant from a small number of services, and staying pregnant to the next calving date. Therefore, to achieve an ideal calving interval of about 365 to 395 days, conception should be early, i.e. by at least 85 to 115 days after calving. The interval (number of days) from calving to first service (CFS) and first service success rate are important indicators towards ensuring a short calving interval. However, according to a survey conducted among dairy farmers, it was found that the average CFS interval is often more than 90 days. Fewer than 50% of CFS intervals are less than 80 days. An Australian survey showed that top farmers manage to get 73% of CFS intervals of less than 80 days. Heat detection is poor when less than 60% of CFS intervals are within 80 days after calving. Furthermore, a short calving interval is also highly dependant on the success rate of first service. The success rate of first AI is also often poor, i.e. less than 40%. When first AI is done at 60 days after calving, there is a possibility of a second heat before 85 days in milk to get cows pregnant. However, not being successful with the first service and not detecting the next estrus cycle would extend the calving interval beyond 365 days.

Heat detection signs

The estrus cycle of dairy cows lasts on average for 21 days. During this period, for about five days, cows seek out other cows that are also coming in or going out of the heat cycle. Only on one of these five days will the cow that is in heat, stand still for other cows to mount her as would have been the case for the bull for natural service. This is described as standing heat and is used as the most important heat detection sign. Observation studies have shown that the cow that is in heat may be mounted by other cows more than 50 times during the day of standing heat. However, heat detection is hampered by the fact that about 25% of cows are mounted only a few times, i.e. on average about 1½ mounts per hour. The action of mounting lasts only a few (4 - 6) seconds and most mounts occur during the evening and night, i.e. from 20:00 to 04:00. Therefore, cows are on heat for about a third of the day and usually spend a total of 3 - 5 min actually standing to be mounted. It is for these reasons that heat detection should be done several times per day as the interaction among cows is actually very small and is often missed.

There are a number of signs other than standing heat that can be used as heat detection indicators. These include the following:

Early signs of heat (before standing heat):

- a thin watery mucus string may flow from the vulva, especially when laying down,
- cows may bellow and urinate often,
- cows show an increased interest in the activities of other cows,
- cows have a higher activity, such as walking around a lot, and
- standing when other cows are laying down.

Additional signs of standing heat:

- the cow that is in heat will show an interest in other cows, smelling the genital area,
- will try to mount other cows,
- the cow will stand still allowing other cows to mount her,
- the cow will rest her head on the rump of other cows,
- a strong mucus flow from the vulva may be observed,
- smudges of mucus may be observed on the tail and pin bones,
- all the cows in heat often form a small group,
- bull calves show an interest in the cow in heat and will try to mount her, and
- a reduction in feed intake and milk yield may be observed.

Post heat signs:

- wet and ruffled hair at the shoulders, from other cows resting their heads here,
- the hair at the tail head is ruffled and chafe marks may be visible,
- mud from the hoofs of cows mounting may be seen on the sides of the cow in heat,
- cows having been active during the night may be tired, lying down in the morning to rest,
- a mucus discharge may be observed when a pipette is inserted into the vagina, and
- a bloody mucus discharge on the tail and pin bones is usually an indication that the cow was on heat the previous 2-3 days.

When to do heat detection

Heat detection must be done daily. A specific person must be responsible and accountable for this important task. Looking for cows in heat should be done after milking and after feeding, i.e. when cows are resting. After feeding, cows usually stand around or lie down to ruminate. Cows that are in heat or are coming in heat will often be in a separate group being active away from the rest of the herd. This may be used as the first sign of heat detection. Although the average time of standing heat is 14 hours, some cows stand to be mounted for less than eight hours. Some cows allow being mounted for a longer period, even up to about 24 hours. When heat detection is only once a day, and the actual time of heat spotting is 20 min, only about 52% of heats may be detected. When heat observation is for 10 min at a time, only about 26% of heats are detected. Increasing the number of detection events to four per day, increases the number of heats detected to about 50% when heat spotting is for 10 min, while it is 82% when the actual time of heat spotting is 20 min. With three to four intense heat observations for 20 min each during early morning, midday, and late evening, a 90% detection rate can be achieved. Depending on the feeding programme, heat detection could take place at 08:00, 14:00 and 20:00 each day. Heat observation should take place at least two to three hours after feeding. During hot weather, heat detection could be done earlier in the day or later in the evening. During cool weather, the middle of the day is generally the best time to do heat detection.

Cows tend to show heat more actively when they are on pasture or in soil-based open camps. Concrete surfaces are not conducive to heat activity especially when the surface is uneven, wet and slippery. Naturally, the heat activity of cows is low during feeding and milking. Cows in heat and other cows that are coming in heat or going out of heat, play an important role in a heat detection programme. As the number of cows in heat increases, the number of mounts per heat period also increases, i.e. from 12 to 53 mounts per heat period when one to three cows are in heat at the same time. Cows that are pregnant or in the early estrus cycle do not make good heat detectors. It is important that during these intense heat observation periods, heat spotters should only look for cows on heat and that it should not be part of another task. Research has shown that about 30% of cows are inseminated when they are not fully on heat, either being too early or too late. Usually, in these cases, other signs rather than standing heat were used as a heat detection tool. Standing heat is the only true sign that a cow is in heat.

When to inseminate

Although a number of signs can be used as heat detection indicators, the decision to inseminate cows should be based on standing heat and not secondary signs as these could indicate that cows are coming into heat or going out of heat. The period that cows are in heat usually last about 18 hours, while it may vary from 4 to 30 hours among cows. About 20% of cows have short heat periods of less than 6 hours. Ovulation takes place about 12 hours after the end of the heat period. After ovulation, the ovum survives for about 6 hours, while sperm cells have a lifetime of about 28 hours in the uterus. This is why it is important that the start of the heat period is detected correctly as this determines when insemination should be done.

It seems that conception rate is higher when insemination is done at the end of the estrus cycle (Figure 28.1). At 18 hours before the end of the estrus cycle, the heat activity of cows increases. When insemination takes place this early, conception rate is about 60%, increasing to 80% at 6 hours before the end of estrus. At the end of estrus, conception rate is still high at about 75%.

It is for this reason that heat detection should be done more regularly during the day, at least 3 - 4 times per day to establish the start of the heat period accurately. When cows typically show standing heat, the starting point of the heat period is regarded as halfway between the current and previous heat detection observation. Heat detection once-a-day could mean that the start of the heat period could be judged incorrectly by 12 hours.

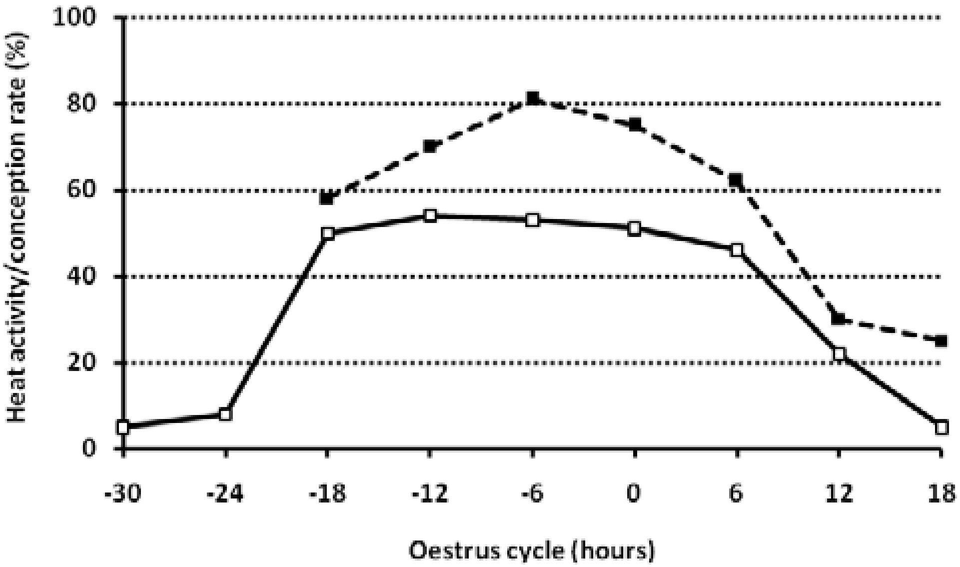


Figure 28.1. The effect of estrus cycle on the heat activity (□) and conception rate (■) in dairy cows (Ducker, 1985b)

Evaluation of heat detection

The efficiency of heat detection should be estimated on an ongoing basis as this gives an early warning of reproductive problems in a dairy herd. It is not very useful to only evaluate indicators like calving interval or the number of AI's per conception as this only refers to cows that have calved down again. Complete and accurate records of all inseminations or services by a bull and veterinary pregnancy check results are required to estimate heat detection efficiency. There is, however, a difference between the accuracy and the efficiency of heat detection. Inaccurate heat detection refers to the insemination of cows that are not in true estrus. This usually results in a poor conception rate as indicated by a high number of services per conception. Inaccurate heat detection is usually indicated when more than 10% of heat intervals are shorter than 3 to 17 days or when more than 15% of heat intervals are longer than 25 to 35 days. Inefficient heat detection on the, other hand, refers to only a few heats being detected (meaning many heats are missed). This is indicated by the number of days between services. Heat detection efficiency is estimated by dividing the normal heat cycle length (21 days) by the average number of days between services. This means that when the average number of days between services is 42, only 50% of heats is being detected, i.e. (21/42) x 100%. By reducing the number of days between heats, heat detection efficiency increases. For cows that have been confirmed pregnant, the heat detection efficiency could be estimated based on the number of days open minus the number of days (interval) to first service divided by the number services per conception minus one service. Similarly, heat detection efficiency could be estimated by subtracting the number of days of the voluntary waiting period from the days open and dividing that by the number of services per conception minus one service.

In closing

Profitable milk production and the improvement of the genetic merit of a dairy herd is dependent on the ability of cows to calve down regularly. The genetic improvement of a herd is dependent on the genetic merit of the heifers born into the herd. They are raised to replace cows that are being culled from the herd. The reproductive ability of dairy cows can be improved by the application of efficient reproduction management which involves correct heat detection methods. While standing heat gives the best indication that cows are on heat, regular heat observations are required to establish the correct time of insemination. Heat detection efficiency should be estimated on a regular basis, at least following every pregnancy check by a veterinarian.

CHAPTER 29

THE ARTIFICIAL INSEMINATION OF DAIRY COWS

Introduction

The artificial insemination (AI) of dairy cows has become a standard practice in most dairy herds. This primarily involves depositing live semen after being thawed from a deep-frozen (at -196°C) state and having been stored in a semen tank, at the correct time and place, inside the genital tract of dairy cows. The success of this operation depends on the proper storage of semen, i.e. maintaining the liquid nitrogen inside the tank at the correct level and applying the correct thawing process for semen after removal from the semen tank, and the insemination or depositing of semen in the uterus body of the cow. Efficient heat detection is critical to determine the correct time for insemination. To get as many as possible live semen at the correct place, the insemination technique or skills of the inseminator is of primary importance. This not only affects the reproductive performance of dairy cows, but also their productive life or lifetime performance. This also affects the replacement rate of dairy cows which in turn affects the number of heifers to be reared.

Training in artificial insemination

In South Africa, most dairy farmers do their own AI or there may be a number of self-trained inseminators from the farm workforce. In some countries, it is a common practice to use professional technicians to artificially breed dairy cows. This is usually done as part of an arrangement with the company supplying the semen. However, in the USA, there seems to be shift away from hiring such technicians for inseminating dairy cows towards becoming owner-inseminators. This trend should not be seen as an indication that AI, although being a simple technique, is an easy practice. Owner-inseminators do not seem to be more proficient in getting cows pregnant than appropriately trained technicians. Overall, the insemination success of owner-inseminators may vary by 25%. The number of AI's per conception may differ from 1.54 to 2.86 which indicate a success rate of 65 to 35%. It seems that some inseminators have a natural ability to work with cows. The training of inseminators is therefore important as the correct procedure should be followed for each cow. Training involves handling reproductive tracts, using material obtained from an abattoir, as well as using live cows in training. The first objective is to locate the entrance of the cervix and to thread the insemination rod (pistolet) through the cervix. Another important aspect of insemination is the correct deposition of the semen inside the uterus. Training should also emphasise the importance of sanitation during the thawing process and handling of semen. Furthermore, there should be an ongoing process to evaluate the technique of inseminators as a poor performance would have a significantly negative effect on the reproductive performance of dairy cows ultimately affecting milk production cost. The best way to evaluate the inseminators' performance is to determine the percentage of positive AI's every month, as well as estimating the accumulative success rate of inseminators over time. From this, seasonal effects on AI success rate could be estimated, as well as observing a change in the success rate of inseminators over time. Keep in mind that the performance of inseminators is estimated at best six weeks to 2 months following insemination as this is the time when most veterinarians do pregnancy checks on cows. This means that a poor performance can be followed for a considerable time before corrective measures could be put in place. Farm records have shown a large variation between inseminators as well as a monthly variation for inseminators. Using the proportion of pregnant cows of all cows tested at each herd visit for pregnancy checks is a poor indicator of herd reproduction performance.

Semen storage

Semen is stored in a special container (semen flask) that is filled with liquid nitrogen at a temperature of -196°C (Holt, 2000). Nitrogen, which is in a gaseous form, flows from the semen flask every time that it is opened to put in new semen straws or to take out semen for insemination. For this reason, the semen tank should be filled up regularly as the level of liquid nitrogen should never reach a specific minimum level. There must be enough liquid nitrogen to cover the semen straws inside the tank. When the semen is not covered, sperm cells will die or their life expectancy may be reduced. When transporting the semen tank while it contains live frozen semen, it is important that the flask is handled with care. For this purpose, it is best to put the flask into a wooden crate before moving it around. The crate should have two handles enabling it to be picked up, as well as a lid to specifically protect the neck of the semen flask as the semen inside the flask is virtually hanging from the rim of the semen flask. The wooden crate should also be secured to the vehicle to prevent it moving around when transporting the semen flask. The flask should not be dragged across the floor. It must also not be dropped or knocked against obstructions (Potgieter, 1985).

The semen flask should be stored in a cool, dry, well-ventilated clean area. It should be put on wooden slats and not directly on a concrete floor. The flask should also not be exposed to direct sunlight nor should it be exposed to draughts as this would increase the loss of liquid nitrogen when opening the flask to take out semen for insemination. It must be put out of reach of children, although in a place where it can be observed daily for signs of moisture or freezing accumulating at the plug in the neck of the flask. Flasks have different maintenance requirements as well as keeping abilities. A four-month flask should be checked every month and at 56 days after the last filling-up (30 cm), the liquid nitrogen should not be less than 18 cm. Liquid nitrogen should not be less than 5 cm to ensure that the semen is protected against increases in temperature inside the flask (Graves & Smith, 2007).

Identification of the flask and semen

Each flask should be properly identified. The owner's name, address, and account number should be included near the neck of the flask to ensure that the semen inventory is correct and up-to-date. This is especially important for the liquid nitrogen supplier as delivery often takes place when no one is at the dairy. Within each flask, metal containers hang from the neck of the flask. Semen straws are put into these metal containers. Each bull's semen should be identified on an inventory list and the semen straw described, e.g. being yellow with a brown plug. The process of lifting up a semen container to remove a straw for insemination should not be longer than 10 seconds to prevent other semen straws being exposed to high temperatures. The change in the temperature inside the neck of the flask varies from -180°C to +2°C at the opening. It is for this reason that in order not to harm the semen in the other straws, picking out semen straws should be done quickly. When not locating a particular semen straw immediately, the container with semen straws should be lowered back into the liquid nitrogen before attempting again to remove the correct semen straw.

Handling of semen

Semen should at all times be protected against direct sunlight, chemicals, variation in the temperature inside the flask, water, and being shaken around. Before the insemination process can start, all the required equipment should be set up to reduce the risk of sperm being killed during thawing, the preparation of the pistolet, and actual insemination process. Under all circumstances, preparations should be done quietly and hygienically. The following equipment should be placed on a small table next to the insemination stall before the cows are brought in for insemination, i.e. a sharp pair of scissors, a paper towel, gloves, lubricant, container with sheaths with one pulled out slightly, a wide-neck thermos flask, thermometer, semen pistolet and the semen flask. The thermos flask should be filled with warm water. Two containers with hot and cold water should be kept ready for maintaining the warm water inside the thermos flask at 35°C. Use the thermometer to mix the water when hot water is added.

Thawing of semen

Before insemination, the semen must be thawed (Gilbert, 1980). This is done by taking the correct semen straw out of the flask and putting it in an upright position into warm water inside a thermos flask. Research has shown that the largest number of sperm survive the thawing process when the temperature of the water used for thawing semen is at 35°C. The reason for this is that during the thawing process, semen goes through a temperature zone which is harmful to the semen causing them to die. Thawing semen at 35°C reduces the interval when semen is affected by the harmful temperature. Because the plug of the semen straw sometimes, during thawing, shoots off, the straw must be put into the thawing water in a vertical position. It is important that insemination should follow as soon as possible after thawing. Thawing takes about 20 seconds. While the straw is thawing, one should make sure that the correct bull's semen was taken out and that the plug at the top end is still intact.

Insemination

Following thawing of the semen, the straw must be dried using a paper cloth. This is important as only a few droplets of water coming into contact with the semen could be harmful as this affects the salt concentration of the liquid in which semen is in suspension resulting in an osmotic shock. To prevent exposing the semen to a temperature shock, the pistolet must be heated up before putting the straw into it. This can be done simply by putting it under one's armpit for a few minutes. Uploading the semen straw onto the pistolet should be done quickly. The top of the straw must be cut off to allow for the semen to be pushed out during insemination. The sheath of the pistolet should be put over the straw and pistolet to protect the semen against pathogens during the insemination process.

In the early days of AI, the optimum deposition site of semen created some controversy among inseminators. Most results indicate that the uterus body is the best place for semen deposition. However, failure to understand the anatomical features of the reproductive system of cows could lead to poor insemination performance. Usually, trainers use a dissected tract of the cervix, uterus body, and uterine horns. Laying this out on a table gives a poor indication of the position of each of these anatomical features inside the body of cows. Recently, radiography (a photograph of an X-ray) has been able to illustrate the reproductive anatomy of cows better than laying it out on a table. The uterine body is the area between the internal opening of the cervix and the internal uterine bifurcation, i.e. where the uterine horns separate. Measurements taken from radiographs indicate that the uterine body is only about 15 mm long, although this may range from 10 to 22 mm among cows. It is to be expected that such a small space for semen deposition would make for large errors in insemination.

Some inseminators also have the impression that cows with a large cervix and reproductive tract have a larger uterine body. This, however, does not seem to be the case. Presently, it is recommended that semen should be deposited just through the cervix while care must be taken in not going too far into the uterus as semen may then be deposited inside one of the uterus horns. Naturally, no conception will take place when ovulation takes place in the other uterus horn. Studies have indicated that highly successful inseminators (achieving non-return rates or success rates of greater than 78%) deposited semen inside the uterine body in 86% of all cases. Inseminators with poor success rates tend to deposit only 34% of the semen inside the uterus. After insemination, the uterus should be massaged through the rectum wall to stimulate the movement of the sperm. Cows should also be kept in a quiet environment preferably separately from the rest of the herd until the end of the heat period.

In closing

The insemination of cows has become a standard procedure in most dairies. The success rate of inseminators varies considerably as techniques vary with shortcuts often resulting in poor performances. The success rate is dependent on a number of factors which include semen storage, handling of semen during thawing and the depositing of semen. Insemination techniques should be monitored regularly by an independent observer as a poor performance has long-term effects. Points to remember when inseminating cows include the following: ensure that the cow to be inseminated is truly on heat, restrain the cows first before thawing a semen straw, and develop good sanitary procedures and insemination practices. This includes keeping the insemination equipment dry and clean, protecting the pistolet, once assembled, against contamination and cold shocks. Materials to be used for lubrication of the rectum should not come in contact with the vulva region. The vulva region should be wiped clean with a paper towel as this is important in preventing contamination of the interior of the reproductive tract while inseminating the cow. A folded paper towel can be inserted into the lower portion of the vulva. The pistolet can be placed in the folds of the paper towel, thereby ensuring that it is inserted into the vagina without contacting the lips of the vulva.

CHAPTER 30

RECORD KEEPING FOR REPRODUCTION MANAGEMENT IN DAIRY HERDS

Introduction

The productive life of a dairy cow starts when she calves down for the first time. Following parturition, the lactation period starts and cows are milked every day, usually twice a day. For a high lifetime performance and lifetime efficiency, it is important that cows calve down on a regular basis. As the gestation period of cows is approximately 280 days (9.2 months) and the recovery period of the uterus after calving is 20 - 40 days, it means that a next calving can only happen 12 to 13 months later. Therefore, after calving, cows must be inseminated (or serviced by a bull) to become pregnant for the following lactation period. Furthermore, to ensure healthy calves at birth, cows must be inoculated against specific diseases while during the course of the lactation period they often develop various diseases which require medical attention and treatment. Some of these veterinary treatments result in milk having to be discarded for a specific withdrawal period.

It is for these reasons that records have to be kept of all the events happening to cows during each lactation period. Information is required on their milk production and milk composition to enable selecting or culling cows, reproduction management with regards to calving difficulty, treatments of post calving problems, first and all service dates, and whether they have become pregnant or not to determine the following expected calving date and drying up dates. From this information, specific actions should be taken. The general aim of record keeping is to enable the following:

- to get a clear and concise view of the whole operation,
- to identify problems within the operation,
- by analysing records the profit potential of the operation may be highlighted,
- for selection purposes, and
- to generate information on the milk yield and genetic merit of animals which will improve their sale value.

All animals, i.e. cows, heifers and even bulls, within a dairy herd must be identified. It is important that identity tags must be easy to read. It should contain all the relevant information like the animal's name or number, birth date, and sire. This can be done by using numbered neck straps, ear tags and freeze branding of identification number on the rump or at the back of the back legs. Registered Jerseys require a tattoo showing the animals breed identification number and year of birth as well as a metal tag clipped into the ear.

There are different record keeping systems for all the productive events for cows and heifers within a dairy herd. The format could be simple or very complicated, depending on the record keeping system or herd management programme. While it is possible to have a simple system for small dairy herds requiring a few records, some basic records should be kept similar to for large dairy herds requiring sophisticated record keeping systems. It is, however, important to refrain from keeping too many records as this may be time consuming while also requiring a considerable amount of time to evaluate the records into useful information. For this reason, the record keeping system of a dairy should be tested against the following principles:

1. It must be useful - records not being used for management decisions should not be recorded at all.
2. Records must be kept in such a way that it is easy to access and to adapt to information.
3. The record keeping system must be simple to use.
4. Duplication must be prevented as far as possible.

Different record keeping systems for a dairy

The size of a dairy determines the type of record keeping systems. The following record keeping systems may be used for smaller herds:

A. Byre sheets

These sheets should contain the daily milk production of cows recorded once a week or every day. Morning and evening milk production should be recorded separately. Further information that is required on such a sheet should include the following: name of the cow, recent calving date, current lactation number, and feeding group or the amount of concentrates being fed.

B. Individual cow cards

Individual cow cards may consist of a ledger book or commercial cow cards usually obtained from a farmers' co-op or dairy processor. A large amount of information may be included on such individual cow cards. This should include at least the following information: the cow's name (or number), an identification number related to the breed society or milk recording system, dam and sire name and identification number, information on all previous lactations with regards to calving dates, service dates, pregnancy check dates, information on lactation milk yield and milk composition records, and information on calves born and inoculation programmes. The problem with individual cow cards is that all the information recorded on them is done by hand making it difficult to extract and to estimate specific parameters for herd management purposes.

C. Breeding wheel for cows and heifers

Breeding wheels are used for the reproduction management of cows and heifers in the herd. Separate breeding wheels may be used for cows and heifers while for a small herd one breeding wheel may be used. The breeding wheel consists of a circular metal disc of which the surface is divided in months and days. Older models use a soft board with different coloured pins for each cow. A metal breeding wheel uses magnetic cubes for each animal. Cubes have different colours on the sides. Each colour depicts a different reproductive phase for the cow identified on the cube. A smaller disc with pointers is put on top of the surface of the breeding wheel showing (1) today's date which is used as the calving date for a specific cow, (2) expected heat observation periods of 3 x 21-day intervals, (3) insemination date which is also the next expected calving date, (4) 2 x 21-day intervals indicating heat return dates, (5) pregnancy check dates which is 60 days after the last insemination date, (6) drying off dates which is 60-day before expected calving dates indicating when to dry off cows, and (7) steam-up date which is 21 days before the expected calving date.

Usually a cow is added to the breeding wheel when she calves down, while heifers are added at first service. Once a cow is inseminated, this specific cow's marker is changed to a different colour depicting that she has been inseminated. This is moved to the present date. The marker stays at this position unless the cow is inseminated again with the marker being moved from the outer to the inner rings depending on the number of services up to that stage. If the cow is not inseminated again, the marker stays at that specific place until it is due for a pregnancy check which is usually 42 or 60 days after AI. If confirmed pregnant, the colour code of the cow is changed while staying at the same place as this also indicates that cow's next expected calving date. Once time has moved on, until the pointer indicating 60 days before the current date reaches the specific cow's marker, it is changed to a different colour showing that the cow has been dried off. Similarly, the cow's marker colour is changed again once the steam-up pointer reaches the marker which is usually 3 weeks before the expected calving date.

Using a breeding wheel, it is possible to see the reproductive status of all the cows in the herd based on the different colours of the markers. As cows calve down and are inseminated, the markers move on the disc indicating the change in the status of the herd. This makes the monitoring process of reproduction management difficult unless specific information is recorded over time. Usually a breeding wheel for cows is used in conjunction with other record keeping systems.

D. Insemination and pregnancy check sheets

When using cow cards it is difficult to do estimations with regards to specific indicators, requiring some duplication of records. Although AI dates are recorded on cow cards, an insemination or service sheet should be kept up to date. This is simply a chronological list of insemination dates of cows and heifers and other information, such as sire names, name of the inseminator or applicable comments on the insemination process. Pregnancy check results are also included onto this list of AI dates. The success rate of inseminators could be estimated by counting the number of their successful inseminations vs. all inseminations done by each inseminator. This should be estimated at least every month for each inseminator, as well as a rolling average of their success rates.

E. Health register

A health register of all veterinarian treatments, both preventative and for specific treatments, such as inoculations, dosing, mastitis treatments, etc. should be kept up to date for each cow.

F. General daily diary

A general daily diary should be kept to record all events, such as veterinarian visits, movement of cows between pasture camps, while planning of specific activities should be noted for specific actions.

Computer-based herd management programme

Computer-based herd management programmes are currently increasingly being used in the management of large dairy herds especially. The reason for this is because of the large number of records that are being collected on a daily basis on a dairy farm. Most of these records are used as management tools. However, for a computer-based management programme to be useful, the same principles apply as for a manual or a pen-and-paper system. Records being collected must be useful. Unfortunately, because of the ease of collecting records, it results in a large number of records being collected with little practical value. This is often seen in reams of paper with records of cows which have to be transferred manually to a spreadsheet programme for further analysis. For a herd management programme to be practical, it must be possible to extract records into a spreadsheet programme for records to be analysed further, using a different analyses to those provided by the management programme. This is specifically problematic for programmes that are not updated regularly.

Managers who use a computer-based programme successfully have usually evolved from a pen-and-paper system knowing which records are required for practical herd management. A computer-based programme is especially important in the development of herd analyses and action lists, i.e. which cows are to be kept behind for pregnancy check, etc. A computer-based herd management programme may help to improve the management of a dairy herd, although demanding a higher standard of management from the dairy manager.

List of cows

The most simple computer-based management programme is to have a list of all the cows in the herd with the appropriate records in a spreadsheet like Excel. Such a list of cows should contain the following information: each cow's herd name or number, birth date, last calving date, current lactation number, status (lactating or dry), number of days in milk or number of days after calving (for dry cows specifically), feeding group or concentrate level, first and last insemination date, pregnancy status (pregnant or not), and expected next calving date when confirmed pregnant by adding a standard gestation period of 280 days to the last service date.

From such a list, the following information could be estimated:

- The number of cows in the herd and in milk.
- The ratio of cows in milk to dry cows in the herd.
- The average number of lactations for all cows in the herd giving an indication of the average age of the herd.
- The average number of days in milk. This indirectly gives an indication of the reproduction management status in the herd as cows are usually milked until 60 days before their next expected calving dates and with cows experiencing reproductive problems, more cows are milked longer than the standard 300-day lactation period, which results in an increase in the average number of days in milk.
- The average number of days from calving to first service.
- The proportion of cows that were inseminated for the first time within 80 days after calving.
- The number of days from calving to conception (days open).
- The proportion of cows that have conceived within either 100, 150 or 200 days after calving.
- The number of inseminations per conception which can be used as an indicator of inseminator proficiency. The inverse of the number of AI's per conception is an indication of the conception rate for the herd or for a group of cows.
- The heat detection rate can be estimated. This is based on the number of days between the first and last insemination date which is then divided by the number of services minus one. Alternatively the average

number of days between heats could be estimated by the difference between the last insemination date and calving date minus an arbitrary voluntary waiting period of 32 days divided by the total number of inseminations. The average number of days between heats divided by the expected heat interval of 21 gives an indication of the number of heats being missed. The inverse (21 divided by the average number of days between heats) gives the heat detection rate. This means that for an average number of days between heats of 42, only every second heat (42/21)) was spotted, giving a heat detection rate of 50% (21/42).

List of heifers

For heifers, a similar system could be used. A list of heifers should contain the following information: each heifer's herd name or number, birth date of heifers, feeding group, first and last insemination date, pregnancy status (pregnant or not), and expected next calving date when confirmed pregnant by adding a standard gestation period of 280 days to the last service date.

From such a list the following information could be determined:

- The number of heifers in the herd.
- The average age of all the heifers in the herd.
- The average age at first service – this is estimated as the difference between the heifer's birth date and first service date.
- The proportion of heifers inseminated for the first time before 14 or 17 months of age – this can be estimated for all heifers or for only those heifers that have had a first service.
- The average age at conception – this is estimated as the difference between the heifer's birth date and service date when conception occurred.
- The proportion of heifers conceiving before 15 or 18 months of age - this can be estimated for all heifers or for only those heifers that have been confirmed as pregnant.
- The expected age at first calving. Age at first calving for heifers is estimated after being confirmed pregnant by adding an average gestation period of 280 days to the last insemination date.
- The number of inseminations per conception, an indicator of inseminator proficiency. The inverse is used as an indication of the conception rate for the herd.
- The average number of days between heats can be estimated using the first and last insemination date divided by the number of services minus one. This can also be used to estimate the heat detection rate for heifers.

In closing

A large number of records could be recorded in dairy herds. It is important that records are transformed to information to be used in the management of the herd. Using a pen-and-paper system can be used for smaller herds while a spreadsheet system should be used for larger herds. Keep the minimum number of records as some are at most interesting, which is not necessarily required in everyday management of dairy herds. A breeding wheel (cow calendar) is a useful tool to manage the reproduction management of a dairy herd. Keeping it up-to-date gives a general impression of cows that have calved down, cows that have been inseminated, i.e. once or more times, cows that are pregnant, cows that dried off and cows being steamed up. Whatever record keeping system is being used for a dairy farm, it must enable the manager to compile specific action lists, e.g. what to do when regarding the different groups of cows in a dairy herd. This is possible even from a list of cows or heifers with their relevant reproductive information such as calving dates, insemination dates, pregnancy check results, or expected calving dates.

CHAPTER 31

REPRODUCTION NORMS AND STANDARDS FOR DAIRY HERDS

Introduction

It is well-known that the fertility of dairy cows affects the profitability and sustainability of a dairy herd. Cows must calve down to come back in milk again. A new lactation period should start regularly, at least once every 12 to 13 months. For a successful pregnancy, cows must, after calving, come on heat and be inseminated successfully, after which they must stay pregnant to the next calving date. Often, because of various problems, the interval from calving to conception increases. Cows are then usually milked for longer than the standard 300-day lactation period. When a significant number of cows in the herd experience problems in getting pregnant, more cows in the herd will be milked while being in late lactation. This usually results in a decrease in the average milk yield of the herd. This is because in late lactation the milk yield of cows is generally lower. This is observed as a higher average number of days-in-milk for cows in milk. Another reason why cows should calve down regularly is to ensure a sufficient number of heifers to replace cows inevitably culled from the herd. Furthermore, the genetic merit of replacement heifers determines the genetic progress of a dairy herd.

The daily milk production of a dairy herd is affected by the number of cows in milk and also the amount of milk each cow produces. For this reason, the number of cows in milk in proportion to all the cows in the herd is for most farmers (and advisors) a general reproduction management indicator. However, this indicator increases when more cows are being milked for a longer period than the standard 300-day lactation period. Similarly, the average number of days-in-milk for the herd also increases when cows are being milked for longer than the standard 300-day lactation period. This is because cows that are difficult to become pregnant are being milked until their milk yields are at a low level or until 60 days before their next expected calving dates. Both these indicators could be improved by culling not-pregnant cows that are still in milk long after 300 days. This, however, does not improve reproduction management.

People affect the fertility in cows

Not commonly considered is the effect of reproduction management on the fertility of dairy cows. Getting cows pregnant on dairy farms has come a long way since bulls were commonly used. However, when not using bulls, people have to do heat detection and inseminate cows using specially designed equipment. In small herds, it is relatively easy to do heat detection as cows are regarded as individuals with farmers often "knowing" each cow's specific breeding behaviour. In large herds, however, this has become a problem as cows almost disappear among other cows within the group or housing system. This lack of attention of cows specifically affects high producing cows as they tend to have different heat signs, e.g. heat periods being shorter and less pronounced than lower producing cows. Recent research has also shown a negative relationship between milk yield and reproductive performance. Many farmers, especially in high producing herds, use this as an acceptable reason for poor reproductive performance in cows. However, while the genetic relationship between milk yield and fertility is negative, it is not high – only about 20% – which indicates that a number of other factors also affect the fertility in dairy cows.

To prevent cows in large herds not receiving the attention they deserve, someone should be appointed to do heat detection. Very few cows are inherently infertile and come in heat and conceive from natural service by a healthy herd bull. However, when poor management, e.g. not treating cows early for uterine infections, or poor heat detection and insemination techniques, intervenes in this process, cows often do not conceive early or not at all, resulting in cows being culled because of infertility. On the other hand, to aid heat detection, cows are injected with appropriate hormonal treatments ensuring that they will come on heat on a specific day, thereby seemingly improving their fertility.

Usually in large herds, a specific person is responsible for servicing cows. The contribution of these background workers in a dairy is extremely important as poor reproductive performance results in extended lactations reducing the total daily milk yield of the herd. The recovery in milk yield also takes time, i.e. from 10 to 12 months following corrective measures.

Specialist workers for reproduction management

It is best that a specific person is appointed to do heat detection (and recording) otherwise everyone is under the impression that someone else is doing it. The same applies for inseminators as this technique requires specific training and skills. It seems that some workers have a natural ability to inseminate cows while others never really develop the required skills. Although appointing heat spotters and inseminators seems to be a common practice in large herds, often these workers are not valued correctly. This is because their work is usually done outside normal working hours. The technique of inseminators can't really be evaluated while it is being done. While the inseminator's technique outside the cow may be regarded as correct, the site of semen deposition is a crucial factor affecting the pregnancy of cows. When semen is deposited inside one of the uterus horns, pregnancy would not take place when ovulation occurs in the other uterus horn. It is for this reason recommended that semen should be deposited inside the uterus body. This is, however, difficult as the uterus body is relatively small, i.e. only about 25 mm.

The performance of these workers can only be evaluated about six weeks after it was done when pregnancy checks are done by the herd veterinarian using rectal palpation on his regular visit to the farm. Although blood tests can be done earlier, it is not yet a common practice on farms.

Evaluate the performance of heat spotters and inseminators

Each herd should have a system to evaluate the performance of these workers. For inseminators the success rate of first AI and the average number of services per conception (SPC) can be used. The inverse of this is conception rate or inseminator efficiency. However, it is important to also consider the number of AI's of cows that have not been confirmed to be pregnant. For this reason, an all-services-per-conception estimation gives another indication of the performance of inseminators. Australian survey results indicate that top managers require 1.96 services per conception (51% conception rate), while advice on reproduction management is required when the SPC is higher than 2.32 (conception rate of 43%). A South African survey among Holstein herds showed that the top 10% and bottom 10% of farmers required 1.62 and 2.35 services per conception. However, when evaluating herd performance, the number of natural services should also be considered as that would reduce (improve) the average SPC figure.

To determine heat spotting efficiency, two indicator traits can be used, i.e. the interval (number of days) from calving to first service (CFS) and the average number of days between heats (breeding interval). The proportion of CFS intervals within 80 days after calving also give an indication of the recovery of cows after calving. Breeding interval (BI) is estimated by subtracting the CFS interval from the interval between calving date and conception date (DO), and dividing that by the number of services per conception (SPC) minus one, i.e. (DO-CFS)/(SPC-1). Dividing 21 by BI gives the heat detection efficiency. This means that for a BI of 42 days, heat detection is 50% which means that only every second heat is observed. The most accurate way is to estimate the average number of days between heats by using service dates for each cow. Although other methods can be used to estimate BI, such as including the voluntary waiting period, whatever method is used, it should be used consistently following each pregnancy check result (Fetrow *et al.*, 1990).

To evaluate the performance of heat spotters and inseminators, records of all cows in the herd should be used. Specific results should further be included on an ongoing basis in graphs showing the trend in the herd over time. Neglecting to consistently evaluate these workers could result in a large negative effect on milk production. Having to use a mob-up bull or synchronisation programmes to get a cow pregnant is early indicators of problems in reproduction management. The fertility of dairy cows is strongly affected by management with cows showing poor fertility under poor heat detection and insemination techniques.

Trends in reproduction management

In the past, farmers used bulls to service cows. Due to various practical reasons, this practice was replaced by the AI industry. Bulls earmarked for the AI industry undergo a progeny testing programme. Semen from bulls with positive genetic merit values are made available to farmers for inseminating cows. This enables farmers to obtain high genetic merit bulls from all over the world at a fraction of the cost and without the practical problems of keeping a bull. Some 30 years ago, dairy herds were small and cows were treated as individuals; however, because of financial pressures, dairy herds have increased in size and the individual attention that cows have received has disappeared. This is especially a problem for high producing dairy cows.

Historical indicators

In the early years of commercial dairy farming, farmers also used individual cow cards or sheets containing all relevant information for each cow. When herds became larger, this way of keeping information made management difficult. This resulted in the development of a number of computer-based herd management programmes, each with its own specific features. However, often these programmes were developed by computer experts with little farming background. Because the computer does all the work, this has resulted in farmers building up large data bases of records with little practical value.

Earlier reproduction management was evaluated on the results of the national milk recording scheme, providing farmers an annual herd calving interval figure. From the farmers' own recording of AI dates and pregnancy check results, the number of AI's per conception was estimated. These two figures were regarded as sufficient for reproduction management.

1. Calving interval

Calving interval, i.e. the number of days or months between consecutive calving dates, has always been used as an indicator for reproduction management in dairy herds. A long calving interval has the following negative effects on production and profitability:

- A larger number of cows are culled annually because of poor reproductive performance,
- Fewer heifers are available for replacing culled cows,
- Annual milk yield of the herd is reduced,
- Fewer bull calves are available for rearing as veal or to be marketed, and
- Higher veterinary and insemination costs for the herd.

Although the average calving interval for the herd is very important, it is not a good indicator of everyday reproduction management. Calving interval is based on historical information and only refers to cows that have become pregnant and have calved down again. No information is available on cows not calving down again. A perfect average calving interval of 365 days could be made up by short or long calving intervals; both of which are problematic. A shorter (320 days) calving interval results in either a short dry period (20 days), when cows are milked for a standard lactation period, or a shorter lactation period (260 days), when cows are dried off at 60 days before the next expected calving date. On the other hand, a longer (410 days) calving interval, using the same principles, results in extended dry periods (110 days) and lactation periods (350 days). No information is also provided on the proportion of cows calving down over a 12-month period in relation to all the cows in the herd. In some herds with acceptable calving interval figures, only 75% of cows in the herd calve down over a 12 month period. An analysis for the Elsenburg herd indicated that 83% of cows have calved down over the previous 12-month period which indicates reproductive problems in the herd.

In a herd experiencing long calving intervals (more than 365 days), milk production per lactation increases, though the annual production per cow is reduced (Figure 31.1).

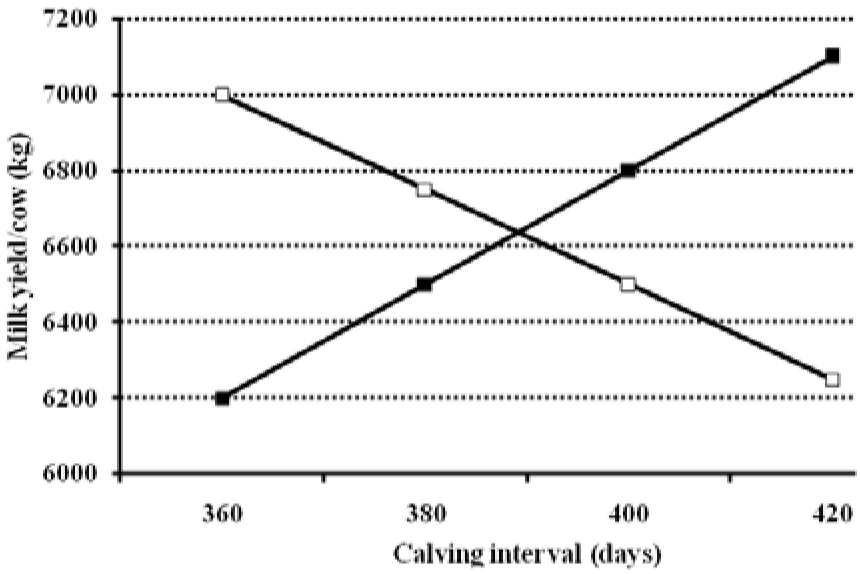


Figure 31.1. The effect of calving interval on the milk yield of cows per lactation (■) and milk yield of cows per year (□) (Ducker, 1985a)

Although difficult to achieve, a calving interval of 365 days is theoretically possible. The gestation period of cows is approximately 280 days. After calving and without any uterine or other infections, the uterus may be fully recovered within 20 to 40 days. This leaves about 45 to 65 days during which cows could be inseminated. As the average heat interval is 21 days, cows therefore have at least two to three opportunities to be serviced to become pregnant within 85 days after calving.

2. Number of services per conception

The average number of services per conception (SPC) has been used as an indicator of cow fertility and as a standard for reproduction management. Although this figure is very important, it must be used in the right context. This indicator is rather an indication of the insemination proficiency of inseminators. Within a group of inseminators operating in a herd, success rate of inseminators may vary from 35 to 65% as indicated by the number of services per conception, i.e. 2.85 vs. 1.54. This means some inseminators should be retrained, while a bonus system based on the cost of semen saved could be used as an incentive for inseminators. It is problematic to use SPC as a reproduction management indicator on its own, and it should preferably be combined with average number of days open. When this interval for the herd is high, i.e. in excess of 120 days, a small number for SPC has little value except in showing a saving in the cost of semen. Furthermore, when this figure is only estimated for cows that have become pregnant, the number of services of cows not conceiving is being disregarded. All services per conception would be a better indicator of insemination management and inseminator proficiency.

In a specific herd, the number of services per conception was 1.8 (an AI efficiency of 56%); however, the interval (number of days) from calving to conception for the herd was 140 days. Therefore, adding an average gestation period of 280 days to the 140 days open means that the expected calving interval for the herd would be about 420 days (13.7 months). While the AI efficiency in the herd is above average, the reproduction problem in this herd is poor heat detection. Based on the number of days open, it could be estimated that heats were observed on average only every 53 days for a heat detection efficiency of 39%. This means that only every second to third heat was detected. By improving heat detection while maintaining the same insemination efficiency, calving interval for the herd would be improved.

Alternative reproductive indicators

The calving interval estimated for a herd is the result of a combination of a number of factors that could be used for fertility traits, e.g. the interval from calving to first service, the success rate of first service, the interval from calving to conception (days open) and the number of services per conception. Culling cows with reproduction problems could improve calving interval figures while reproduction is not improved. The most important indicator of reproduction management is whether the heifers and cows that are supposed to be pregnant are indeed pregnant. This includes all heifers older than 18 months of age and all cows past 100 days in milk. However, different systems are being used in various countries.

Australian InCalf project

To improve the reproduction management of dairy farmers in Australia, a survey was conducted among 200 dairy herds. Reproduction information from about 30 000 cows was collected. Based on this information specific guidelines were estimated which farmers could use to determine the standard of reproduction management in their own herds. Specific actions should be applied when herd evaluations indicate problems. The following indicators for reproduction management of dairy cows are being used in the InCalf project:

- 100-day-in-calf rate – this is the percentage of cows that have become pregnant within 100-days after calving, and
- 200-day-not-in-calf rate – this is the percentage of cows that are not pregnant within 200-days after calving.

The drivers of these in-calf rates are the following:

- 80-day submission rate – this is the percentage of cows that have been inseminated by 80 days after calving, and
- conception rate – this is the inverse of the number of services per conception.

From the Australian survey the following reproduction management standards are being used to evaluate farmers' own management standards to:

Parameters	Top farmers	Seek advice
80-day submission rate (%)	73	< 61
Conception rate (%)	51	< 43
Services per conception	1.96	> 2.33
100-day-in-calf rate (%)	58	< 45
200-day-not-in-calf rate (%)	13	> 19

A South African survey

An effort has been made to determine similar indicators for South African dairy farmers. Initially, only a small number of records were obtained to establish the possibility of such research. This study also showed the potential of using reproduction management information to estimate breeding values for cows for different fertility traits. This study was followed up by another survey resulting in a larger data set with reproduction management information of heifers and cows. About 18000 heifer and 43000 cow records were available for this survey. Indicators have been adapted from the Australian InCalf project. In Table 31.1, the average reproduction management indicators for heifers and cows for 26 Holstein herds in comparison to the top 3 and bottom 3 herds are shown.

Table 31.1. The average reproduction management indicators for heifers and cows for 26 Holstein herds (AI = artificial insemination)

Animals	Parameters	Average All herds	Top 3 herds	Bottom 3 herds
Heifers	Age at first service (months)	17.7	14.5	23.8
	First service before 15 months of age (%)	30	68	0
	First service before 18 months of age (%)	61	89	7
	Age at first calving (AFC) (months)	27.8	24.6	33.4
	AFC before 24 months of age (%)	21	60	1
	AFC before 27 months of age (%)	50	84	8
Cows	Interval calving date to first AI (days)	92	89	104
	First AI before 80 days-in-milk (%)	51	62	44
	Services per conception	2.16	1.62	2.35
	Days open (days)	140	112	164
	Pregnant before 100 days-in-milk (%)	40	57	31
	Pregnant before 200 days-in-milk (%)	81	90	72

Results in Table 31.1 show a large variation in the standard of reproduction management among dairy herds, especially when comparing the top and bottom three herds, i.e. comprising the top and bottom 10% of herds. On average, only 30% of heifers were serviced for the first time before 15 months of age. This seems to indicate poor feeding of heifers or a lack of understanding about the requirements of an early age at first calving. Heifers have to be confirmed pregnant by 15 months of age to ensure age at first calving of less than 24 months of age. When first service is after 15 months of age, age at first calving will be after 24 months of age increasing the rearing cost of heifers. Even in top performing herds, only 84% of heifers calved down before 27 months of age.

For dairy cows, a short calving interval depends on an early first service, i.e. within 80 days after calving and few services per conception to result in as short interval from calving to conception. On average, days open for all cows were 140 days, ranging from 112 to 164 for top and bottom herds. Although 81% of cows were confirmed pregnant within 200 days after calving, the cows not confirmed pregnant by then would take a long time to get pregnant or not at all. The evaluation of the reproductive status of a dairy herd should be done after at least each pregnancy check result. It takes at least 10 - 12 months to observe a positive effect specifically on the proportion of cows in the herd calving down within each month once changes and improvements in incorrect reproductive management practices have been made.

In closing

Reproduction management affects the fertility of dairy cows. Farmers should therefore know their herd's reproduction management standard. Information on the different fertility traits of dairy cows can also be used to estimate breeding values for these traits. This would aid the genetic improvement of the fertility of dairy cows. Farmers are encouraged to record useful records.

CHAPTER 32

CHANGING THE REPRODUCTION MANAGEMENT PROTOCOL

Introduction

The fertility of dairy cows is, next to mastitis and farm-gate milk prices, the biggest problem for dairy farmers. It is well-known that cows have to calve down to start a new lactation period to produce milk. In South Africa, selection programmes in dairy herds focus mainly on conformation traits and milk yield. There has been no emphasis on improving the fertility of dairy cows except for culling cows that have not become pregnant. This is usually only done after an extended and costly breeding period. Internationally, fertility traits, such as daughter pregnancy rate, are increasingly being used in the selection of sires for breeding. Although heritability estimates for most fertility traits are low, genetic progress is possible though at a slow rate of improvement.

There seems to be a lack of understanding of the interaction between the reproductive performance of dairy cows and their daily milk yield. This is to be expected as it is easy to confuse fact and perception when working with a large number of cows. A low milk yield today could be the result of poor reproductive performance 10 to 12 months ago. The reason for this is because reproductive problems in getting cows pregnant at present result in fewer cows calving down in about nine months from today. When a considerable number of cows do not conceive early, they are milked for an extended period after the normal drying off date. While this increases the cow's milk yield per lactation, it reduces her milk yield per year as the extended lactation occurs during the time when the milk yield of cows is naturally low. When a large proportion of cows in the herd experience extended lactations, it has a direct negative effect on the herd's daily total and average milk yield. Furthermore, more cows are culled because of not becoming pregnant. This increases the cull rate resulting in a larger proportion of first lactation cows in the herd. As first lactation cows generally have lower milk yields than older cows, this further reduces the total daily milk output of the herd. A poor reproductive performance in heifers also extend their age at first calving which further increases the production cost of milk, as there are more animals in the herd in a non-productive state.

Poor fertility results in a number of negative responses in a dairy herd, and eventually also affecting farm profitability negatively. Not only is longevity of cows dependant on the reproductive ability of dairy cows, but poor reproduction results in higher cull rates in cows reducing their productive lives while increasing replacement costs. Less obvious effects not always observed or attributed to poor reproduction include: (1) a higher average number of days in milk because more cows are in late lactation, and (2) a lower average lactation number for all cows in milk because of fewer older cows in the herd. Both these factors have a negative effect on the average milk yield of the herd resulting in a loss in farm income.

A real case scenario

A commercial Jersey herd experienced a low milk yield (less than 10 liters per cow per day) while receiving a total mixed ration formulated to produce at least 20 liters of milk per day. Cows in the herd had an average condition score of more than 3.0, emphasising an excessive energy intake in relation to the daily milk yield of cows. By compiling a list of all the cows in the herd with information on their last calving dates, number of days in milk, it was established that most cows were in late lactation, i.e. more than 200 days in milk. As most cows were in late lactation, feeding high levels of concentrates, increased herd condition score. A breeding programme using natural service to get cows pregnant was initiated. When cows eventually started calving down about 10 to 12 months later, the herd milk yield increased to about 20 liters of milk per cow per day without feeding additional feed or concentrates. Herd milk yield increased from about 1250 to 2200 liters of milk per day. The higher milk yield was mainly due to more cows in the herd in early lactation. To determine the effect of lactation stage (or number of days in milk), a simple linear regression was fitted between average days in milk vs. average daily milk yield. As expected, this indicated a negative response on milk yield with increasing number of days in milk. The average milk yield of the herd was reduced by 1.5 liters per cow per day for every 21 days beyond 150 days-in-milk.

Definition of cow fertility

Research has shown that cows differ in their ability to return to reproductive cycling. Therefore, the interval from calving to first heat or service becomes the first indicator of fertility in dairy cows. The definition of fertility in dairy cows is based on three traits, namely, the ability of cows to recover quickly after calving to start cycling (coming on heat), to become pregnant from a few inseminations or services, and to stay pregnant to the next calving down. For this reason, calving interval (CI) and number of service per conception have become important indicators of fertility in dairy cows. Most dairy farmers have reproductive targets to aim for as the importance of short CI and a small number of services per conception are well accepted. Most local dairy farmers use targets such as age at first calving of 24 months, CI of 365 to 395 days, and number of services per conception of about 2.0. The problem is that these fertility indicators are strongly affected by management skill, while in some instances reproductive results could be manipulated, e.g. "improved" by culling cows not becoming pregnant as reproductive records of such cows are not reflected in a herd summary. Culling cows, however, does not improve reproduction management. It has been shown that CI actually consists of a number of traits which are better indicators of fertility in dairy cows, while the number of services per conception is affected strongly by the insemination skills of the inseminator. It is for this reason that farmers use bulls (natural service) on cows rather than to risk failing at artificial insemination.

Changing the reproduction management programme

A national survey conducted in Australia regarding the reproductive status of dairy cows provides some norms and standards with which to compare a dairy herd's reproductive standard. This is currently being used to evaluate the reproductive performance of dairy herds. By compiling a list of cows with all the required information, dairy farmers could establish their own standard of reproduction management (Varner, *et al.*, 1985).

In cooperation with the herd veterinarian, the following reproduction management system for the Elsenburg dairy herd was established:

- a visit by the herd veterinarian once every two weeks,
- cows that have calved down since the previous visit are examined for uterine infections, retained placenta, etc., with cows being treated as required,
- cows more than 50 days in milk are checked for estrus cycling, cows not active are injected with a suitable hormone to initiate the cycling process and a heat spotting marker is put on the cow's tail-head,
- cows more than 150 days in milk not confirmed pregnant are put on a synchronised breeding programme and inseminated according to the instructions of the programme,
- cows more than 35 days after their last insemination are checked for pregnancy by rectal examination, and
- cows to be dried off are checked for pregnancy.

Results

In Table 32.1 the effect of the change in reproduction management is shown. The herd increased in size from 122 to 166 cows, reflecting an internal herd growth rate of about 17% per year. The percentage of cows in milk increased, because cows are being milked until 60 days before their next expected calving date. The average lactation number for the herd increased, indicating that fewer older cows were culled as reflected in the increase in the number of cows in the herd because of first lactation cows entering the herd.

Table 32.1. Reproduction management indicators for the Elsenburg dairy herd following a change in reproduction management (AI = artificial insemination)

Parameters	August 2005	May 2007	Target
Number of cows in the herd	122	163	-
Cows in milk (%)	68	85	82
Average lactation number	2.56	2.76	> 3.00
Average days-in-milk	208	155	< 150
Number of days from calving to first AI	97	63	< 85
First service before 80 days-in-milk (%)	52	79	73
Number of days from calving to conception	198	151	< 100
Cows pregnant from first AI (%)	26	26	> 60
Number of AI's/conception	2.61	3.03	< 2.00
Cows pregnant before 100 days-in-milk (%)	22	38	> 58
Cows pregnant before 200 days-in-milk (%)	62	77	> 83
Average number of days between heats	58	45	< 30
Heat detection rate (%)	36	47	> 70

The result of applying a specific reproduction management programme is observed in the shorter interval from calving to first service, i.e. 97 to 63 days, which is also demonstrated in a larger percentage of cows inseminated for the first time before 80 days-in-milk. This also resulted in fewer days from calving to conception, namely 198 vs. 151 days. The conception rate of inseminators decreased from 38 to 33%, which is possibly an indication that inseminators require retraining because they may be using an incorrect technique or heat detection may be poor with cows not being inseminated when they are in true standing heat. Poor conception rate results from a poor success rate of first insemination. Although improving from 36 to 46%, heat detection was poor. The percentage of cows confirmed pregnant within 100 and 200 days-in-milk improved, although still lacking behind what top farmers achieve.

In Figure 32.1 the proportion of cows becoming pregnant within specific days open intervals after calving is shown. A larger proportion of cows became pregnant within 100 days after calving following the change in reproduction management. Similarly the proportion of cows that became pregnant after 200 days-in-milk was smaller, indicating a general improvement in reproduction management.

Although most reproductive parameters showed an improvement, the production performance of the herd is still poor, probably because of poor heat detection as indicated by the number of days between heats and insemination techniques of inseminators. A heat detection rate of 47% indicates that only about every second heat is being detected.

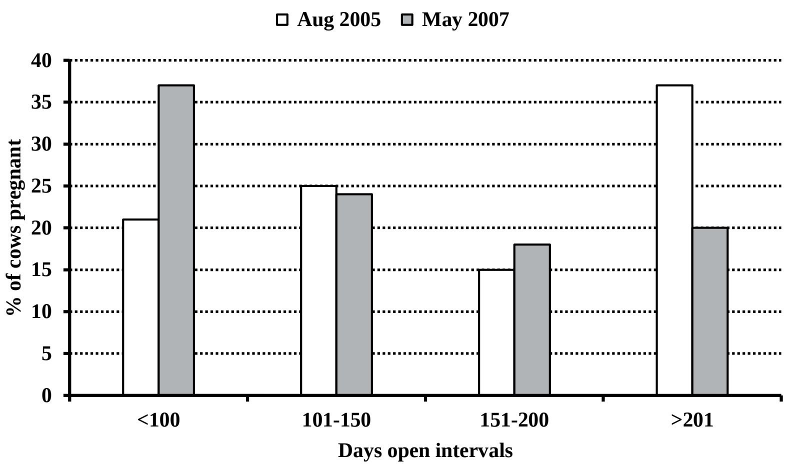


Figure 32.1. The proportion of cows that became pregnant within specific days open intervals on two separate occasions following the adoption of a new reproduction management programme

In closing

The reproduction management of a dairy herd is complex. There are a large number of factors affecting the standard of reproductive performance. The application of a specific reproduction management programme resulted in an improved performance, although still lacking on most indicators. Specifically, heat detection and number of services per conception require considerable improvement, as the average interval between heats is long and the number of services per conception is high. Before culling cows for poor reproductive performance, the ability of workers with regards to heat detection and insemination techniques should be improved as these factors may affect the fertility of dairy cows. This is an indication of poor people skills impacting on the performance of cows, making it difficult to identify cows in a dairy that suffer from true infertility. For the improvement of fertility in dairy cows, the effect of sire selection using fertility traits in their daughters should be considered as well.

CHAPTER 33

EVALUATING REPRODUCTION MANAGEMENT USING FARM RECORDS

Introduction

Poor reproduction has become a major issue in most dairy herds. The result is a loss in milk income and reduction in herd life. Reproduction management in dairy herds has become more difficult as higher milk yields cause a large negative energy balance during the first two months of the lactation. Larger herds with less emphasis on individual animals and labour not familiar with reproductive biology also result in a poor reproductive performance in dairy herds. It is possible that the genetic merit of cows for fertility has changed over the last 30 years. However, based on low (< 10%) heritability estimates for most fertility traits, poor reproduction is probably a management problem. Various software packages are available to assist dairy farmers, veterinarians and consultants with on-farm reproductive management.

While elaborate reproduction management programmes may provide a large volume of information, a simple recording system may also provide valuable information to help with reproductive management. On-farm reproductive management is supported by regular, at least monthly, pregnancy diagnosis checks by a veterinarian (or a suitably trained person) using rectal palpation of candidate cows. For such an event, a list of cows to be examined is usually prepared. The list usually includes various records, such as cow identity, the service or artificial insemination (AI) date, number of AI's, name of inseminator, with the outcome of the pregnancy diagnosis check being added to the list. Following the pregnancy diagnosis check, parameters such as the number of cows confirmed pregnant as a percentage of cows being checked on the day, often referred to as conception rate, as well as the number of inseminations per conception for the positive cows, are often used as an indication of the standard of reproductive management in the herd. Using such records would not give a complete indication of reproduction management in the herd. The average number of services per conception is an indicator of inseminator proficiency, which is related to heat observation, insemination technique, and semen quality.

However, using a complete list of all the cows in the herd, both dry and lactating cows, with relevant information with regards to days-in-milk, number of services per cow, first and last service dates, and whether cows are pregnant or not, a number of parameters could be determined to give an indication of the standard of reproduction management in a dairy herd. By compiling records from a number of pregnancy diagnosis checks, information could also be used to show trends over time. In this chapter, some alternative, easy-to-determine reproduction parameters extracted from cow list sheets are presented and compared to guidelines based on an Australian survey on reproductive management.

Farm records collected

Information recorded on eight hand-written reports for a 180-cow dairy herd consisting of Holstein and Jersey cows, over a two-year period, was used (Muller, 2011). Each report had information on the date of the veterinary pregnancy check, each cow's identification number, recent calving date, last insemination date (at least six weeks earlier), identity of inseminator, number of insemination, and the pregnancy check result. All this information was transferred to an Excel spread sheet programme. In Table 33.1 an example list of 10 cows is presented.

Table 33.1. An example list of 10 cows presented for pregnancy checking with relevant information (AI = artificial insemination, PD = pregnancy diagnosis) (Muller, 2011)

Cow name	Last calving date	Last AI date	Inseminator	All AI's	
17	20/7/2006	24/9/2006	G	1	Yes
561	15/5/2006	23/10/2006	G	3	No
610	9/6/2006	29/8/2006	G	1	No
648	22/10/2006	8/6/2007	Bull	3	Yes
673	8/11/2005	13/9/2006	G	4	Yes
695	21/8/2006	15/10/2006	CJB	1	Yes
696	8/8/2006	16/11/2006	G	6	Yes
Beautty	31/7/2006	24/9/2006	G	1	No
Belinda	5/9/2005	14/9/2006	G	8	Yes
Berdine	14/6/2006	24/10/2006	G	2	Yes

The following reproduction traits were determined for all cows: insemination success rate (pregnant = 1 and not pregnant = 0), the interval (number of days) from calving date to first insemination date (this was estimated for cows at first insemination only), percentage of first inseminations within 80 days post calving (≤ 80 days in milk = 1 and > 80 days in milk = 0), number of inseminations for cows confirmed pregnant, the interval from calving to conception (days open), the percentage of cows confirmed pregnant from first insemination (success from first insemination = 1 and success from other insemination numbers = 0), the proportion of cows pregnant within 100 and 200 days post calving (≤ 100 days in milk = 1 and > 101 days in milk = 0 and ≤ 200 days in milk = 1 and > 201 days in milk = 0), inseminator success rate (yes = 1 and no = 0), breeding period (interval from calving date to last insemination date minus an arbitrary voluntary waiting period of 21 days), average days between heats (breeding period divided by the number of inseminations), and heat detection rate (21 divided by the average days between heats). A heat detection rate of 100% was used in the case of cows having interservice intervals of less than 21 days.

Results from this herd

A total of 541 artificial insemination (AI) records from 261 cows were available. Rectal palpation showed that 56% of inseminations over all cows and inseminators resulted in a confirmed pregnancy. The interval from calving date to first AI date was about 94 days (Table 33.2).

While 49% of first inseminations were within 80 days after calving, 31% of first inseminations occurred more than 100 days after calving. According to a survey conducted in Australia, "good" managers achieved 73% of first inseminations within 80 days after calving. It is suggested that at a rate lower than 61%, reproductive problems are experienced in a herd. The average number of inseminations per conception in the test herd was 2.51, which indicated an insemination efficiency of 40%. This is also lower than available guidelines. The importance of insemination efficiency is further highlighted when the number of inseminations for cows not becoming pregnant is included in the analysis. By counting all the inseminations for all cows up to a specific date and dividing this total by the number of cows confirmed pregnant, all insemination efficiency is 19% at 5.27 AI's per conception. This figure emphasises the poor inseminator proficiency, as some cows are inseminated repeatedly while not becoming pregnant.

Table 33.2. Mean (± standard deviation) reproduction parameters for a dairy herd based on service records from cow pregnancy diagnosis checks lists (DIM = days in milk) (Muller, 2011)

Parameters	Test herd	InCalf guidelines[1]	
		"Good" managers	Reproductive problems
Interval calving date to first service (days)	94 ± 61	-	-
First service before 80 DIM (%)	49	73	< 61
Cows pregnant from first service (%)	36	-	-
Interval calving date to conception (days)	179 ± 116	-	-
Cows pregnant before 100 DIM (%)	31	58	< 45
Cows pregnant before 200 DIM (%)	66	87	< 81
Number of services per conception	2.51 ± 1.68	1.96	< 2.32
Breeding period (days)	166 ± 135	-	-
Interval between heats (days)	67 ± 42	-	-
Heat detection rate (%)	39 ± 19	-	-

[1]InCalf guidelines based on an Australian survey (Little, 2003)

The percentage of cows confirmed pregnant within 100 and 200 days post calving was 31 and 66%, respectively. These parameters were also much lower than recommended guidelines. The mean number of days from calving to conception for cows confirmed pregnant was 179 days, indicating an expected calving interval period of 459 days. Only 36% of first inseminations resulted in a positive pregnancy diagnosis. The insemination success rate of the four inseminators varied from 50 to 64%. One inseminator, who was responsible for about 85% of all inseminations, achieved an overall AI success rate of 56%. The insemination success rate of the main inseminator varied on a monthly basis from 33% to 81% (Figure 33.1). The monthly progressive insemination success rate deteriorated linearly (R^2 = 0.70) from 65% to 46% over a 22-month period, possibly indicating a lack of interest in maintaining good operating procedures.

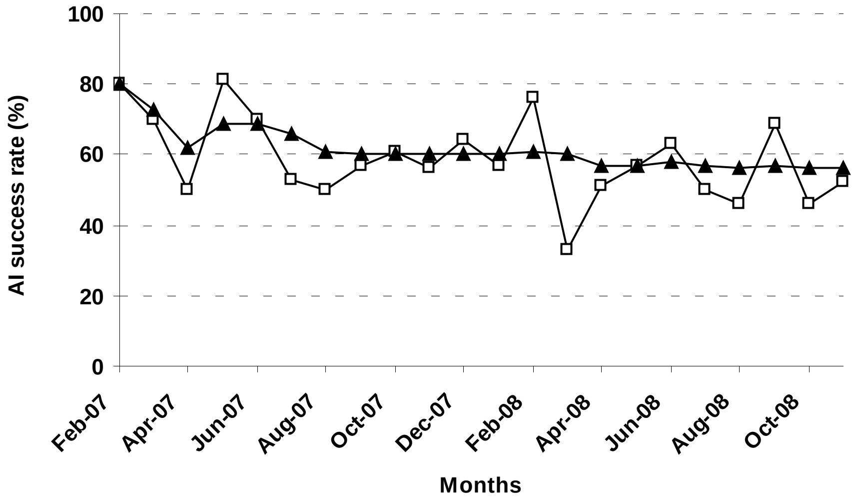


Figure 33.1. The monthly (□) and monthly progressive (▲) insemination success rate of one inseminator over a 22 month period

Furthermore, the average breeding period for all cows was 166 ± 135 days and the average interval between inseminations was 67 ± 42 days. This means that the heat detection rate in the herd was only 39%, indicating that heats were observed and cows inseminated only once every 67 days.

Australian InCalf project

To determine and to improve the standard of reproduction management in dairy herds in Australia, a national survey was conducted of about 200 dairy herds, comprising reproduction information on approximately 30000 dairy cows in both seasonal and year-round calving systems. Different recommendations were developed for each system. The success of the implementation of these norms and standards has been such that the system is increasingly being implemented by veterinarians and dairy extentionists in New Zealand. For herds with a year-round calving system, the evaluation of reproduction management is based on the following norms and standards:

1. The percentage of cows that became pregnant within 100 days after calving. Top managers get 58% of cows pregnant within 100 days, while advice is required when fewer than 45% get pregnant within 100 days after calving.
2. The percentage of cows not pregnant by 200 days in milk. Top managers get 87% of cows pregnant within 200 days, while advice is required when fewer than 81% of cows are not pregnant within 200 days after calving.

These two traits are being driven by the following:

1. the percentage of cows being inseminated within 80 days after calving, and
2. the number of services per conception (or the inverse conception rate).

When these two traits are below 61 and 43%, respectively, reproduction management is poor and requires major intervention.

Development of alternative reproduction guidelines

Using the Australian Incalf system as a guideline, an evaluation system for reproduction management has been developed for the Elsenburg dairy herds. Additional information is being estimated to give a better indication of reproduction management for an ongoing herd. A commercial computer-based management programme has been developed to give similar information. Usually a survey for a herd is conducted once the herd veterinarian has completed a regular herd visit for pregnancy checks.

To determine the standard of reproduction management, a list of all the cows in the herd is required. The list should contain the following information: each cow's herd name (or number), last calving date, milk status (dry = 0 or lactating = 1), number of days in milk, lactation number, first and last service dates, number of services for each cow, and whether she is pregnant or not.

From this information, the following traits are estimated: the interval (number of days) from calving to first service (CFS), whether CFS interval was within 80 days after calving (yes or no), the interval from calving to conception (days open, DO), whether DO was less than 100 or 200 days-in-milk (yes or no), the number of services per conception, and next expected calving date by adding 280 days to the conception date.

To analyse these records the list of cows should be sorted for milk status (dry or in milk) with the cows in milk, sorted for number of days in milk from high to low.

From this list, the following key questions can be answered:

(1) are cows pregnant that are supposed to be pregnant,
(2) when did cows become pregnant,
(3) when was first service, and
(4) what is the conception rate or AI success rate?

The same system is being applied in other herds with the aim of determining the standard of reproduction management in herds. This provides guidelines towards taking specific actions to improve reproduction management. In Table 33.3 the key indicators are presented as an example of the system. The numbers in bold in the table reflect better performances not requiring advice.

Table 33.3. The key reproduction management indicators for four dairy herds in comparison to Australian guidelines for indicators requiring advice (DIM = days in milk)

Parameters	Dairy Herds				Advice required
	1	2	3	4	
Are these cows pregnant?					
Cows more than 100 DIM (%)	70	50	32	61	-
Cows dry + more than 100 DIM (%)	78	60	41	69	-
Cows more than 200 DIM (%)	90	69	52	81	
All dry cows (%)	100	100	100	100	-
When did cows become pregnant?					
Pregnant within 100 DIM (%)	28	45	**46**	**47**	**< 45**
Pregnant within 200 DIM (%)	73	71	79	76	**< 81**
Days open (d)	155	156	124	139	-
When was first service?					
Interval calving to first service (days)	93	100	77	80	-
First service less than 80 DIM (%)	46	49	42	**73**	**< 61**
Pregnant first service (%)	33	52	50	21	-
Service success rate					
Service per conception	2.54	**1.98**	**2.02**	2.38	**> 2.32**
Conception rate (%)	39	**51**	**50**	42	**< 43**
All services per conception	3.01	3.55	3.44	3.11	-
All services conception rate (%)	33	28	29	32	-

Some of these parameters indicate the present pregnancy status of the herd differing from the Australian InCalf parameters, which suffer from the same problem as calving interval only referring to cows that have been confirmed pregnant. The main question refers to whether cows are pregnant that are supposed to be pregnant. This includes the percentage of cows pregnant more than 100 and 200 days-in-milk, as well as dry cows. Records from more herds are required to determine top and bottom guidelines. However, it is to be expected that all dry cows should be pregnant, most cows (+ 90%) more than 200 days-in-milk should be pregnant, and + 60% of cows more than 100 days-in-milk should be pregnant. For other parameters, the InCalf guidelines could be used to establish the standard of reproduction management.

With a few exceptions, most parameters in these four herds were below the minimum InCalf guidelines. Except for two herds, which had shorter intervals from calving to first service than the top herds, based on results from a South African survey for Holstein cows, most parameters were below minimum reproduction norms and standards. In all four herds, all dry cows were confirmed pregnant, while for cows more than 200 days-in-milk, the percentage of cows confirmed pregnant for these four herds varied from 52 to 90%.

In most of these four herds the interval from calving to first service was late, in excess of 80 days, while only in one herd, the percentage of first service within 80 days after calving was better than 61%. The success rate of first service is also low, less than 50% in three herds. This resulted in a high number of services per conception, or a low (< 50%) conception rate. All services per conception efficiency, i.e. referring to the sum of all services divided by the number of cows confirmed pregnant, was also less than 35% in all herds. This means that a considerable number of cows have had multiple services while not being pregnant. However, some of these figures could improve as cows that have been inseminated recently (within the past 42 days) are still being regarded as not pregnant. It is for this reason that pregnancy checks on cows should be done on a regular basis to confirm their pregnancy status, as this determines further actions to be put in place to get cows pregnant. This is specifically important for cows past 150 days to reduce the negative effect of extended lactations. Such a within-herd survey gives the opportunity to manage each cow as required.

In closing

It is possible to determine the standard of reproduction management in daily herds. This should be done on a regular and ongoing basis to determine which cows are pregnant and when did they become pregnant. Cows not pregnant late in lactation has a negative effect on the herd milk yield as extending the lactation period past 300 days-in-milk results in low milk yields. There are a number of factors affecting the fertility of dairy cows. This includes correct heat detection, semen storage, semen handling, insemination techniques with regards to the site of semen deposition, and keeping cows stress-free and relaxed. Farmers must be careful not to cull cows on reproductive failures when reproduction management indicates a poor performance.

CHAPTER 34

NON-GENETIC FACTORS AFFECTING FERTILITY IN HOLSTEIN COWS

Introduction

Profitable milk production and genetic improvement in dairy herds depend on fertile cows being able to calve down annually to initiate a new lactation period. However, several studies have indicated a decline in the reproductive performance of dairy cows. For instance, with South African Holsteins, calving interval (CI) increased from 386 days in 1986 to 412 days in 2004 (Makgahlela, 2008). The general perception is that selection for higher milk yields in dairy cows has led to a general decline in the fertility of dairy cows because of a low (ca 20%) unfavourable genetic correlation between yield and fertility. The low genetic correlation between milk yield and fertility is related to other factors, such as increased herd sizes, less labour inputs per cow, overcrowding, poor environmental housing conditions, etc., which could also have contributed to the decline in fertility. Breeding and selection programmes in dairy herds in South Africa have focused mainly on the improvement of milk yield and conformation traits. While it is well accepted that the reproductive performance of dairy cows affects herd profitability, specifically through the cost of rearing high numbers of replacement heifers, higher veterinary and insemination costs, extended lactations, dairy farmers put little emphasis into the improvement of cow fertility. At best, non-pregnant cows are culled because of reproductive failure. This is also done only after a considerable effort was put into getting cows pregnant. This usually includes a high number of inseminations, fertility hormone treatment sessions and eventually using natural service by a home-bred bull. This usually results in a protracted interval from calving to conception leading to a high CI.

To improve the fertility of dairy cows, information on their genetic merit for fertility is required. Fertility in dairy cows is a complex trait as it consists of a number of traits while also being linked to the standard of within herd reproduction management. Presently, estimated breeding values for CI for the four major dairy breeds in South Africa are estimated with genetic herd profiles provided. Although this is a first step towards the genetic evaluation of the fertility of South African dairy cows, it has been pointed out that cows that do not re-calve again for any reason, including those cows culled for not becoming pregnant, are not included in the genetic evaluation. This means that information on the perceived least fertile group of cows is excluded, which could possibly lead to inaccurate estimated breeding values for fertility for sires. While the absence of a subsequent calving date does not provide a CI, some reproductive information could be gathered from service records, like the interval from calving to first service and whether first service was within a set period after calving.

Farmers keep service records

As dairy farmers routinely record artificial insemination (AI) and natural service records and pregnancy test results for herd management purposes, such data could be used in the genetic evaluation of dairy cows for fertility. These records provide the opportunity to estimate specific intervals that could be used as indicators of cow fertility. Traits to be considered include the interval (number of days) between calving date and first service date, as well as the interval between calving date and conception date. These interval traits have been used in predicting reproductive performance of dairy cows in other countries. In Canada, a national recording scheme for fertility traits as part of a new milk recording scheme has been implemented. Insemination data have been accumulated since 1997 and a national genetic evaluation programme for dairy cow fertility traits has been developed. Four fertility traits, namely, age at first service in heifers, non-return rate to 56 d in heifers and cows and the interval from calving date to first insemination date have been used for Canadian dairy breeds. Other researchers also use fertility traits such as the number of days between calving date and first insemination date, number of services per conception, the number of days between first insemination and conception. In most cases, heritability estimates for fertility traits were low, from 3% for non-return rate in heifers to 13% for age at first service. It was generally concluded that female fertility is a complex set of traits related through genetic and environmental factors. Genetic correlations between these different fertility parameters indicated that there is likely not a single characteristic that would serve well for selection purposes. It has been suggested that some of these traits should be combined in a fertility index.

Estimation of genetic parameters for fertility traits in Holstein cows

Genetic parameters for alternative fertility traits to CI have been estimated for South African dairy herds, albeit using small data sets, i.e. 2639 lactation records of 751 Jersey cows and 3642 lactation records of 1375 Holstein cows. Results showed that heritability estimates for key fertility traits were within the range of estimates from overseas studies. A larger data has been compiled to estimate genetic parameters for fertility traits in Holstein cows. This gives the opportunity to determine the effect of non-genetic factors on alternative reproduction traits to CI in Holstein cows.

All AI records (n = 69181) from 24646 lactations from 9046 individual Holstein cows, calving down in the period between 1991 and 2007, in 14 Holstein herds were available. Data used were from herds in both zero-grazing and pasture-based production systems in South Africa. The outcome of each AI event was known, i.e. yes = pregnant or no = not pregnant. Pregnancy diagnosis was based on rectal palpation by a veterinarian, usually on a monthly farm visit. Cows experiencing calving problems or other problems such as retained placentas were treated by a veterinarian as required. Insemination records were linked to the calving date of each cow, lactation number, dam and sire identification numbers. By using this information, fertility traits that measure the ability of cows to show heat early in the breeding period and the probability of the success of insemination and confirmation of pregnancy were derived. Traits were the interval (number of days) from calving date to first service date (CFS), the number of days from calving date to conception date (DO), number of services per conception (SPC), whether cows were inseminated within 80 days post partum (FS80d), whether cows were confirmed pregnant within 100 (PD100d), and 200 days post partum (PD200d). Non-interval traits were recorded as binary threshold traits coded as 1 = no and 2 = yes. Reproduction records exceeding four standard deviations from the mean for each trait were deleted from the data set.

Results and discussion

Descriptive statistics for fertility traits evaluated are presented in Table 34.1. Cows became pregnant in most lactation periods (85%). Although average values for some traits were acceptable from a management point of view, large variations were observed as indicated by high standard deviations. This is to be expected as observed values for these traits are the result of a complex interplay among several elements such as the decision policy of the dairy farmer with regards to the voluntary waiting period (VWP), post-calving treatment of cows, nutritional management, environmental factors, and the genetic merit of cows for fertility. The coefficient of variation for interval traits was 39 and 70% for CFS and SPC respectively. Although the mean interval from CFS was 77 days, only 64% of first services occurred within 80 days postpartum. The interval from calving to conception (DO) was high and variable at 134 days. While 64% of first services were within 80 days post calving, first AI success rate was poor at less than 40%. Only in 36 and 71% of all lactations were cows confirmed pregnant within 100 and 200 days postpartum respectively.

Table 34.1. Descriptive statistics of the data analysed for fertility traits (DIM = days in milk)

Traits	Number of records	Mean	Standard deviation	Coefficient of variation (%)
Calving to first service (days)	16605	77	30	39
Days open	14255	134	74	55
Services per conception	14255	2.55	1.79	70
First service within 80 DIM (%)	16648	64	48	75
Cows pregnant within 100 DIM (%)	16648	36	48	134
Cows pregnant within 200 DIM (%)	16648	71	45	64

Poor heat detection resulted in an extended interval from first service to conception. Only in 36% of lactations had conception been concluded within 100 days post calving, while 29% dragged on for longer than 200 days after calving. Poor service efficiency (less than 40%) is reflected in the relatively large number of services per conception (SPC) of 2.55 as observed in this survey.

The extended intervals from calving to first service could be ascribed to the reproductive management of cows after calving, e.g. cows having uterine infections or reproductive problems such as cystic ovaries not observed early. Uterine infections could be caused by calving environment, i.e. wet and dirty conditions, the birth weight of calves (poor sire selection), presentation (position) of calves during the birth process, retained placentas because of nutritional imbalances, and a host of other potential causes.

The effects of herd, calving year, calving season and lactation number on fertility traits of Holstein cows are presented in Table 34.2. Herd had the largest effect on the variation for all the fertility traits, with the exception of DO, evaluated in this study. This is probably because of management factors such as the calving down process (dystocia, disinfection of the uterus, a clean calving down area), applied voluntary waiting period, heat detection rate and inseminator proficiency.

Table 34.2. Estimated least square means of the effect of herd, calving year, calving season and lactation number on fertility traits in South African Holstein

	Fixed effects			
Traits	Herd	Calving year	Calving Season	Lactation number
Interval calf to first AI date (d)	<u>2598201</u>**	118646**	25816**	75173**
Days open (d)	1259070**	<u>2273999</u>**	21501[1]	331422**
Services per conception	<u>1473.7</u>**	1059.9**	27.9[1]	34.1[1]
First service < 80 days-in-milk	<u>487.6</u>**	41.4**	6.1**	11.8**
Pregnant < 100 days-in-milk	<u>119.7</u>**	25.4**	9.2**	14.7**
Pregnant < 200 days-in-milk	<u>196.9</u>**	37.3**	7.5**	32.3**

**P < 0.01; *P < 0.05; [1]Not significant

The effect of herd and calving year on the interval traits CFS and DO is presented in Figure 34.1. Large differences were found between herds, i.e. minimum and maximum intervals were 75 and 142 days for CFS and 115 and 185 days for DO, respectively. Over years, the largest increase (3.5 days) in CFS occurred from 1991 to 1994. From 1995 the interval CFS did not change over time probably indicating herd managers not being able to improve this trait or that managers had accepted this level of reproductive performance. The interval DO increased from 127 days in 1991 to 153 days in 2006 with the largest increase occurring from 1991 to 1998 at 2.1 days per year. These results suggest that farmers have adopted a specific strategy regarding the VWP and insemination protocols to maintain a DO interval of about 147 days. In the USA the number of days open in Holstein and Jersey herds increased from 126 days in 1976 to 169 days in 1999.

(a)

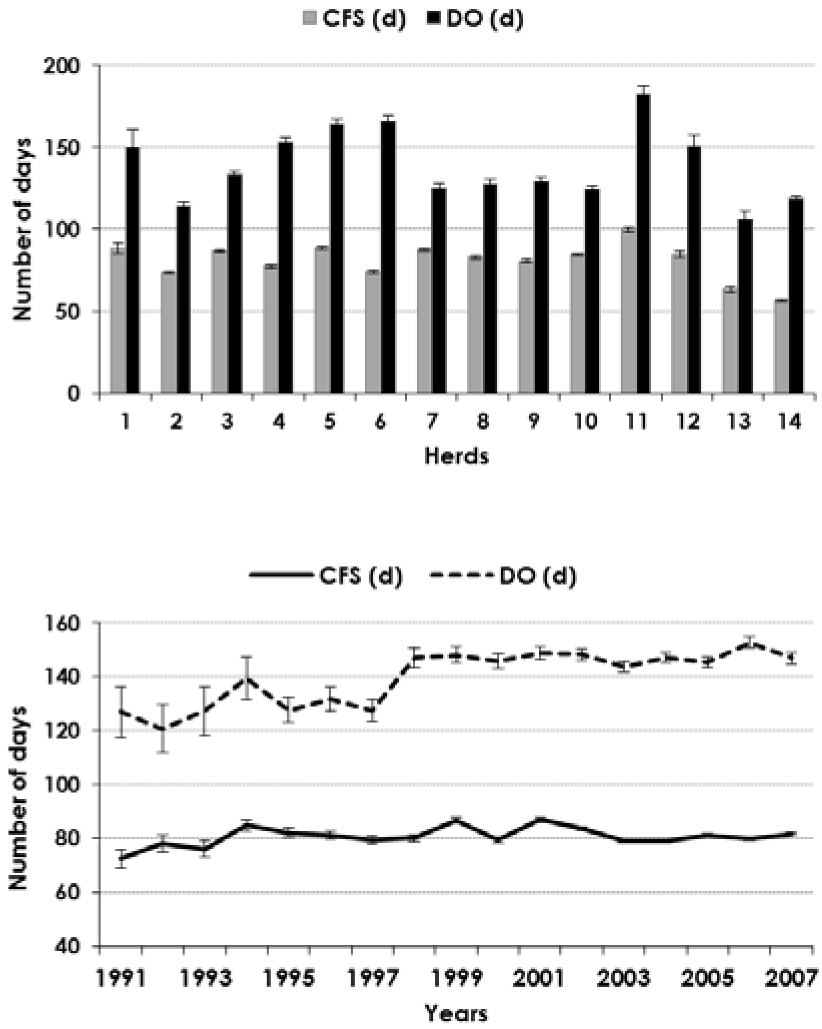


Figure 34.1. The effect of (a) herd and (b) calving year on interval traits for calving date to first service date (CFS) and days open (DO)

Extended DO intervals could be because of a conscious decision by managers to postpone the first insemination after calving possibly to save on insemination costs. This, however, resulted in extended lactations causing a loss in milk income towards the end of the lactation especially for cows with a low milk yield persistency. The interval from calving to first service and DO intervals were both affected by lactation number, although differences were small. The average number of days for CFS decreased from 84 to 79 days from lactation 1 to lactation 3. The reason for the observed longer CFS for first lactation cows is not clear; however, physiological stress of first calving could affect their reproductive performance while cows continue to grow during their first pregnancy, therefore having to partition dietary energy intake between maintenance, growth, lactation, and reproduction.

The effect of herd and production year on the number of services per conception (SPC) is presented in Figure 34.2. Large differences were observed among herds, i.e. minimum to maximum values for Herds 7 and 6 were 1.9 and 3.3 SPC, respectively. For production year, a linear trend ($P < 0.01$) was observed from 1992 to 2006, with average number of SPC increasing from 2.1 to 2.9.1. Specifically, from 1998 onwards the insemination efficiency was below 40%.

(a)

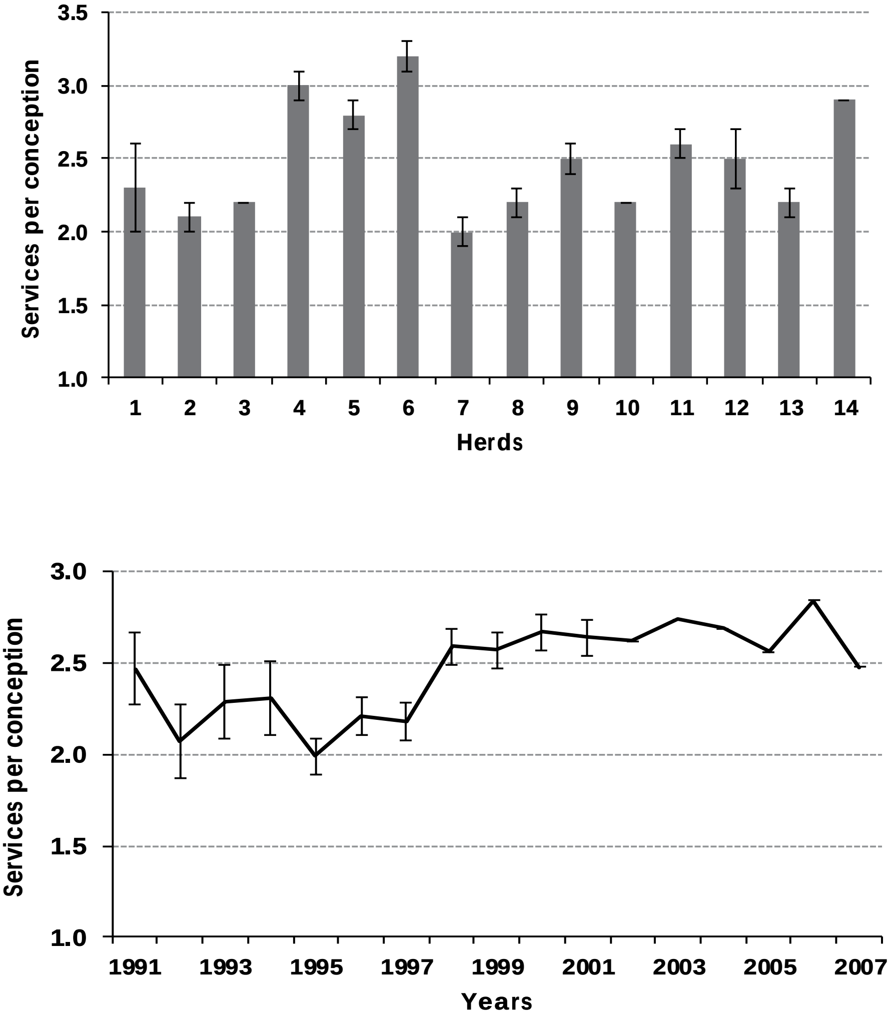
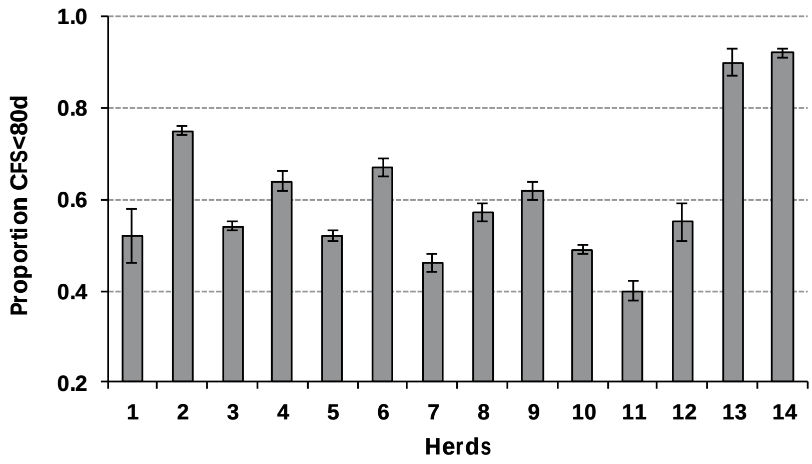


Figure 34.2. The effect of (a) herd and (b) calving year for the number of services per conception for all cows in 14 Holstein herds

The number of services per conception was lower during the cooler months of the year, i.e. from April to September with the higher number of services per conception observed in the summer, i.e. from October to March. According to an Australian survey, herds showing an average SPC above 2.32, indicate herd reproductive problems. The number of services per conception was higher than 2.32 in seven of the 14 herds surveyed in the present study.

Overall, the percentage of cows that were inseminated for the first time within 80 post-partum (FS80d) differed ($P < 0.05$) between herds being 64% on average (Figure 34.3). For Herds 11 and 14 FS < 80d was 39% and 93%, respectively, indicating substantial management differences between these two herds. Over the years evaluated, the percentage of FS < 80d after calving, followed a downward trend from 77% in 1991 to 56% in 2007. This indicates that fewer heats were observed (poor heat detection) or fewer cows showing heat early in the lactation period (possibly a decline in genetic merit for fertility). Although small, FS < 80d percentage increased by parity, i.e. from 56% for first parity cows to 62% for third and fourth parity cows. This is a positive result because of a general perception that older cows, usually producing more milk, would be prone to show first estrus later after calving. Data from this study do not support that perception.

(a)



(b)

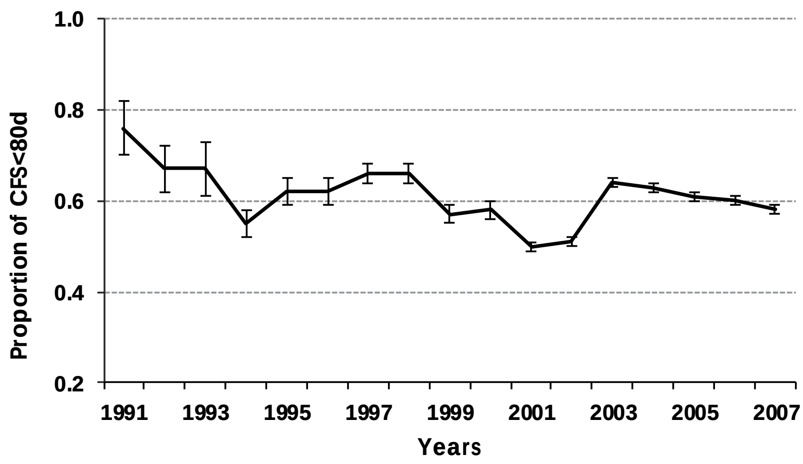
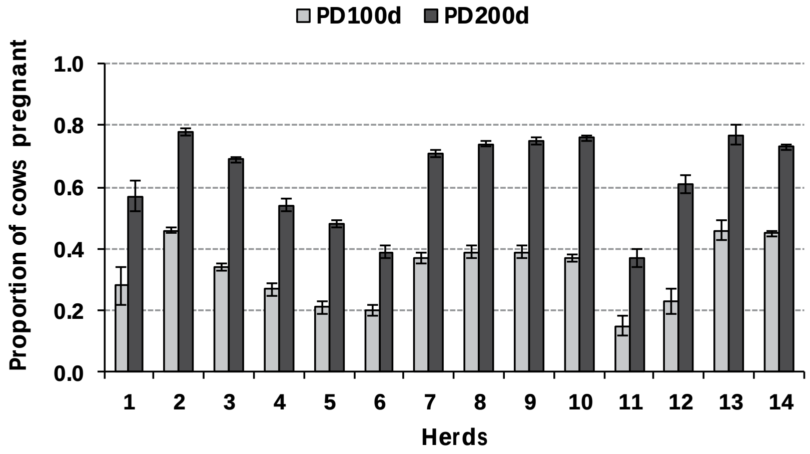


Figure 34.3. The effect of (a) herd and (b) calving year on the proportion of first services conducted within 80 days post-partum (FS80d) in 14 Holstein herds

The percentage of cows confirmed pregnant within 100 and 200 days post-partum, as affected by herd and year of calving, is presented in Figure 34.4. On average, the percentage of cows confirmed pregnant by 100 and 200 days post-partum was 36% and 71%, respectively. Relatively large differences were observed between herds, i.e. the minimum and maximum values were 14% and 45% for PD100d and 38% and 75% for PD200d, respectively. Even at the higher end (indicating better managers for this group of herds), observed results were lower than those found in an Australian survey. Part of the differences between herds could arguably be ascribed to deliberate changes in reproductive management.

(a)



(b)

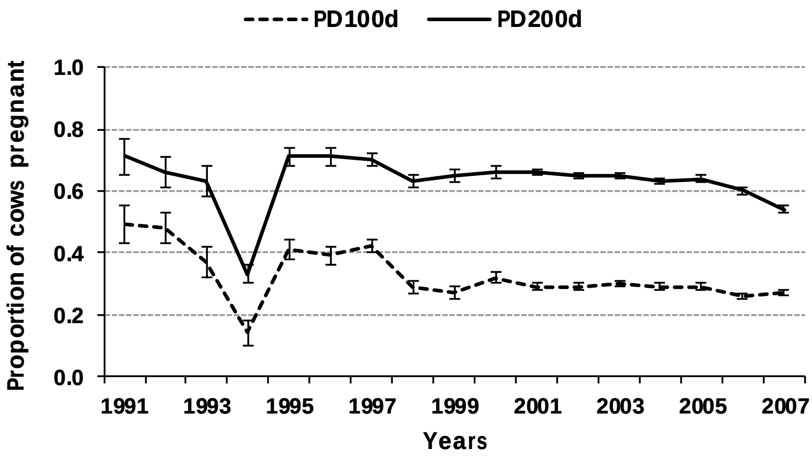


Figure 34.4. The effect of (a) herd and (b) calving year on the proportion of cows confirmed pregnant within 100 (PD100d) and 200 (PD200d) days post-partum for 14 Holstein herds

The percentage of cows confirmed pregnant within 100 days post-partum decreased from 44% in 1991 to 27% in 2007. Although fewer cows were confirmed pregnant by 200 days post-partum in 2007 in comparison to 1991, i.e. 55% vs. 68%, this reduction was not significant.

The percentage of cows confirmed pregnant within 100 and 200 days post-partum differed between seasons of calving. Cows that calved from January to September showed higher percentages of pregnancy 100 days post-partum than cows that calved from October to December. A number of US dairy farmers deliberately do not breed cows during parts of the summer to prevent a reduction in pregnancy rate. There is no evidence that local farmers use a similar practice.

A survey of 19 Holstein-Friesian dairy herds in Ireland showed that fertility performance was generally poor, with the interval to first service being 84 days, and first AI success rate was only 41%. In the present study, first AI success rate varied from 24% to 50% between herds. The 100-day in-calf rate was 46% and CI 404 days. Irish researchers noted that the major cause of poor reproductive performance in dairy herds was the prolonged interval to first service and the poor success rate of first AI. The result of this is that only 46% of cows were confirmed pregnant by 100 days-in-milk, although this varied considerably between herds, i.e. 16% to 71%. Other researchers found first AI success rates of about 40% and 48% in seasonal New Zealand and United Kingdom Holstein cows, respectively.

In closing

These results provide a first preliminary indication of the standard of reproduction management in South African Holstein herds. Reproduction traits were significantly affected by all the fixed effects considered, with herd (presumably an indicator of managerial and inseminator skills) having the largest effect. Interval traits showed an increase over time, although reaching a plateau of 80 days for the interval CFS and 140 days for DO probably indicating a large management effect on these traits. The effect of season on the success rate of inseminations should be studied further, once more data is available. It is evident that the fixed effects considered should mostly be included in analyses aimed at estimating genetic parameters for these fertility traits to ensure unbiased parameters.

CHAPTER 35

THE FLOW OF ANIMALS IN A DAIRY HERD

Introduction

The flow of animals in a dairy herd refers to the continuing process of cows annually calving down to start a new lactation period or milk production phase and heifers entering the herd as first lactation cows. At each calving down event, heifer or bull calves are born. On most farms, except for breeders raising bulls to be sold for breeding purposes, bull calves are sold soon after birth. Heifers, on the other hand, are usually reared to replace cows that are culled from the herd. As the number of heifers being born in the herd usually outnumbers cows leaving the herd, herd expansion, i.e. growing in number, occurs naturally. When herd expansion does not take place, usually one of two problems occur in a dairy herd, namely the cull rate of cows is too high or too few heifers reach first calving. When herd expansion has to be stopped because of limited farm size, surplus heifers can be sold to other dairy farmers who are in need of expanding their herds or in maintaining herd size. Therefore, in herds with low cow culling rates, not all heifers have to be reared to first calving. In such instances, beef sires can be used on some cows in the herd in a terminal crossbreeding programme to increase the beef output of the herd.

On most intensive dairy farms in South Africa, the culling rate of cows is high, forcing farmers to rear all heifers to first calving or, in worst case scenarios, having to purchase heifers to maintain herd numbers. When this happens, the reproduction management and culling strategies of a dairy farm should be evaluated to determine the reason for this as high cull rates increase the cost of production. This is usually the result of a higher veterinarian cost, high cull rates, and cows in the herd not surviving to 5th or 6th lactation to reach higher milk yields, while all heifers born in the herd must be reared to first calving thereby reducing the effect of selection. While many farmers are mainly concerned about the survival of heifer calves from birth to weaning, very few know how many heifers are lost between weaning and first calving.

The impact of factors affecting the number of cows in a dairy herd is not always clear as cow and heifer numbers are always changing. Age at first calving affects the ratio of heifers to cows in a dairy herd with the proportion of heifers increasing when first calving is later than 24 months of age. Some factors affecting the number of cows in a herd include the following: the proportion of cows in the herd calving down each year, the proportion of cows remaining in the herd (opposite of the culling rate of cows), heifer to bull ratio, and survival of heifers from birth to first calving. The effect of these factors on the number of cows in a herd is demonstrated by using a simple model:

1. The number of progeny born in a specific year is estimated by multiplying the number of cows in the herd by the percentage of cows calving down in a year.
2. The bull to heifer ratio (usually 50:50) determines the number of heifers born.
3. Because some cows are culled during year one, fewer cows calve down in year two.
4. In year three the number of heifers born in year one that survived rearing to first calving is added to the number of cows in the herd.
5. This number of cows determines the number of heifers born from year three onwards.
6. From this point onwards the herd increases in size.

By changing each of these factors by - 10% or + 10%, the effect on the final number of cows in the herd can be shown (Table 35.1).

Table 35.1. The effect of factors affecting the number of cows in a dairy herd over a 9-year period from a base herd of 100 cows

Factors	Standard herd proportions	- 10% to standard herd		+ 10% to standard herd	
		Number of cows	Annual change (%)	Number of cows	Annual change (%)
Cows calving down (%)	0.85	181	9.0	263	18.1
Cows remaining in herd (%)	0.80	126	**2.9**	363	**29.2**
Heifer to bull ratio (%)	0.50	179	8.8	260	17.8
Heifer survival (%)	0.75	182	9.1	263	18.1

The sensitivity test indicates that the number of cows being culled each year has the largest effect on the number of cows in the herd in year 10 (figures in bold in Table 35.1). By decreasing the proportion of cows remaining in the herd by 10% the annual increase in cow numbers is about 3% while a 10% increase results in an annual increase of about 29%. In contrast, other factors have a smaller impact on cow numbers in year 10.

Cull list

Keeping a cull list of all the animals leaving the herd enables farmers to establish the reason(s) for culling cows and heifers. From this information, management practices can be adjusted to prevent cows being lost from the herd. Cows are lost when they are culled for involuntary reasons, i.e. for preventable reasons. Research has shown that reproduction management is one of the major factors that affect the culling rate of cows as well as the survival rate of heifers to first calving as cows and heifers not becoming pregnant are culled because of infertility.

A cull list for a dairy herd should contain the following information: cull date, name or number and birthdate of the animal, recent calving date and lactation number of cows, the number of cows and animals (heifers and cows) in the herd, as well as the reason for culling.

In Table 35.2, the distribution of cull reasons for culled dairy cows and heifers from a dairy herd over a 10 year period is presented. As expected, the main reason for culling cows and heifers is reproduction, i.e. animals not becoming pregnant. Almost 42% of culled heifers die at an early age, on average 4.3 months of age. This is confirmed by the distribution of the age of culling of heifers presented in Figure 35.1 showing that most (36%) of culled heifers are lost before they reach six months of age. A large proportion (24%) of culled heifers is also lost between 18 - 24 months of age, while 14% of culled heifers are lost after 24 months of age. These culls are mostly due to heifers not becoming pregnant as indicated by the average age at culling of heifers as indicated in Table 35.2.

Table 35.2. The distribution of cull reasons for culled dairy cows and heifers from a dairy herd over a 10 year period

Cull reasons	Dairy cows (%)	Lactation number at culling	Heifers (%)	Age at culling (m)
Reproduction	52.9	3.1	43.4	23.4
Died	14.9	3.6	41.8	4.3
Mastitis	13.1	3.9	-	-
Sick	9.5	3.8	6.6	5.0
Production	5.5	1.1	0.5	16.1
Injuries	3.0	3.9	6.1	7.1
Unknown	1.0	6.0	1.5	13.6

This indicates that heifers were provided all opportunities to become pregnant. It is important that the correct reason for culling cows is recorded, e.g. cows being sold for breeding purposes are not regarded as involuntary culls. This should, however, not include cows being sold rather than going directly to the abattoir.

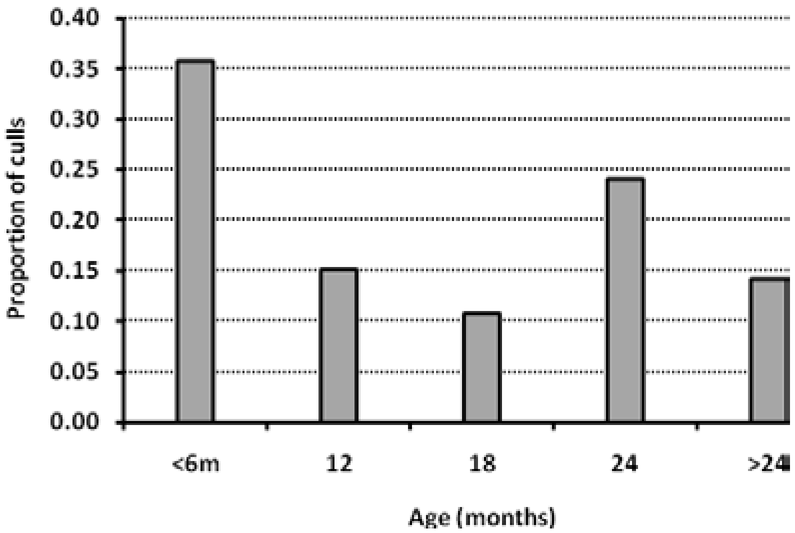


Figure 35.1. The proportion of the age of heifers being culled from a dairy herd over a 10-year period

Reproduction performance of heifers in commercial herds

In a recent survey, the standard of reproduction management for heifers in 11 Holstein and 5 Jersey herds in South Africa has been established (Muller *et al.*, 2014). Birth and service records of 2435 Jersey and 10637 Holstein heifers were collected and compared between breeds. Age at first service was earlier for Jersey heifers than for Holstein heifers (Table 35.3) with a larger proportion of Jersey heifers inseminated before 15 and 18 months of age. This resulted in an earlier age at first calving, i.e. 26.4 vs. 29.4 months for Jersey heifers. A greater proportion of Jersey heifers calved down before 27 months of age, i.e. 79 and 36% for Jersey and Holstein heifers, respectively. A high conception rate was achieved in both breeds. This possibly indicates that a large proportion of natural services were used to get heifers pregnant as only one service record is recorded once pregnancy is confirmed.

Table 35.3. Mean (± standard deviation) reproduction parameters for heifers in 5 Jersey and 11 Holstein herds (Muller *et al.*, 2014)

Parameters	Jersey herds	Holstein herds
Age at first service (months)	16.8 ± 8.1	19.3 ± 4.8
AFS < 15 months of age (%)	65 ± 48	10 ± 30
AFS <18 months of age (%)	88 ± 33	47 ± 50
Age at first calving (months)	26.4 ± 8.6	29.4 ± 5.2
AFC < 24 months of age (%)	45 ± 50	7 ± 25
AFC < 27 months of age (%)	79 ± 41	36 ± 48
Services per conception	1.55 ± 0.91	1.50 ± 0.96
First service success rate (%)	64 ± 0.48	70 ± 46

These results show breed differences in fertility traits. These results could be used as benchmark figures for dairy farmers, while genetic parameters for fertility traits for heifers could be estimated.

The distribution of age at first service for heifers is presented in Figure 35.2 showing more Jersey heifers being inseminated before 15 months of age. While in Holstein herds only 10% of heifers were inseminated before 15 months of age, more than 60% of Jersey heifers were inseminated before 15 months of age. More than 30% of Holstein heifers were inseminated after 20 months of age in comparison to only 10% of Jersey heifers. This probably explains why only 7% of Holstein heifers calved down before 24 months of age, while 45% of Jersey heifers calved down before 24 months of age. This may indicate different approaches by dairy herd managers to heifer rearing affecting the age at first service.

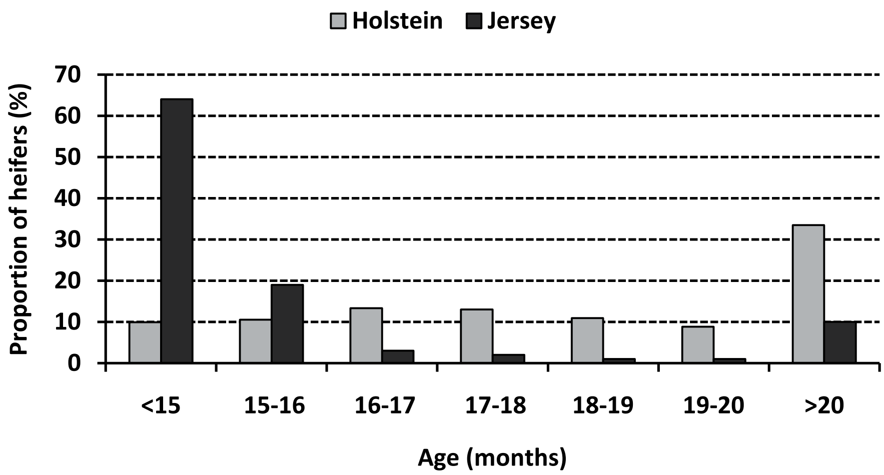


Figure 35.2. The distribution of age at first service for heifers in 5 Jersey and 11 Holstein commercial herds (Muller *et al.*, 2014)

Do an own herd analysis

Farmers should, on a regular basis, at least monthly or after each herd veterinarian visit for pregnancy checks, evaluate the pregnancy status of heifers. This can be done according to a list of heifers containing the following information: name or number of heifer, birth date, first and last service date, and whether she is pregnant or not. Sorting such list according to age, the following information can be obtained:

- the number of heifers in the herd,
- average age of heifers in the herd (this increases with a later age at first calving),
- age at first service (birth date and first service date interval),
- age at conception (birth date and last service date interval when confirmed pregnant),
- expected age at first calving (last service date plus a gestation period of 280 days),
- the number of services per conception,
- the proportion of heifers serviced before 14 and 15 months of age,
- the proportion of heifers conceived before 15 and 18 months of age,
- the proportion of heifers with expected age at first calving before 24 and 27 months,
- breeding interval (age at conception minus age at first service divided by services per conception minus one), and
- heat detection efficiency (21 divided by breeding interval).

While sorting such a list for age of heifers, blank spaces in the different columns indicate very easily which heifers have not been serviced at least once or are not pregnant, while the breeding interval gives an indication of heat detection efficiency. Summing all the services for all heifers (pregnant or not) and dividing this number by the number of confirmed pregnancies, gives a so-called all services per conception figure. This is an important indicator as this also includes all services of heifers that are not pregnant yet.

In closing

The flow of animals in dairy herds affects the number of cows in a herd which is highly correlated to dairy farm profit. Parameters required to estimate the number of cows in a herd include the proportion of cows in the herd calving down, the proportion of cows staying in the herd (the inverse of cow cull rate), heifer to bull ratio, and the proportion of heifers surviving to first calving after two years of age. The cull rate has the largest effect on the flow or internal herd growth rate of cows in the herd. Cows are culled for a number of different reasons. To determine ways to reduce culling rates, a list of animals leaving the herd (herd cull list) should be kept up to date. Indicators that show a loss in farm income are the following: age at first calving past 24 months of age, a high number of first lactation cows in the herd (indicating a high replacement rate), a high average number of days-in-milk (DIM) of lactating cows (indicating a larger proportion of cows in late lactation), and a low average lactation number for all the cows in the herd (indicating a high replacement rate resulting in a so-called young herd). A herd with a larger proportion of older cows produces more milk per day than a so-called young herd.

CHAPTER 36

USING TECHNOLOGY IN REPRODUCTION MANAGEMENT OF DAIRY COWS

Introduction

Reproduction management in dairy herds has come a long way since bulls were mainly used to get cows pregnant. Usually a bull was bought every second year from a neighbour who had a registered herd (with a breed society) and was showing cows. Such a herd was considered to be above average genetic merit. In the early years, it was also common to share bulls among farms. Using bulls has always come with some danger, as they tend to become aggressive with age, asserting themselves within the herd. Sire selection was mostly based on the conformation traits of their daughters. Later on, the production performance of bulls was estimated based on the performance of their daughters in bull progeny testing programmes. The artificial insemination (AI) industry was developed to prevent the spread of infectious reproductive diseases among dairy cows and herds. Following the development of the AI industry, came the estimation of genetic parameters and breeding values for production traits for cows, heifers and bulls. Artificial insemination gives dairy farmers the opportunity to use bulls from all over the world at a fraction of the cost of keeping a bull, while ensuring a high genetic merit dairy herd. Although the genetic merit of a large number of production traits are being estimated for bulls, farmers do not select bulls on production parameters. On most dairy farms a so-called mob-up bull is being used to get cows pregnant or to use on heifers that are being kept a distance from the dairy.

Although most cows are fertile, i.e. they will come in heat, show signs of heat and will get pregnant when serviced by bulls, poor reproduction management has resulted in cows seemingly becoming increasingly infertile. This is mostly because of the application of poor reproductive techniques with regards to heat detection and insemination by people. This problem is exacerbated by herds becoming larger and cows producing larger quantities of milk, making cows seem less fertile. Research has shown that under good reproduction management high producing cows have the same reproductive performance than lower producing cows.

Applying technology in reproduction management

In some situations, reproductive technology can be applied to improve the reproductive performance of a herd (Seidel, 2011). This is usually done to get heifers and cows pregnant as close to the optimal time as possible. This means heifers that are not pregnant at about 18 months of age, require some help towards a confirmed pregnancy. This is to prevent extending the age at first calving of heifers. The same applies for cows in milk on reaching a specific lactation stage (number of days after calving), i.e. 150 - 200 days after calving. The reason for this is the major negative economic effect of the non-productive stage of a cow's life being the growth phase of heifers from birth to first calving and the dry period of cows following each lactation period. The feed cost of the lactating cows in the herd amounts to about 50% of the total cost of production, while rearing replacements accounts for about 23% of the cost of producing milk. Because milk production of cows accounts for about 88% of the gross income of a dairy farm, much attention is going into getting cows pregnant. The milk production of cows per day of the calving interval gives a simple indication of the effect of reproductive problems in dairy cows. With present day high genetic merit cows for milk yield, it is possible to extend the lactation period past the normal 300-day lactation period while keep the dry periods at about 50 - 60 days. However, the extension of the lactation period occurs at the time when the milk yield of cows is naturally low. The efficiency of lifetime milk yield is reduced because of low milk yields during the extended period. Extending lactations usually happens when it is difficult to get cows pregnant soon after calving, i.e. past 100 days in milk. Shortening the calving interval, or the interval from calving to conception (days open), reduces the average days in milk for the herd and, consequently, a greater proportion of cows would be in an earlier stage of the lactation period when peak yield and greater income over feed cost occurs.

Different reproductive technology tools

Using reproductive tools involves two systems, namely, changing the genetic merit of fertility in dairy cows and/or using hormonal treatments in dairy cows to stimulate and control the reproduction cycles of dairy cows. Both these systems should be applied simultaneously within a herd.

Genetic merit

Changing the genetic merit of a dairy herd is a long-term process and involves (1) the selection of the most fertile cows, and (2) improving the herd's genetic merit for fertility through sire selection. The most fertile cows are those that have become pregnant soon after calving, i.e. a short interval between calving and conception (days open) requiring only a few inseminations per conception. This, however, requires good management with regards to the voluntary waiting period during which the uterus must recover after pregnancy and the calving process. At present, improving fertility within a dairy herd mainly involves culling cows not becoming pregnant at all or only becoming pregnant towards the end of the current lactation period. Maintaining a high standard of reproductive management in a dairy herd would prevent cows being culled for infertility.

Fertility parameters in bulls are reflected in the reproductive performance of their daughters. Traits like daughter pregnancy rate, service sire calving ease, daughter calving ease, and productive life are commonly being used overseas. In South Africa, calving interval and age at first calving are being used as fertility indicators (Mostert *et al.*, 2010). Both these traits are affected strongly by management factors, while estimating breeding values for fertility traits requires information on services dates and pregnancy check results of cows, as the interval from calving to first service and the interval from calving to conception give a better indication of fertility in dairy cows.

Research conducted at Elsenburg showed, in a survey among Holstein dairy herds, that the mean interval from calving to first service was 77 days, while 64% of first services occurred within 80 days after calving (Mostert *et al.*, 2010). In 10% of lactations first service was more than 120 days post partum. The eventual conception rate was high (85%), and the interval from calving to conception (days open) was high (on average 134 days), while in 22% of lactation periods the days open interval was more than 6 months. For these cows, the following calving interval would be more than 15 months. In only 36 and 71% of lactations cows became pregnant within 100 and 200 days after calving, respectively. Heritability estimates for the interval from calving to first service, days open and number of services per conception were 4%, 8% and 10%, respectively. While these values are low, they are in agreement with overseas research results indicating that selection based on these traits would improve fertility, although the response would be slow. The genetic correlation between the interval calving to first service and days open was positive meaning that a late first service resulted in a longer interval from calving to conception while the genetic correlation with pregnancy success was negative. To get information for these traits, records on calving down dates, insemination dates and pregnancy check results have to be included in a national data set. For sire selection, modern day dairy farmers use an appropriate selection index which usually includes fertility traits.

Reducing dystocia through improving calving ease has progressed considerably over the last few decades as the effect of calf size on the uterus recovery has been demonstrated under practical farming conditions. For AI, sires' information is available on calving ease and daughter pregnancy rates. Calving difficulty can be further reduced by making pelvic measurement on heifers and culling the few with the smallest pelvic measurement. Adequate nutrition and attention to age and live weight at breeding are also essential to reduce dystocia in heifers. These measures further eliminate the wasteful practices of a late calving age or using a small sire breed like Jerseys on heifers.

2. Assisted reproduction programmes

There are a number of reproductive technology tools that could be used to get cows pregnant (Seidel, 2011). These include tools in routine use, such as AI, vaccination, cryopreservation of semen, readily available hormones, such as progesterone, gonadotropin-releasing hormone (GnRH), prostaglandin, follicle-stimulation hormone (FSH), or ultrasound to determine ovarian status, pregnancy, sexing, and pathology of the uterus. Other tools that may be considered include hormone assays, superovulation, nonsurgical embryo recovery and transfers, cryopreservation of embryos and oocytes, in vitro fertilisation and sperm injection, splitting embryos and transvaginal oocyte aspiration.

The programmes to assist dairy farmers getting cows pregnant are usually applied through the herd veterinarian. The cost implications of using some of these reproductive tools should in all instances be considered carefully especially for commercial farmers. Standard programmes include checking cows on a regular basis, i.e. once a month or for larger herds even once a week, for retained placentas and uterine infections during the voluntary waiting period. This may also include checking cows for heat activity by detecting follicle development. Cows showing no signs of uterine infections could be given a suitable hormone treatment to stimulate heat cycles. When reproduction performance is poor, semen may be tested for sperm viability using a microscope. Further treatments include hormonal programmes for cows to synchronise estrus, or ovulation synchronization, for timed AI. This programme requires no heat detection as cows are inseminated on a timed basis. Optimal procedures require the use of three naturally occurring hormones, progesterone with a controlled internal drug release (CIDR), gonadotropin-releasing hormone (GnRH) and prostaglandin-F-2 alpha. Ovulation synchronisation is used as a catch-up system to inseminate cows that have not been confirmed pregnant by at least 200 days-in-milk. This is an alternative to keeping a so-called mob-up bull to service cows that are not pregnant after a specific breeding programme. These hormonal treatments could also be applied as a standard management practice starting earlier in the lactation period from 100 days-in-milk. This could be applied for all cows or only those have not been inseminated or shown heat by 150 days after calving.

Further ways to use technology in reproduction management include using sexed semen. Commercially available sexed bovine semen at 90% accuracy is now a reality. By using sexed semen the proportion of female offspring increases from the standard 1:1 ratio for heifers and bulls to more than 65% heifers. For dairy herds suffering from high cull rates this may be a way to maintain herd size. This is preferred to buying-in heifers as genetic progress could be affected. Some dairy farmers often use a multi-ovulation embryo transfer (MOET) programme to increase the number of progeny of specific high performing cows. The success of a MOET programme is often questionable specifically with regards to the cost involved.

Most of the reproductive tools listed are in routine use in progressive commercial herds with the rest being used under experimental conditions. Ultrasonography, initially, was only used in research, but is presently increasingly being used by veterinarians to evaluate follicle development, early pregnancy diagnosis and uterine pathology.

In closing

A wide-range of reproduction technology programmes is available for dairy farmers. Improving the genetic merit of fertility in a dairy herd should be the basis of reproduction management. This should be supported by sound reproduction management involving the early treatment of cows after calving for uterine infections, correct heat detection, and insemination techniques. The application of different hormonal programmes should be used through the herd veterinarian. These programmes should, however, at most be supportive of reproduction management.

SECTION 4

DAIRY CATTLE BREEDING

CHAPTER 37

GENETIC IMPROVEMENT OF DAIRY HERDS

Introduction

Breeding in farm animals is defined as the deliberate improvement of a breed, or herd, or of specific traits. Conformation traits, milk production parameters, fertility, etc. usually receive attention in breeding programmes for dairy cattle. Genetic improvement can only be achieved when better-performing animals than the average of the herd or breed are used (selected) as parents. Because cows make up a dairy herd, it follows that the parent that should ensure herd or breed improvement is the sires that are selected to get cows pregnant. However, in spite of careful sire selection and well-planned breeding programmes, progeny born in a herd may perform better, similar or worse than the original parents. For this reason, it is important that the production of cows is recorded to identify poor performing animals, in terms of the average of the group, and that they are removed (culled) from the herd. This should occur on an on-going basis as not culling poor performing cows would not only have a negative effect on the genetic improvement of a dairy herd, but also on herd income. The selection of better parents and culling of poor performing cows are therefore important cornerstones of breeding. When no selection or culling takes place, breeding becomes animal multiplication usually resulting in little or no genetic progress. Furthermore, genetic improvement of specific traits in a herd would be affected negatively when cows are lost through involuntary culling because of poor management.

Breeding objectives

It is important to describe the breeding objective for a dairy herd as this gives the framework of the selection of sires and culling of cows. A breeding objective should preferably comply with the so-called "**SMART**" principles, i.e. **S** = have a Specific objective, **M** = be Measureable, **A** = be Attainable, **R** = Relevant to other traits, and **T** = Tractable. Production parameters fit all of these principles. Conformation traits often do not comply with these principles as most of these traits are evaluated on a subjective basis. Some conformation traits could; however, be measured to improve the genetic progress, although this may not fit in with the general breeding objective for a higher milk yield. The expected genetic progress could be estimated by the following equation:

$$R = \frac{r * h^2 * S}{L}$$

The components of the equation are as follows: **R** = the expected progress, **r** = accuracy of selection, **h²** = heritability estimate for the specific trait, **S** = selection intensity (the average superiority of the selected animals in comparison to the average performance of the initial group before selection), and **L** = the generation interval. From this it follows that, because in a dairy herd fewer bulls than cows are required, the selection differential is much higher for bulls than for cows in the herd. Sire selection is responsible for more than 80% of the genetic improvement of a dairy herd.

Herd profiles indicating genetic progress

Dairy farmers participating in the national milk recording scheme usually receive a herd profile with regards to the herd's genetic trends for milk, fat and protein production, fat and protein percentage, somatic cell count, calving interval and inbreeding. Comparing these trends to the national herd gives an indication of the genetic progress for a specific herd. A study showed a continuous improvement in genetic merit for milk yield parameters for the Elsenburg Holstein herd (Muller & Botha, 2003). Initially, before 1984, little attention was given to a high milk yield in the herd. At the time, line-breeding to improve body conformation traits or type seemed to have been the main emphasis. In 1984 a breeding policy to improve the milk yield of cows in the herd was adopted. This breeding policy was based on the selection of bulls on their estimated breeding values for milk yield and the culling of poor performing cows during first lactation. Initially, selection threshold values were estimated for first lactation cows based on their 4% fat corrected milk (FCM) and protein yields for the first 90 days of the lactation, as well as completed first lactations. Cows producing less milk than the selection threshold values were culled. From 1978 to 1984, the genetic progress in terms of milk, fat, and protein yields in the Elsenburg herd was 16.2, 0.5, 0.6 kg per year, respectively. During the same period, the genetic change in milk, fat, and protein yield of the national Holstein herd was 42.5, 1.1 and 1.1 kg per year, respectively. This means that the genetic merit for milk yield parameters for Holstein cows in the Elsenburg herd was lagging behind the national breed. From 1984 to 1997, the situation changed, however, with the new breeding objective. The genetic progress for milk, fat and protein yields in the Elsenburg Holstein herd was 92.3, 2.3 and 2.4 kg per year, respectively. In comparison to this the national herd changed by 76.4, 2.1 and 2.1 kg per year, respectively, indicating that the Elsenburg herd was gaining on the breed (Muller & Botha, 2003).

The higher genetic merit of the herd resulted in an improvement in milk, fat, and protein yield of 212.3, 6.9 and 4.9 kg per year, respectively. This means that over a 10-year period first lactation cows produced 2123, 69, and 49 kg more milk, fat and protein, respectively, than at the beginning of the selection period. Overall, the average milk yield of all cows improved by 64% from 5112 kg in the 1983/84 milk recording year to 8360 kg in the 1997/98 year. Fat and protein yields in the herd improved also (189 to 293 kg and 172 to 269 kg, respectively), although by a slightly smaller margin (55%) because of a small (5%) reduction in fat and protein percentages. Even using a negative price for volume, milk income per cow per lactation was 55% higher in the 1997/98 herd than the 1983/84 herd. The total milk production per day also increased, even though fewer cows were milked resulting in a more efficient herd in terms of milk output in comparison to feed input. There was also no negative effect on the reproduction figures in the herd.

Recent estimates indicate that the estimated breeding value (genetic merit) of the Elsenburg Holstein herd is above the national herd genetic merit being 236 vs. 188 kg for milk yield, 10.8 vs. 4.8 kg for fat yield, and 9.4 vs. 5.2 kg for protein yield, respectively.

The genetic improvement of a dairy herd depends on the following factors:

1. **Heritability estimate of traits**
   All traits in dairy cows are the result of the combined effect of genetic and environmental effects. The genetic part of an animal is fixed at fertilisation while variation between animals is further influenced by environmental effects. The heritability (h^2) of traits is indicated as a proportion or as a percentage value. This indicates the proportion of the selection differential that is transferred to the progeny. Genetic effects as indicated by h^2 estimates vary from small to large (Table 37.1). For traits with low heritability estimates (less than 20%), the environment has a large effect on the phenotype. The heritability of milk yield is approximately 25%, while traits like shoulder height, live weight, and chest circumference have heritability estimates of 50, 37 and 41%, respectively. It is generally accepted that traits with higher heritability estimates would show a faster improvement through breeding and selection.

Table 37.1. Heritability estimates for different traits in dairy cows

Trait	Heritability estimate (%)
Fertility	10
Type (conformation)	14 - 35
Milk yield	20 - 30
Milk yield – first lactation	33
Milk yield – second lactation	10
Milk yield – third lactation	24
Fat yield	40
Fat percentage	50 - 60
Protein percentage	50 - 60
Persistency of milk yield	30
Teat length	98

2. **Genetic correlations**
Most traits in dairy cows are genetically related or correlated (Table 37.2). Correlations between traits could be positive or negative. A positive correlation between two traits means that both traits will improve at the same time. In such a case, selection for one trait would result in an improvement in the other trait. A negative correlation, like between milk yield and fat percentage, means an improvement in milk yield usually results in a negative response in the fat percentage, although there is an increase in fat yield.

Table 37.2. The genetic correlation between different traits in dairy cows

Traits	Genetic correlation
Milk yield and fat percentage	- 0.43
Milk yield and fat yield	0.81
Milk yield and type (conformation)	0.05
Fat yield and type (conformation)	- 0.15
Milk yield and shoulder height	0.07 - 0.69
Milk yield and chest circumference	-0.16
Milk yield and live weight	- 0.14
Fat percentage and protein percentage	0.48 - 0.62

3. **Measuring accuracy**
Genetic improvement is possible only when traits can be measured accurately. For instance, body conformation traits are difficult to measure accurately as in most cases subjective ways are used to describe specific traits. For this reason, the general conformation of dairy cows has changed very little although milk yield has increased substantially over the last 30 years. The reason for this is that milk yield and milk composition can be measured accurately and repeatedly, making selection for milk yield parameters easy. The trend in the genetic progress for milk yield traits can also be described over time. In contrast to this, the change in body conformation traits over time is difficult to describe.

4. **Number of traits**
Including a large number of traits in a selection programme would reduce the genetic progress for each individual trait. However, it is not recommended any more that single-trait selection be used in dairy breeding as there are a number of economically important traits that should receive attention in a breeding programme. For this reason, multi-trait selection is being used presently. Specific indexes have been developed to simultaneously improve traits such as milk yield, milk composition, fertility, and longevity.

With regards to a selection programme aimed at the improvement of milk production traits the effect of selection for specific traits is shown in Table 37.3. Highest values for traits within rows are indicated in bold. Selection based on milk yield resulted in higher response for milk than selection based on fat, protein or total solids yield. Selection based on fat and protein percentage resulted in a decline in milk yield. There is only a small difference (106 vs. 108) in monetary value when milk vs. protein yield is used as the selection trait. Changing the monetary value of protein to fat, i.e. 70:30, selection emphasis should be based on protein yield rather than fat yield. At the same time, because of a positive genetic correlation, selecting for protein yield would also improve milk and fat yields. Selection for the percentage of fat and protein would not improve yield parameters.

Table 37.3. The change in different milk yield components as affected by selection for individual components

Production components	Selection trait					
	Milk (kg)	Fat (kg)	Protein (kg)	Total solids (kg)	Fat (%)	Protein (%)
Milk	**455**	264	325	366	- 386	- 289
Fat	10.6	**14.5**	10.9	12.4	4.6	4.6
Protein	10.5	8.9	**11.8**	10.6	- 21.3	- 19.4
Total solids	**45.1**	38.1	40.4	44.8	0	2.8
Monetary return (R)	106	103	**108**	104	-	-

Breeding is a long-term process

Dairy cows have long generation intervals, at least four to five years. The present herd is the result of selection and culling processes of sires and cows over the past four to ten years. The first indication of the performance of the progeny of sires selected today will only be observed in four years time from today. This four year period is made up by the initial breeding period of at least two to three months followed by the pregnancy period of about nine months from today before the first heifer calf is born. This is followed by the heifer rearing period of at least two years to first calving after which the lactation period of at least 10 months follows. This is then only the first progeny of a specific bull and at least 20 daughters of that bull are required to observe the bull's breeding value. This means that it would be difficult for dairy farmers to evaluate the performance of a specific bull in their herds, as their operation time is often very short, e.g. often less than 10 years. The estimated breeding values of bulls that AI companies sell already provide enough information on the worth of a specific bull which needs no confirmation by dairy farmers. Breeding values of bulls also include reliability values based on the number of progeny in the progeny testing scheme. Bulls should be used in a dairy herd taking this information in consideration. High reliabilities mean that bulls may be used heavily, while low reliability value bulls should be used with circumspection and at low levels. Because cows are kept for as long as possible in a dairy herd, it means that a poor performing bull in terms of milk yield will have a negative effect on the herd for a long time. The repeatability of the milk yield of dairy cows is also relatively high meaning that daughters of a bull with poor milk production merit will have a lower milk yield than high genetic merit bulls in their first lactation and all other lactations that follows while they are in the herd. It is for this reason that the production performance of first lactation cows should be evaluated and poor performing cows culled before they remain in the herd from second lactation onward.

For a successful breeding programme to affect farm profits the following should be considered:

1. Milk sales are the largest (more than 85%) source of income for a dairy herd. Most dairy processors pay higher prices for protein than for fat. For this reason protein yield should be the most important trait in the selection of sires. There is also a positive genetic correlation between protein yield and fat and protein percentages.
2. While an individual cow contributes 50% of her genetic merit to her immediate offspring, the effect of one cow on the genetic merit of a herd is small. The average cow also only produces two to four offspring in her lifetime. The best way an individual cow contributes to the herd or breed is through the sons that she produces.
3. Corrective mating to improve specific conformation traits in cows should not be done at the expense of the genetic merit for milk yield. Conformation traits should always be of less importance in comparison to production traits. Improving mainly the general conformation of cows in a herd does not imply that milk yield will also improve. The genetic correlation between conformation and milk production is small, about 5%. Presently mating programmes are available to improve both production traits while maintaining most conformation traits. These programmes take into consideration the heritability estimates of traits and their economic contribution towards herd income.
4. A breeding objective should be aimed at the improvement of the herd and not only within family lines.
5. The improvement of specific traits is

dependent on their heritability estimates as this gives an indication of the environmental effect on the phenotype. Large heritability estimates indicate a smaller environmental effect and a quicker response to selection.

6. A group of bulls should be selected for breeding purposes rather than single bulls. Using a smaller number of bulls increases the possibility of poor genetic progress. It is generally recommended that 15 to 20% of cows should be bred with one bull. This means that for a herd of 100 cows at least 5 to 6 bulls should be used.

In closing

Genetic improvement of a dairy herd depends on the genetic merit of sires that are selected to get cows pregnant, as well as culling of cows not performing according to the breeding objective. The genetic merit of a heifer is fixed at fertilisation, while the environment, which includes a large number of factors, affects the phenotypic performance of dairy cows during the lactation. Single-trait selection of sires is not recommended as a number of traits affect the economic performance of cows. For this reason, multiple trait selection using specific indexes have been developed to be used in sire selection. To improve production parameters, selection should be based on protein yield, as this provides the best monetary return.

CHAPTER 38

THE NATIONAL MILK RECORDING SCHEME FOR DAIRY COWS

Introduction

Dairy farmers in South Africa face enormous challenges to produce sufficient amounts of milk to produce dairy products of high quality and quantity to provide for the nutritional requirements of the country. Initially, capturing of milk recording information focused mainly on the phenotypic performance of individual dairy cows. This data was later used in genetic evaluation programmes towards the selection of animals of superior genetic merit. Besides the use of milk recording information for genetic evaluation, the South African performance recording system addresses the needs of herd production tendencies, milk composition, and quality, as well as production efficiency. With the worldwide tendency to larger dairy herds, especially in intensive production systems, more emphasis has recently been placed on information about the relationship between phenotypic values and health traits and nutritional requirements.

Background

Milk recording in South Africa started in 1917. State milk recorders travelled by train to perform milk recording tests on farms. From 1956, the Milk Recording Scheme was conducted on a co-operative basis with 16 co-operatives participating using 63 milk recording personnel, equipped with vehicles, to enable on-farm milk recording. The technical supervision and financial aid in the form of subsidies were provided by the Department of Agriculture. Milk recorders tested, on the farm, a milk sample of each recorded cow for its fat content by means of the Gerber test. This information on the quality and quantity of each dairy cow was then provided to farmers.

During the 1970's, because of the use of more effective milk analysing equipment, the analyses for protein, butterfat and later also the somatic cell count (SCC) and milk urea nitrogen (MUN) contents of milk became possible. Later, because of rising costs, the concepts of centralised milk testing and also owner sampling were started in South Africa. This led to an increased participation in milk recording of cheaper and more effective services. The scheme is continuously evaluated according to international standards and adapted regularly to comply with the changing needs of clients and the latest developments in animal recording and improvement (including breeding value prediction and goal setting). International Committee for Animal Recording (ICAR) accreditation is therefore needed.

Aim of the Scheme

The aim of the Scheme is to promote the biological and economical efficiency of milk production, in acceptable quantities and of acceptable quality, in the national herd by

a. identifying low producing female animals in participating herds and determining the possible causes of their poor production, and their elimination from the herd, if necessary;
b. making the necessary adjustments in management and feeding practices and recommending culling of poor performing producers;
c. estimating the potential producing ability of animals and promoting the use of proven bulls through artificial insemination; and
d. to develop value added products and services in the field of livestock improvement and to promote the use thereof.

The status and results on performance testing: 2001/2002 to 2010/2011

Dairy farmers in South Africa are increasingly under pressure to improve the efficiency of their dairy herds to ensure economic survival. Efficiency is defined as the ratio of output vs. input. It is clear that the term efficiency is meaningless without defining the outputs and inputs of the production system. At any given cost level, the greater the total economic efficiency, the greater the profit margin. The way to achieve maximum economic efficiency of milk production will differ between farms and even from year to year, depending on a large number of factors.

The average production of all dairy cows in milk recording for the decade from 2001/2002 until

2010/2011 is summarised in Table 38.1. During this period the performance data of all recorded animals was still captured on the Integrated Registration and Genetic Information System (INTERGIS). The total amount of completed lactations for this period was reasonably constant, around 115 000, representative of approximately 30% of all dairy cows in the country. However, the production level of recorded lactations were approximately 60% higher than for non-recorded cows.

During this period, the average milk production per lactation improved from 6609 to 6956 kg, while butterfat production improved with more than 10% from 3.73% to 4.17%. The average protein production also improved from 3.28% to 3.47%. These improvements were partially due to better management practices and effective selection decisions by dairy farmers, based on estimated breeding values (EBVs) for these production traits.

Table 38.1. Average production of performance recorded cows for the test years 2001/2002 and 2010/2011

Test Year	Total number of lactations	Milk production (kg)	Fat (%)	Protein (%)
2001/2002	113 652	6 609	3.73	3.28
2010/2011	115 494	6 956	4.17	3.47
Difference	+ 1 842	+ 347	+ 0.44	+ 0.19
% difference		+ 5.0	+ 10.6	+ 4.5

Outline of the scheme

Phase A: Reproduction phase

Reproduction and calving ease traits of cows and bulls are evaluated through insemination records and calving down data.

Phase B: Lactation phase

This consists of the performance of each cow in the Scheme in terms of its (a) daily and (b) total lactation yields for milk, butterfat, protein, and lactose, and lactation somatic cell count and MUN contents. The daily milk yield figures enable members to feed cows according to production level towards improving feeding management. Total yield figures are the basis on which animals are culled, used for commercial purposes or identified as potential dams for breeding purposes. For practical reasons, official milk performance recording is done on a 5-weekly basis on 10 milk recording events over a calendar year. At each milk recording event, the actual 24-hour milk yield of each lactating cow in the herd is recorded. A milk sample of each cow is also collected which is then analysed for fat, protein, lactose, SCC and MUN by a central laboratory at the Agricultural Research Council's (ARC) head office in Pretoria. Total lactation yields are then calculated over a 305-day period. The lactation period can also be extended beyond 305 days in the case of high producing cows. This creates the possibility of determining the lifetime performance of dairy cows. Extended lactations are also standardised to a 305-day period for evaluation purposes. Research has proven that the correlation between daily and 5-weekly production statistics is very high.

The phenotypic value for a specific trait for each animal is measured and therefore available. In using BLUP methodology, it is possible to estimate the contribution of the genetic production ability and the environmental effects that influences actual production for a trait. Genetic improvement for a trait is permanent, while favourable environmental effects only enhance production as long as the circumstances apply. The following equation reflects this hypothesis:

$$V_P = V_G + V_E$$

where V_P = Phenotypic Value for production traits, e.g. milk, butterfat, and protein production,
V_G = Genetic Production Ability for a specific trait, and
V_E = Environmental effects, e.g. influences due to feeding and management practices.

BLUP is the acronym for 'Best Linear Unbiased Prediction'. BLUP is the best available estimation of the 'actual' breeding value of an animal (for most production traits).

BREEDING VALUE (EBV) – Estimated breeding value (EBV) is the BLUP breeding value of an animal and is an estimation of its genetic ability (value) as a parent in a breeding programme. The measurement, e.g. milk yield, of an animal is influenced by the environment the animal is kept in, e.g. herd, rainfall, nutrition, age of the dam, etc, as well as the animal's own genetic potential for milk yield. The animal's breeding value is estimated by:

- Comparing the animal to its contemporaries or group partners, i.e. those animals exposed to exactly the same environmental conditions. The differences between animals is then directly attributable to genetics,
- Using all information available for an animal's relatives, and
- Making use of genetic linking between herds.

Estimated breeding values for traits are presented in the unit that traits are measured, e.g. kg for milk production, etc. EBVs are used to predict how the future progeny of an animal should perform within the breed. An animal's EBVs are based on all the performance and pedigree information of itself and related animals within the INTERGIS database. Within year and analysis, EBVs are comparable to each other. An animal with a breeding value of, for example + 180 kg for milk production, will genetically be a higher producer than an animal with a breeding value of +20 kg, regardless of the environment they are kept in.

As more information about an animal's performance becomes available, its breeding value becomes more accurate. Accuracy varies between 0 and 99%. The accuracy of every EBV will depend on the reliability and completeness of performance records and pedigree information. It is a function of the heritability of the trait as well as the contemporary group composition and group size. It is therefore essential that all information should be recorded as precisely and accurately as possible. The more accurately data is recorded, the more reliable breeding values will be estimated to enhance accurate selection of superior animals.

The genetic profile for each herd, as well as the genetic trends for the measured and available traits, is presented to the farmer in the form of a herd profile document. This information enables the farmer to accurately select superior animals based on his selection criteria. The genetic profile also reflects the inbreeding coefficient of every animal, as well as the inbreeding level of the herd and the breed as such. It is therefore possible to manage inbreeding by applying corrective mating where necessary.

General routine for milk recording

Organisation in respect of a milk recorded herd.
Each member must apply for membership of the National Dairy Animal Improvement Scheme and supply his address and any other particulars that may be required, regarding the farm and parlor on which the scheme will be applied. All the cows of the same breed on this farm will constitute a single recorded herd.

Equipment
Only milking machines and milk meters, or similar apparatus officially approved by international standards, may be used. The milk meters must be calibrated to the nearest 0.2 kg and must be able to take a representative milk sample.

Determining the mass of milk
Lactation results are based on twice (2X), three times (3X), and more milking sessions per day. Cows are classified as milked 3X if they have had one or more 3X milking sessions and the herd will be classified as a 3X milked herd if more than 40% of the cows are milked 3X.

Collecting and testing of milk samples
The mass of milk will be measured to the nearest 0,2 kg and a minimum of 2 kg of milk is required to qualify for an official test. A sample consists of 28 millilitres of milk in a sample bottle with a preservative. This sample will be tested for a minimum of butterfat, protein and lactose, but also for somatic cell count and MUN if required. The single sample will be projected to a composite 24 hour value using a formula that takes into account the hours in-between each milking and the ratio of the kilograms of milk produced at each milking. Only lactations with five or more tests will be considered as official. Lactations with less than five tests will be marked as unreliable.

Calculation of performance

Lactation milk yield:

Using the standard lactation curves estimated for each breed, each age group and each season of calving, a daily production is determined which is used to determine the projected 305-day milk yield for each cow.

Lactation butterfat, protein and lactose yield:

Each test carried out contributes to the estimation of butterfat, protein and lactose yield. Butterfat, protein and lactose yields are calculated by multiplying the total mass of milk recorded for the period by the percentage of butterfat, protein and lactose for the period, divided by 100.

Lactation butterfat, protein and lactose percentage:

The total milk, butterfat, protein and lactose yield are used to estimate the butterfat, protein and lactose percentages for the lactation, as obtained in the calculations for production traits.

Herd averages:

Herd averages are estimated for each test year, using the 305-day projected lactations. Herd averages include, amongst others, the following:

- Average milk yield for 305 days;
- Average butterfat yield and percentage for 305 days;
- Average protein yield and percentage for 305 days;
- Average lactation length (days in milk);
- Average age at first calving (months);
- Average calving interval between 1st and 2nd calving dates;
- Average calving interval for all the cows in the herd;
- Average somatic cell count (SCC); and
- Average milk urea nitrogen (MUN).

Feedback to participants

Great improvements have been made in the past few years in making performance and registration data in various forms available to participating farmers through INTERGIS (with the following website address: www.intergis.agric.za). Various programmes have also been put in place in INTERGIS to assist in the efficient running of IRIS. Several outstanding reports, in addition to the IRIS reports, have been generated, and are of great assistance to farmers towards improving their standard of management. The following information is provided following milk recording:

1. With every completed lactation, a comprehensive certificate will be generated indicating the production levels for milk, butterfat, protein, intercalving period (ICP), somatic cell count (SCC), updated lifetime production, as well as a complete 3-generation pedigree of the animal.

2. Following every official milk recording, the following reports on production performance are available:

    a. Summary of the test day data. This includes results on the average and total production, as well as the predicted 305-day average for each cow.
    b. A production report (animal report) for all cows tested on that specific day. The focus is on total production of each cow at that stage of the lactation as well as the projected 305-day production data. This information provides the opportunity to select or cull a cow at a relatively early stage of the lactation, since gross income per cow is also calculated.
    c. In addition to the official reports mentioned above, numerous relevant reports are also available through INTERGIS. There are two distinct categories, namely:

       Reproduction and Performance related reports. The following reproduction reports are available :

       i. Herd reproduction report
       ii. Herd status report
       iii. Descriptive reproduction report

       The following performance related reports are available :

       i. Breeding herd selection report
       ii. International breeding values for bulls
       iii. BLUP blood hound (searching tool for specific bulls)

3. Herd averages over a test year period (calendar year) within breed, region and age groups are available each year. It is therefore possible to evaluate a herd's performance against other herds within a

region and on a national basis.

4. Recently more emphasis was placed on information regarding the relationship between phenotypic values, health traits, and nutritional requirements. The intensive production systems in the dairy industry demand creative, dynamic, and interactive reports, to ensure economic sustainability for dairy operations. Therefore, it was necessary to develop more advanced functionalities in the management programme, to assist dairy farmers in timely decision making in improving cow efficiency. State of the art technology was used to develop these functionalities. These functionalities enable the farmer to get more practical information from milk recording data, with a specific focus on economically important traits such as SCC and MUN. This information is also available in INTERGIS through Livestock Manager.

In closing

Participation in the National Milk Recording Scheme includes the following benefits:

1. The Scheme makes use of modern technology when production data is calculated to be utilised in farm management decisions. It incorporates accurate projections based on both own individual cow and herd data.
2. The actual production per lactation for milk, fat and protein, factors affecting the milk price, are calculated for each cow. Efficient producers are identified for use in future breeding programmes, as well as poor performing cows reducing herd profits.
3. The genetic potential of animals is determined through BLUP breeding values. Based on this, cows could be directly evaluated within the breed across herds.
4. Herd genetic trends over production years are determined giving an indication of the herd's genetic progress for production parameters.
5. By using breeding values and genetic trends, a well-planned breeding policy can be applied in order to meet future market requirements.
6. Health problems within the herd can be monitored through analysing the somatic cell count (SCC) of individual cows.
7. The feeding status of cows can be monitored through analysing milk samples of individual cows for milk urea nitrogen (MUN).

CHAPTER 39

SIRE SELECTION IN DAIRY HERDS

Introduction

The genetic merit of sires for all traits is based on the production performance of their daughters. This can only be established in a structured progeny testing programme. This is usually done on a national scale as a minimum number of female progeny has to complete at least a first lactation in as many herds as possible. Semen from test bulls in the progeny testing scheme is handed out or sold at a minimum price to dairy farmers who then uses the semen servicing cows randomly in their herds. The production performance of all the female progeny of a specific bull is recorded and the bull's genetic merit estimated from this information. In addition, all information of cows related to a specific bull is also included in the estimation of his breeding value. A larger number of daughters increase the reliability of estimated breeding values (EBVs) for sires. It would therefore be difficult for individual farmers to determine the genetic merit of home-bred or herd bulls. An additional problem is the long generation interval in dairy cows, being about five to six years. The result of a decision to use a specific bull in a herd can only be observed after at least four years when the first daughter of a bull has completed her first lactation. Because of this long interval, it becomes a big risk to use bulls of unknown breeding value as their progeny would remain in the herd for a number of years. Therefore, semen from sires tested by artificial insemination (AI) companies should be used for breeding. A large number of sires are selected and tested annually and farmers should preferably use bulls that have recently completed their progeny testing programme, as they generally have higher breeding values than older bulls. A larger number of progeny may affect the EBVs of sires positively or negatively while also increasing the reliability of their EBVs.

Breeding objectives

Most dairy farms are highly intensive operations requiring a large start-up capital outlay. Farmers need some scientific knowledge about feeding, housing, genetics, and reproduction of dairy cows, while practical skills are essential in managing such high cost operations. It would therefore be expected that maximum profit would be an acceptable objective for most dairy farmers. However, each producer, and his advisor, whether from the feed industry, AI companies, dairy breed societies, veterinarians or animal scientists, seems to have a different way of reaching this objective. Some believe the highest milk yield per cow is the way to reach this objective, while other producers prefer reducing the cost of production. The emphasis on production vs. conformation traits also differ. These different viewpoints indicate different breeding and selection objectives. However, regardless of the production system, the highest profit margins will be reached by having high producing, well-adapted cows in the dairy herd. While farm resources determine the herds' feeding programmes, sire selection and cow culling programmes are controlled by the dairy farmer. Therefore, the breeding programme determines the genetic merit and milk yield of dairy cows.

The selection of bulls to be used in dairy herds seems to be both a scientific exercise and an art, as some farmers have an intuitive approach to sire selection. This follows that each farmer has his own philosophy with regards to sire selection. However, describing such an objective provides an important scientific base for the breeding programme. Whatever sire selection approach is used, maximum dairy farm profit is based on the balance between production cost and herd income. For a profitable operation a dairy herd should consist of cows producing the most milk and best milk composition, while calving down every 12 to 13 months and having long productive lives. This implies that a breeding objective for a dairy herd should include traits for production parameters, fertility, and productive life.

Sire selection by dairy farmers

Irrespective of the fact that more than 90% of a dairy herd's income is derived from milk sales, sire selection objectives as described by farmers; as well as breed societies, do not necessarily include the genetic merit for milk, fat or protein yield as primary selection traits. The description of selection objectives is often vague, usually including a number of individual, mostly conformation traits. Often, a first criterium is the reliability values for estimated breeding values. Traits used by farmers mostly include body conformation traits, i.e. feet and legs, udder traits, body size, etc. Surprisingly high pin bones get a lot of attention as farmers believe it is related to fertility. Breed societies' journals mention traits like medium framed cows (indicating size), well-developed rumps and loins, well-placed legs and hip bones, well-attached udders which are high above the hocks, etc. These objectives seem to indicate selection objectives improving body conformation traits in dairy cows, while milk yield parameters, which determine the main source of farm income, seem to be of less importance.

This anomaly is demonstrated when observing the semen sales of an AI company supplying semen to Western Cape dairy farmers. For a specific year, nine Holstein bulls, representing 75% of all semen sales, had an average EBV value for milk of 559 kg. However, the average breeding value for milk yield of five bulls with the highest number of straws sold was 389 kg. By using other selection objectives, i.e. highest Net Merit (an index comprising 12 different traits), highest milk income or lowest semen price, the average breeding value for milk yield for five bulls selected in each group was in comparison 1114, 1196 and 659 kg, respectively. The monetary value of bulls as indicated by EBVs per Rand paid for semen of bulls selected as indicated above in comparison to the five bulls bought by farmers was 4.7, 6.2 and 6.9 vs. 3.4 kg/Rand, respectively. This means that the bulls bought by farmers had the lowest genetic merit for milk yield and the least genetic value in terms of money spend. Even buying the lowest priced bull semen, the genetic merit of those bulls for milk yield would have been higher. This seems to indicate that bulls were bought for other reasons than for the milk yield potential of their daughters.

It is not clear how much emphasis should be put on type traits to be included in sire selection objectives. Breed societies have always maintained that the ideal conformation and type traits should be the main emphasis of a breeding objective. This is maybe important for dairy farmers showing cows while fitting in with the role of breed societies. While many high producing dairy cows often have acceptable body conformation traits, the opposite does not necessarily apply, i.e. that "good looking" cows would produce high levels of milk. Each trait has its own heritability estimate, while each is affected differently by the environment. There is a small, about 5%, positive genetic correlation between milk yield and overall body type. This means that selection for milk yield would not necessarily affect body type traits in cows negatively. However, recent research has shown that cows with specific conformation traits seem to have longer productive lives. Cows with specific type traits seem to be better able to withstand management risks usually encountered on a dairy farm. However, under no circumstances should high producing cows be culled because of a few poor conformation traits, unless these traits affect their production significantly.

How to select sires

Because the milk yield and milk composition of cows determines herd income, estimated breeding values for milk, fat and protein yield as well as fat and protein percentages should be used as primary selection criteria. A list of the available bulls for sale from a specific AI company should be sorted from high to low for breeding value for either milk yield, or protein yield, or a combination of fat and protein yield. A combination of milk, fat and protein yield could also be estimated for each bull using the current or average milk price as a guideline. The list should also contain each bull's deviations for fat and protein percentages, reliability values for EBVs and the semen price per straw. A list of Holstein bulls sorted from high to low for 3 x protein yield EBV + fat yield EBV is shown in Table 39.1.

Table 39.1. Holstein bulls sorted for a combination of estimated breeding values (EBV) for protein and fat yield (Prot = protein; Prod = productive life; CE = calving ease)

Sire name	Price (R)	EBV milk (kg)	EBV prot (kg)	EBV fat (kg)	Prod life	3Prot + fat	Prot %	Fat %	Type	CE (%)	Body size
Picardus	140	1738	52	50	+ 2.2	205	+.00	-.06	+ 1.12	7.5	+1.17
Ruble	200	1841	52	49	- 0.2	205	-.02	-.08	+ 0.78	11.8	- 0.38
Altima	90	1494	41	45	- 0.7	168	-.02	-.04	+ 0.59	6.5	+ 0.96
History	150	946	37	56	- 0.1	168	+.04	+.09	+ 1.26	8.5	+ 0.52
Myrle	200	889	33	63	+ 3.8	161	+.02	+.13	+ 0.60	8.5	+ 0.80
Gillespy	270	1609	39	43	+ 2.2	160	-.04	-.08	+ 1.95	9	+ 1.15
Levi	230	424	35	53	+ 2.4	159	+.10	+.16	- 0.28	4.8	- 0.31
Gerard	199	1151	45	19	+ 0.6	155	+.05	-.10	+ 1.54	5.6	+ 1.83
Soto	100	1100	35	47	+ 3.1	151	+.00	+.02	+ 0.84	7.1	+ 2.06
Cancun	140	1050	34	34	+ 1.7	135	+.01	-.02	+ 1.71	10.9	+ 1.27
Dorcy	350	1261	35	30	+ 5.5	134	-.02	-.07	+ 2.21	10.1	+ 0.62
ABC	90	453	27	48	+ 5.0	130	+.06	+.14	- 0.19	6.9	- 0.87
Chase	180	1084	32	35	+ 0.4	130	+.00	-.02	+ 1.22	6.3	+ 1.99
Doberman	160	132	27	45	+ 0.8	126	+.10	+.17	+ 0.84	6.6	+ 0.31
Gallon	180	1255	30	28	+ 4.9	118	-.04	-.07	+ 0.42	7.2	- 0.09
Gaylin	125	1313	35	8	+ 3.8	112	-.02	-.17	+ 0.56	8.4	+ 0.09
Gerwyn	120	345	19	54	+ 1.0	111	+.04	+.18	+ 1.04	6.3	+ 0.79
Orville	120	395	27	25	+ 4.6	107	+.06	+.05	- 0.24	7.3	- 0.17
Armitage	120	596	23	38	+ 1.5	106	+.02	+.07	+ 0.48	5.2	+ 0.34
Tabber	160	472	28	22	+ 2.6	106	+.06	+.02	+ 0.87	7.3	+ 0.93
Ezra	150	845	25	23	+ 3.3	99	-.01	-.04	+ 0.48	7.9	+ 0.60
Garrett	199	863	25	24	+ 2.8	97	-.01	-.04	+ 0.67	5.4	+ 0.94
Franchise	120	492	19	38	+ 1.9	95	+.02	+.09	+ 1.45	8.4	+ 0.94
Shaq	150	819	20	34	+ 3.0	94	-.02	+.01	+ 0.82	9.9	+ 0.56
Geldon	120	417	20	29	+ 2.7	89	+.03	+.06	+ 1.01	8	+ 0.35
Navarro	99	421	17	35	+ 2.3	87	+.02	+.09	+ 0.96	8.6	- 0.01
Ayers	90	606	21	24	+ 3.2	86	+.01	+.00	+ 1.48	8.5	+ 1.01
Shout	115	549	20	26	+ 2.8	86	+.01	+.03	+ 0.73	7.7	+ 1.13
Pennymaker	90	89	20	20	+ 3.8	80	+.08	+.07	+ 0.46	6.9	- 0.68
Yen	75	905	25	6	+ 1.8	80	-.01	-.12	- 0.03	6.8	- 0.57
Classic	99	545	13	39	+ 2.2	77	-.02	+.08	+ 0.21	10	- 0.28
Garman	120	241	11	35	+ 3.6	68	+.01	+.12	+ 0.57	8	+ 0.78
Matic	70	37	8	43	+ 1.3	67	+.03	+.18	+ 0.34	5.5	- 0.23
Trigger	120	311	15	9	+ 4.9	53	+.02	-.01	+ 1.00	7.3	- 0.03

Catalogues of AI companies supplying bulls contain much more information than is shown in Table 39.1, further emphasising the need for a different approach to sire selection than to pick bulls on single traits alone. A group of five to six bulls per 100 cows is selected from a list as shown above. Beforehand, specific selection criteria could be set, e.g. bulls must have positive deviations for fat and protein percentage while a maximum price per straw may also be included. When allocating sires to cows in a breeding list, specific problem body type traits in cows should be avoided. Bulls whose daughters have below average udders should preferably not be used on cows with poor udders. For Holstein heifers, a separate list of calving ease sires should be selected to reduce the risk of calving down problems.

Milk price structures should be considered when establishing breeding objectives. Most dairy processors pay a higher price for protein than for fat as it is required in the production of milk powder and cheese. Fat and protein yields are affected by the volume of milk produced and the percentage of fat and protein in the milk. Ideally, both volume and percentage should be included in a breeding programme, although such bulls are not common in the AI industry. Increasing the volume of milk, while aiming to maintain fat and protein percentages in milk, would be a more practical objective. From the list in Table 39.1, three bulls, History, Myrle and Levi, ranking in the top seven, have been identified for high milk yields and positive fat and protein percentages, although their average breeding values for milk, fat and protein yield is lower than that of the top three bulls.

Using different breeding objectives different groups of bulls can be identified each with its own breeding responses. In Table 39.2 the combined effect (average breeding value) of six bulls selected according to different breeding objectives is shown. Within each column, average breeding values shown in bold indicate the best option for the three breeding objectives.

Table 39.2. The average breeding value for different traits for 6 sires selected according to different breeding objectives

Traits	Protein + fat yield	Reducing stature	Lowest semen price
Price (Rand)	175	153	**72**
EBV milk (kg)	**1420**	798	77
EBV protein (kg)	**42**	32	9
EBV fat (kg)	**51**	40	23
Productive life (m)	1.20	**3.17**	1.47
3 x ProtEBV + fatEBV	**196**	148	55
Protein (%)	- 0.003	0.030	**0.032**
Fat (%)	- 0.007	0.048	**0.090**
Type	1.05	**0.24**	0.32
Calving ease (%)	8.6	7.8	**6.6**
Body size	0.70	**-0.31**	- 0.08

Using different breeding objectives would result in different sires being selected. As expected, selecting bulls for the highest fat and protein yields resulted in higher group average EBVs for milk, fat, and protein yields, although at a lower productive life, fat, and protein percentages while body size of progeny would increase. To reduce body size or live weight of mature cows (stature group of bulls) would result in daughters producing less milk, fat, and protein than the production group, although the productive lives of their daughters should show an increase of about 2 additional months of life in production. The group of bulls selected for the lowest semen prices would result in daughters producing low levels of milk.

The productive lifetime of the dairy cow

Using a mating programme

A more scientific way to select sires would be to use a mating programme. In the USA, especially, dairy farmers are increasingly using such programmes because of the ease of sire selection and scientific methods used in finding a suitable bull for a specific cow. In South Africa, the adoption of mating programmes is slow, though increasing. Its use is specifically seen in larger dairy herds which often have a different philosophy with regards to sire selection and profit margins. One problem local farmers seem to have is that mating programmes are linked to specific AI companies. However, not using a mating programme, the scientific support provided by the AI companies in sire selection is disregarded. A mating programme is a computer based programme based on trained evaluators scoring cows according to 13 breed specific conformation traits. This information is then combined with set guidelines for production traits. The Genetic Management System (GMS) is being used in the Elsenburg Holstein herd since 1997. By using this mating programme, the genetic merit for milk production parameters has increased, while body conformation traits have been maintained. Although mating programmes are easy to use and are based on sound scientific principles, most dairy farmers prefer applying their own selection methods to maintain control over the sire selection process. Because mating programmes are based on very little subjective inputs, it probably takes away the art of sire selection.

Fixing conformation traits in cows

Many dairy farmers select bulls towards improving (or fixing) poor conformation traits in cows in the present herd. This is usually done with the support of the breed society. Disregarding the genetic merit of bulls for milk yield in this process of improving conformation traits could in the long term have a detrimental effect on the milk yield of a dairy herd. This approach may have been acceptable in the past when the conformation of cows varied significantly within a herd. Presently, for each bull, information on a large number of traits is available describing the average body type of his daughters. Computer based programmes are available to select the correct bull for a specific cow. Selecting bulls to "fix" specific conformation traits in a dairy cow is difficult, as the long generation interval makes it very difficult to observe any improvement in a specific cow's progeny, as the daughter has to be at the same age as the mother for the comparison to be valid. It should be kept in mind that each conformation trait has a specific estimated breeding value which means that some traits may genetically change very little at each generation interval. The heritability of fore-udder attachment is, for example, 29%. This means that 71% of the variation in the trait is the result of environmental effects which are not transferred to the next generation. In most cases, poor fore-udder attachment is observed in third or fourth lactation because of stress in previous lactations. This may be due to udder oedema at first calving and high milk yields in following lactations. It is not possible to "fix" the fore-udder of a specific cow as that is determined by her own genetic make-up and environmental effects she was exposed to over her lifetime. By selecting the right bulls, the chances are increased to fix specific conformation traits in her progeny. However, it should be kept in mind that there is negative genetic correlation between milk yield and fore-udder attachment, which means that to improve fore-udder attachment, milk yield might be reduced.

Marketing of semen

Often semen from bulls is made available to farmers at reduced prices. It should be kept in mind that by servicing cows through AI or natural service, two actions take place: (1) getting a cow pregnant for the next lactation period; and (2) affecting genetic change when fertilisation occurs. As semen is regarded as a commodity, it is also affected by supply and demand, resulting in a variation in the price, even though the genetic merit of the bull does not vary. When the availability of the semen of a popular bull becomes a problem, its semen price usually increases irrespective of that specific bull's genetic merit for milk production. A simple way to get a monetary value of a bull's genetic merit for milk yield or other production parameters is to divide its breeding value for milk yield by the semen price. This gives an indication whether bull semen is correctly priced. Therefore, the decision to use special priced bulls or not should always be based on their breeding values in comparison to the current bulls being used in the herd.

Using a herd bull

A herd bull is usually a home-bred bull or one that has been bought from a neighbour or a breeder. Such bulls are often used to get cows pregnant following a structured AI programme. Some farmers, for practical reasons, also use a home-bred bull to get heifers pregnant. In some cases, farmers use herd bulls because of a perception that a specific home-bred bull is genetically better than a progeny tested bull supplied by an AI company. Although this may be possible, it is highly unlikely as AI bulls undergo a stringent selection process before being put into a progeny testing programme before its semen goes on the market. Using herd bulls for breeding purposes is often problematic as they can be dangerous resulting in workers being hurt physically. Usually limited information is available on its genetic merit. This may have a negative effect on the genetic progress in a dairy herd. The cost of keeping a herd bull is also not less than that of the cost of purchased semen from an AI company. When considering buying a home-bred bull, it should be sourced from a breeder that participates in the milk recording scheme as predicted breeding values for production parameters would then be available. No information is, however, available on conformation traits and calving ease. The only advantage of using a herd bull is that it is easier to service cows than to do AI. The progeny of home bred bulls should not make up more than 15 to 20% of all the cows in the herd. A specific herd bull should also not be used in a herd for more than 24 months as it may then service its own daughters, causing inbreeding.

In closing

The genetic merit of a dairy herd is affected by the sires selected to get cows pregnant. Sire selection should be aimed at clear breeding objectives to improve the herd income through the sales of more milk. Sire selection has a long term effect on the genetic merit of a dairy herd affecting its milk yield positively or negatively. Putting too much emphasis on conformation traits could have a negative effect on milk yield. Although the genetic correlation between productive life and body conformation traits for udders and feet and legs is positive, the most important traits for a long productive life is the ability of cows to produce sufficient amounts of milk and to become pregnant soon after calving. It is important to participate in milk recording as in that way each herd contributes to the national herd, while its own genetic trend gives an indication of the response of sire selection programmes. Semen cost in a dairy make up about 5% of the total cost of production which means saving on this cost will not have large effect on present profitability, though having a large effect on long term productivity.

CHAPTER 40

SELECTION OF DAIRY COWS

Introduction

Selection in dairy cattle breeding refers to the selection of the best or highest performing sires and cows to be used in a herd. The selection intensity for sires is high as only a small number is required to breed cows. For cows, a different strategy has to be followed as they make up the herd producing milk for herd income. A dairy herd essentially consists of about 25 to 35% first lactation cows, while the rest of the herd is made up of older cows in second-plus lactation. Cows in first lactation are replacements for cows leaving the herd (to maintain herd size). When the number of heifers entering the herd is higher than the number of cows leaving the herd, they are adding to (increasing) the number of cows in the herd. Older cows leaving the herd are culled because of various reasons like recurring mastitis, not becoming pregnant after calving, injuries, sickness, and death. Selection of dairy cows reflects the current gains in the herd and is based on which first lactation cows stay on in the herd to be dams for future cows. The selection of dairy cows should be based on production performance. Two strategies could be applied, i.e. selecting cows in the top half or culling cows in the bottom half of all first lactation cows. Although sire selection has the largest effect on the genetic progress of a dairy herd, higher selection rates or lower culling rates among first lactation cows also affects genetic progress differently. The culling rate of older cows affects the internal herd growth or the number of cows in the herd.

When herd expansion is limited, or for a higher genetic progress, only the best 40% of first lactation cows may be kept in the herd. This implies that 60% of first lactation cows are to be culled. However, most dairy farmers are reluctant to use low milk yields as a selection or culling tool for first lactation cows as they are usually in milk, healthy and sometimes pregnant. Furthermore, in herds with high cull rates among older cows, all first lactation cows have to be taken up in the herd to maintain herd size. Therefore, heavy culling in first lactation cows would result in herds becoming smaller. However, for genetic herd improvement, it is not a good policy to keep low producing cows in the herd just to maintain herd size. Selection in first lactation can be done because of a high (70%) correlation between first lactation production and lifetime performance. Even though milk yield of cows increases after first lactation, lower producing cows in first lactation always lag behind higher producing cows in later lactations. Furthermore, while first lactation cows make up about 30 to 35% of the number of cows in milk, their contribution to the total milk production per day is often less than 25%.

Some dairy farmers maintain that voluntary culling based on poor milk yields is not a viable option as herd numbers would decline. However, this should not be the case, because for a 100-cow dairy herd of which at least 85% cows calve down each year, 42 heifer calves would be born. As about 85% of these heifers should reach first calving, 36 heifers could enter the herd as first lactation cows. This means that for a culling rate of 25%, to be replaced by first lactation cows, at least 11 first lactation cows are available for voluntary culling provided no herd expansion is planned. When there are no surplus heifers available in a herd for voluntarily culling, it should be regarded as a serious problem. This usually occurs when the culling rate among cows is higher than 35% or the survival rate of heifers from birth to first calving is poor. Usually in such herds all first lactation cows have to be included in the herd to maintain herd numbers. This would have a negative effect on the genetic progress of a dairy herd as no selection because of poor milk yield in first lactation can be applied.

Selecting first lactation cows

From cows calving down, heifer and bull calves are born. Heifers are usually raised on the farm to replace cows that are culled from the herd. This is preferred to buying-in heifers from other breeders as the heifers coming into the herd determine its genetic progress. The genetic merit of purchased heifers is often unknown, while they may also carry infectious diseases into the herd. Heifers are also not available when required, while using home-grown heifers the expansion of the herd can be manipulated. At a low culling rate among cows, surplus heifers become available as an additional source of income for the herd.

Replacement heifers to be reared for inclusion in the herd at first calving at 24 months of age should have the following characteristics:

- be the daughter of a plus-proven bull (for milk production);
- be the daughter of one of the better performing cows in the herd, i.e. cows with milk index of at least 90 and preferably 100;
- be the daughter of a fertile mother, i.e. a dam that became pregnant soon after calving;
- have a good conformation (body type); and
- be well grown out, i.e. about 50% of mature live weight at 12 months of age.

Heifers with obvious conformation defects should not be raised as replacement heifers. While the heritability of body type is about 30%, the genetic correlation between body type and milk yield is less than 10%. For producers without milk recording information, heifers could be evaluated on the basis of pedigree information. However, the accuracy of using pedigree information is not as high as that of using predicted breeding values or actual first lactation performance (Table 40.1).

Table 40.1. The accuracy of heifer selection for milk yield based on different information sources

Information	Accuracy of selection (%)
Dairy type evaluation	5
1 Production record of the mother	25
3 Production records of the mother	32
5 Production records of the mother	34
3 Production records of the mother + 3 records of each grand dam	35
Heifer's own production records	50

In Table 40.1 it is shown that the accuracy of selection is 25% when using one milk production record of the dam. At least three production records of the dam and three records from both grand-dams are required to increase accuracy to 35%. The best way to determine the milk production potential of heifers is to raise them to first calving and then to determine their milk yield during the first lactation. The accuracy of selection is then 50%. Dairy farmers participating in the National Milk Recording Scheme annually receive a genetic herd profile which includes the herd's genetic trends for milk production parameters. The profile also includes predicted breeding values for all heifers that are at least six months old. As part of the herd profile, predicted breeding values of heifers are compared to breed averages. This enables farmers to indentify heifers that are below or above breed averages for all the different production traits. The correlation between predicted breeding value and observed production performance is about 70%, which indicates that the predicted breeding value of heifers is a useful selection tool.

Selection threshold values for first lactation cows

Although it is preferable to evaluate the production performance of first lactation cows on completed lactation periods, it is often not possible because of limited housing space or stocking rates (Heydenrych & Paulse, 1981). Because of a high correlation between the milk yield during the early part of the lactation and a completed (over 300 days) lactation period, it is recommended that the production performance of first lactation cows is evaluated over at least the first 100 days of the first lactation. Considering the feeding and labour cost, three first lactation cows could be evaluated over partial lactations in comparison to one cow completing a full lactation. In small herds, only a few first lactation cows are in milk at the same time, making direct comparisons between cows difficult. In such cases the poorest performing cow within one age group could be better than the best performing cow in another age group. To overcome this, a selection threshold value for milk, fat or protein yield based on the production performance of cows that have previously completed a first lactation in the herd, could be estimated. Selection threshold values could be estimated for partial (the first 100 days of the lactation), or completed (300-days) lactation periods. Depending on the selection intensity, threshold values could be based on the average values for production traits or values higher (e.g. 1.15) or lower (0.85) than the average for all the first lactation cows in the herd. Cows producing less milk than threshold values should be culled from the herd as soon as possible.

For the Elsenburg Holstein herds, the milk, fat, and protein yield of all first lactation cows is estimated using the first three milk recording tests for a partial (105-day) lactation period. After each milk recording event, new milk yield, fat, and protein percentage records are added to the data set and the 105-day production for each cow is estimated. Further, a component value (CV), based on the fat and protein yields of cows is estimated. The ratio between fat and protein is 6:13 for the Elsenburg herd because of a higher emphasis in the milk price on protein production. This may differ for other herds as milk prices differ. Estimating the CV for each cow protein yield of cows is multiplied by 13 and fat yield multiplied by 6. The total of these two values is divided by 2.

The data set for the Elsenburg Holstein herds was started in 1992 and is based on almost 600 cows that have completed a partial (105-day) lactation period based on three milk recording events. In Table 40.2, milk production records, estimated 105-day production performance and CVs for eight first lactation Holstein cows are shown as an example of the data set. This is compared to the records for all cows in the data set. The CV ratio for each cow is estimated in relation to the mean CV of the almost 600 Holstein first lactation cows that have started a first lactation in the herd. The CV ratio for cows in Table 40.2 varies from 0.81 to 1.30 of the overall mean. Cows producing less than 0.85 of the average (marked in bold) are to be culled because of poor production performance. The milk yield of selected and culled cows is on average 22.5 and 16.0 kg/day, respectively. From the full data set comprising all cows and all years, the CV varies between 0.70 and 1.30 for 90% of all cows. This means that some cows produce only 70% of the average cow, while some cows produce 130% of the average cow. Increasing the selection threshold value would increase the expected increase in genetic merit for the herd, although this would be accompanied by culling a larger proportion of first lactation cows.

Table 40.2. Milk recording records (Tests 1-3), 105-day production performance, component value (CV: (6 x fat yield + 13 x protein yield)/2) and component value ratio (CV/average) of eight and all past first lactation cows from the Elsenburg Holstein herd

Milk recording tests	First lactation Holstein cows in milk recording								All cows
	Ce 229	Ce 221	1231	1351	1329	1323	Ce 228	1345	
Test 1									
Milk (kg)	16.5	25.1	26.2	15.8	29.1	15.2	16.0	16.7	21.0
Fat (%)	4.78	4.49	3.96	4.60	3.57	5.73	6.63	6.29	3.89
Protein (%)	3.75	2.82	3.38	3.52	2.87	2.70	3.76	2.78	3.14
Test 2									
Milk (kg)	15.1	26.4	27.4	20.2	26.8	13.7	22.7	23.8	22.0
Fat (%)	3.93	3.50	3.55	3.76	3.32	4.44	3.94	3.67	3.61
Protein (%)	3.15	2.63	2.84	3.09	2.89	3.41	2.95	2.48	3.02
Test 3									
Milk (kg)	15.8	23.6	28.4	18.0	27.1	21.6	24.6	27.3	2.1
Fat (%)	3.38	3.72	3.96	3.95	3.96	4.48	3.62	3.41	3.70
Protein (%)	3.47	2.94	3.12	3.03	3.03	3.44	3.01	2.56	3.13
105-day Production performance									
Milk (kg)	1655	2641	2881	1914	2935	1678	2345	2532	2264
Fat (kg)	66	105	110	77	105	84	97	98	83
Fat (%)	3.96	3.96	3.82	4.01	3.56	5.02	4.14	3.88	3.69
Protein (kg)	57	73	89	60	85	52	72	65	69
Protein (%)	3.45	2.78	3.10	3.15	2.91	3.10	3.09	2.56	3.06
CV	568	791	911	622	868	591	762	716	698
Ratio	**0.81**	1.13	1.30	0.89	1.24	**0.85**	1.09	1.03	1.00

The variation between first lactation cows regarding their component values in relation to the selection threshold value is shown in Figure 40.1. Cows are listed according to calving date with each marker representing an individual cow.

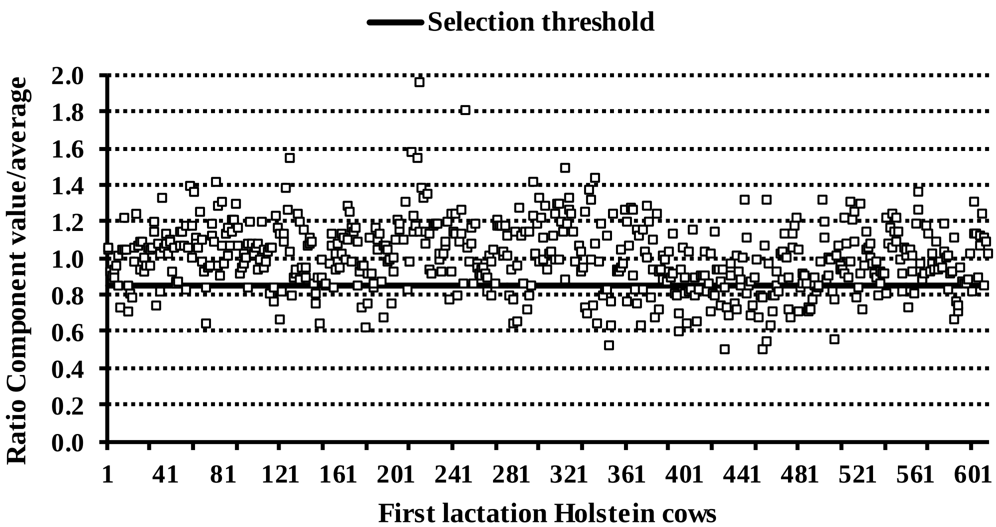


Figure 40.1. The ratio (□) of the component value for all Holstein cows having completed a partial (105-day) first lactation period in the Elsenburg herd

It is, however, important to note that management conditions should be taken into consideration when comparing the production performance of cows over time. Estimation of partial lactation records are based on only three milk recording events and corrections are sometimes required when mastitis or other management problems should reduce milk yield. The sampling of milk is also critical as incorrect sampling could affect milk composition negatively.

The productive lifetime of cows

Most dairy farmers are reluctant to cull cows in first lactation on low milk yields. They are aware of the fact that the lactation performance of cows increase after first lactation, reaching peak milk yields at about 5th to 6th lactation. Because of the high repeatability of the production performance of cows, poor performing cows will always lag behind in later lactation periods or age groups. Therefore, increasing the average milk yield of first lactation cows would also have a beneficial effect on their milk yield in later lactations. As the cost of raising heifers to first calving is high, about R8000 under pasture-based systems and R14000 under total mixed ration systems, this is usually not recovered when cows are culled at an early stage during first lactation. The rearing cost of heifers can only be recovered by extending the lifetime of cows. However, cows seldom get the opportunity for a long productive life as involuntary (or preventable) culling results in a considerable number of them being removed (lost) from the herd. As the heritability estimate for productive life is less than 10%, environmental factors mostly determine the productive lifetime of cows. This includes the feeding level, housing conditions and reproduction management of dairy cows. Therefore, to ensure genetic progress in a dairy herd, cows making up a dairy herd should essentially be divided into two groups each with a specific aim, i.e. first lactation cows for genetic improvement and cows in second-plus lactation to be the main milk producing units of the herd.

Research has shown a positive (0.19 - 0.25) relationship between milk yield during first lactation and the number of lactations cows stay in herds as well as their total lifetime milk production (Table 40.3). Similarly, daughters of higher genetic merit sires also have longer productive lives than daughters of lower genetic merit sires, i.e. 40% vs. 27% of daughters of high and low genetic merit sires respectively reach 6th lactation.

Table 40.3. The effect of first lactation production on the number of lactations completed and lifetime production of Holstein cows

First lactation performance (kg)	Number of lactations completed	Lifetime performance (kg)
< 3600	2.7	10975
4000	3.2	14745
4500	3.2	15495
5000	3.3	17055
5500	3.4	19045
5900	3.5	20630
6400	3.5	21520
6800	3.6	23050
7300	3.6	24675
7700	3.5	24515
> 7 700	3.6	26580

Poor producing cows in first lactation should therefore be culled as soon as possible to prevent them getting pregnant for the next lactation and before any sentimental value for specific cows is established. Often poor producing first lactation cows reach a second lactation especially when they become pregnant soon after calving, and when not experiencing management problems like mastitis. However, keeping poor performing cows would reduce the herd's genetic process.

In the 1950's a study was conducted estimating the efficiency of milk production (Leitch & Godden, 1953). This was based on the amount of feed cows required from birth to culling at different ages as indicated by lactation number. These results showed that cow efficiency increased when cows lived longer (completing more lactation periods) or when milk yield increased. However, milk yield had a greater (and more immediate) effect than the number of completed lactation periods. The efficiency of cows at a low milk yield was 14.4% after three lactations and 17.3% after 10 lactation periods. At a higher milk yield, the efficiency of cows was 19.8% after three completed lactation periods, while the efficiency was 23.9% after 10 lactation periods. This means that cows producing at a higher level have higher efficiencies irrespective of the number of completed lactation periods and require a shorter productive life to recover their rearing costs. The heritability of productive life is, however, less than 10% indicating a large environmental effect on the actual lifetime of cows.

In closing

It is recommended that all heifers be reared to first calving, unless they have low predicted breeding values for milk production parameters, a poor conformation, and a low live weight. Early culling could be done before 12 months of age. After first calving, the milk yield and milk composition of all cows should be recorded over at least three milk recording events and a within-herd selection threshold value estimated. The partial lactation production of each first lactation cow should be compared to first lactation cows that have been in the herd previously. Cows producing less than 0.85 of the mean production could be culled because of poor performance. Dairy farmers unable to do voluntary culling in first lactation should seriously look at their reproduction and herd management programme as this indicates problems with regards to a high culling rate among older cows and/or heifers not surviving to first calving.

CHAPTER 41

THE CULLING RATE IN DAIRY HERDS

Introduction

Dairy herds often operate on low profit margins. This is usually because dairy farmers have little control over the price of milk as well as input costs. Dairy herds need to keep growing to reduce the erosion effect of inflation. Input costs usually increase faster than milk prices. Increasing herd sizes is one way of overcoming inflation. Growing the herd from within is a cheaper option than buying-in heifers while also ensuring genetic improvement in the herd. Dairy cows have to calve down to start a new lactation period. From this, heifer and bull calves are born. Usually, bull calves are sold at an early age for beef with the exception of some breeders that raise bull calves for sale to the artificial insemination industry or to other breeders. Heifers are usually raised to enter the dairy herd at about 24 months of age to replace cows being culled from the herd. Usually, the potential number of heifers that could enter the herd is larger than the number of cows leaving the herd. It is for this reason that dairy herds should grow in size or herd numbers. Therefore, dairy herds showing no or only a small increase in herd size over time actually have problems related to cow and heifer survival. High cull rates among cows indicate a loss in value, while the mortality cost of heifers adds to the cost of production.

Pasture-based dairy farmers are limited by farm size and when the herd has reached maximum capacity in terms of the farm's carrying capacity, surplus heifers could be sold to the industry, creating an additional income stream. Farmers should, however, be well aware of the rearing cost of heifers up to a specific age. Alternatively, a portion of the cows in the herd could be inseminated with a beef sire to increase the beef income of the dairy herd. However, when the cull rate of cows is high, the number of replacement heifers being born in the herd and reared successfully to first calving may be too small to maintain the number of cows in the herd. This then results in a negative herd growth rate. This is usually overcome by buying-in heifers or cows from other herds. A high replacement rate, as indicated by a large proportion of first lactation cows in the herd, also affects farm income as this indicates the number of cows being lost from the herd. A herd with a larger proportion of older cows produces more milk per day than a so-called young herd. Dairy farmers should therefore be aware of the flow of animals in their herds as this affects the internal herd growth rate.

Internal herd growth

Internal herd growth **(IHG)** indicates the growth in the number of cows in a herd. Usually, this should be estimated at a fixed point each year, e.g. coinciding with the end of tax year or for seasonal based dairy farms, at drying-off date which is often a fixed date on the calendar.

For estimating the IHG, four numbers are required, namely, the number of cows in the herd at the beginning (A) and end (B) of the year, the number of cows sold for dairy purposes (C), and the number of cows purchased during the year (D). The number of cows at the beginning of the year is subtracted from the number of cows at the end of the year after which the number of cows sold for dairy purposes is added, followed by subtracting the number of cows purchased during the year. The following equation describes the IHG or increase in herd size (E):

$$E = (B - A) + (C - D)$$

Dividing the number of cows contributing to the increase in herd size (E) by the number of cows at the beginning of the year (A) reflects the rate (%) of the herd's internal herd growth. A negative IHG value indicates that the herd is losing size, thereby indicating the need to purchase additional cows to maintain herd size. A positive IHG rate of 1 to 5% reflects a slow growing herd, providing some flexibility, while a growth rate of 5 to 15% indicates a fast growing herd. This provides an opportunity for herd expansion or for animals to be sold for dairy purposes, creating an additional farm income. A heavier voluntary culling rate, especially among first lactation cows because of poor production performance, also becomes possible. Factors affecting the IHG include the number of cows calving down per year, cull rate of cows, heifer to bull ratio, survival of heifers from calving to first calving, and age at first calving of replacement heifers.

Herd cull rates

Many dairy herds suffer from high cull rates resulting in a limited number or no cows available for sale for dairy purposes. Factors affecting the IHG include the percentage of cows in the herd calving down each year, cull rate of cows, heifer to bull ratio, and survival of heifers from calving to first calving. The effect of these factors could be estimated by using a simple model. By multiplying the number of cows in the herd by the percentage of cows calving down in a year, the number of offspring is determined. The bull to heifer ratio (usually 50:50) determines the number of heifers born. Because some cows are culled in year one, fewer cows calve down in year two. In year three, the number of heifers born in year one which survive rearing to first calving is added to the cows in the herd. This number of cows determines the number of heifers born from year three onwards. From this point onwards the herd increases in size.

Figure 41.1 shows the effect of cow cull rates on cow numbers in three herds. From herd sizes of 100 cows at the start and 75% survival of heifers from birth to first calving, cow numbers in the three herds in year 10 are 236, 143 and 85 cows at cull rates of 20, 25 and 30%, respectively. To maintain a herd of 100 cows, at a survival rate of 75% of heifers from birth to first calving, the herd's cull rate should not exceed 28%.

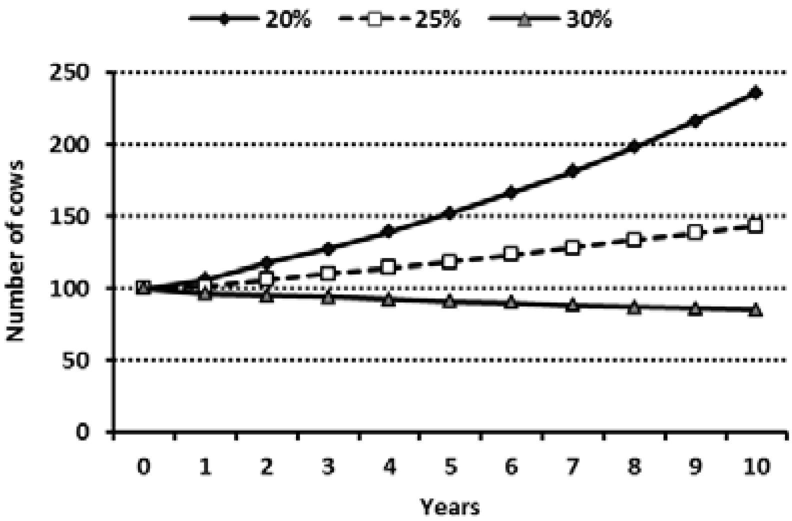


Figure 41.1. The effect of cow cull rate (20, 25 and 30%) on the number of cows in a dairy herd in year 10 from a base herd of 100 cows

Decreasing the survival rate of heifers also affects herd growth negatively, while lower culling rates are required to maintain herd numbers. Herds maintaining higher heifer survival rates show higher IHG rates at similar cull rates used in the example below.

By changing each of these factors, the effect on the final number of cows in the herd can be shown. A sensitivity test indicates that the number of cows being culled each year has the largest effect on herd growth, ranging from - 2.5 to + 3.3% when the cull rate varies from 25 to 15%.

Find out why cows are leaving the herd

Studies have shown that internal herd growth is highly correlated to dairy farm profit. It would therefore be important to determine the reasons for cows leaving the herd, i.e. being culled. In most cases, cows are culled because of involuntary reasons. This usually includes factors such as poor milk yield because of poor genetic merit, cows failing to become pregnant, recurring incidences of mastitis, natural diseases, poor conformation traits (specifically udder traits), and injuries sustained. As the heritability of productive life is low, i.e. less than 10%, improving the farming environment (housing, walkways, feed troughs, etc.) or feeding, reproduction and milking parlour management would in many cases reduce culling rates.

To find out why cows are leaving the herd, it is recommended that a cull list of all animals leaving the herd be kept up to date. Such a list should contain the following information: name of the culled animal (this may include heifer and bull calves dying at birth), the cull date of the animal, its birth date, recent calving date, recent lactation number (zero for heifers), number of cows in the herd and in milk, the number of all heifers in the herd, and the cull reason. From these records, information on the age and lactation stage of cows at culling could be determined, as well as factors contributing to cows being culled.

Many cows are lost because of poor reproduction management or fertility. Very few cows are actually inherently infertile and will get pregnant if inseminated correctly or serviced by a bull. When poor reproduction intervenes, cows often do not conceive at all or have long open periods, i.e. the interval from calving to conception. Crossbreeding has been suggested as a way to improve the reproductive performance of cows, while also improving the survival rate of dairy cows.

Culling rates as affected by crossbreeding

A crossbreeding study was conducted at Elsenburg comparing Holstein (H) and Fleckvieh x Holstein (FxH) cows with regards to milk production and reproductive performance of heifers and cows in a total mixed ration feeding system (Metaxas, 2015). Although other Simmental derived breeds like the Montbéliarde, from France, have been used in crossbreeding studies, the Fleckvieh, a true dual-purpose breed, has not been seriously considered in crossbreeding programmes. The Fleckvieh breed has medium to high milk yields with high milk quality traits. As the reproductive performance of heifers and cows affects their survival and cull rates, these traits were also evaluated. It was found that FxH heifers were inseminated earlier than H heifers resulting in more crossbred heifers being inseminated for the first time by 14 months of age. However, age at first calving was similar for both breeds. Similarly, FxH cows were inseminated earlier after calving than H cows with a larger proportion of FxH cows inseminated by 80 DIM. This resulted in FxH cows showing a shorter interval from calving to conception (days open) and a larger proportion of FxH cows pregnant within 100 days after calving than H cows, being 0.45 vs. 0.29, respectively.

The cull rate of the H and FxH herds also differed resulting in an increase in the number of cows in the FxH herd, while the H herd showed a decline in herd numbers. At the start of the trial, 23 FxH and 22 H first lactation cows were included in the study. The feeding and reproductive management of the two herds were similar. The progeny of the original cows were included in the two herds. Cows were culled for normal reasons, i.e. not becoming pregnant or recurring mastitis cases. Bull calves were reared for either veal, marketed at a carcass weight of 100 kg, or as beef at 18 months of age. Heifers were reared to be included in the two herds. At the end of the trial, the FxH herd consisted of 70 animals, 34 heifers and 36 cows, while the H herd consisted of 30 animals, 15 heifers and 15 cows. This means that while the FxH herd had increased in size by 9.4% per year, the H herd had declined by 5.3% per year. This change in IHG is reflected in Figure 41.2 using a standard herd size of 25 cows at the start of the trial. The difference in the value of the two herds at R8000 per cow amounted to R560 000 over the six year period in favour of the FxH herd.

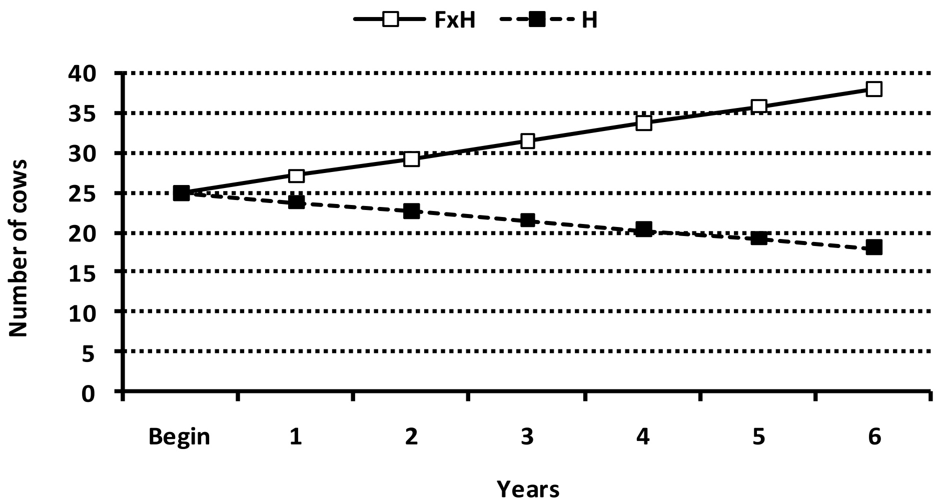


Figure 41.2. The effect of internal herd growth rate on the number of cows in a Fleckvieh x Holstein (□) and Holstein (■) herd

In closing

Internal herd growth is highly correlated to dairy farm profit. Parameters required to estimate IHG include average cow culling rate, calving interval, age at first calving, survival of heifers from birth to first calving, and bull to heifer ratio. Cows are culled for a number of different reasons. To determine ways to reduce culling rates, a list of animals leaving the herd (herd cull list) should be kept up to date. Indicators that show a loss in farm income are the following: age at first calving past 24 months of age, a high number of first lactation cows in the herd (indicating a high replacement rate), a high average number of days-in-milk (DIM) of lactating cows (indicating a larger proportion of cows in late lactation), and a low average lactation number for all the cows in the herd (indicating a high replacement rate resulting in a so-called young herd). A herd with a larger proportion of older cows produces more milk per day than a so-called young herd.

CHAPTER 42

CROSSBREEDING IN DAIRY HERDS

Introduction

Crossbreeding in dairy cattle is becoming increasingly popular worldwide. In South Africa, however, it is a very contentious topic, and is generally not supported by dairy breed societies. Regardless of breed, there is, in South Africa, a strong emphasis on breed purity and body conformation traits. Based on recent research, these are not very good economical principles anymore. No local research has been done in the dairy industry to establish benefits or problems related to crossbreeding; therefore, farmers are relying mostly on overseas results. There is generally a lack of research material and information because farmers using crossbreeding often do not participate in the National Milk Recording Scheme of the ARC, or are unwilling to share information about their on-farm experiences. On-farm crossbreeding "trials" are often done without a control herd, while the crossbred and purebred cows are sometimes on different feeding programmes. In such cases, comparisons are not valid and few deductions can be made from such trials. Observations are often based on a small number of cows which may lead to incorrect conclusions. It is often reported in the lay press that crossbreeding on a specific farm has not resulted in positive results. Usually, very few production results are provided while general statements about the conformation of crossbred cows give an indication as to why crossbreeding had failed. Naturally, the selection of sires of the alternative breed is very important as that determines the success of crossbreeding and not crossbreeding by itself. Another problem in obtaining data to determine the success of crossbreeding is that while the National Milk Recording Scheme has a system that identifies crossbred animals, sire breeds are not well described. Generic descriptions like beef x dairy or dairy x dairy are being used. This is specifically problematic when dual-purpose breeds are being used in crossbreeding programmes.

It is well known that crossbreeding has been done in the poultry, pig and beef industries for many years. In the poultry industry, lines have replaced breeds, whereas in the sheep and beef cattle industry, new breeds have been established through crossbreeding, e.g. sheep breeds like the Dorper and Dormer and beef breeds like the Bonsmara, Simbra, Braford, etc.

In New Zealand, crossbreeding in dairy cattle has been ongoing for many years. Because of this, crossbreds make up about 43% of all dairy cows. This has resulted in the development of the so-called Kiwi cow which is a crossbred between Holsteins and Jerseys. The average milk yield of these cows is 3922 kg at an average live weight of 434 kg. In comparison Holstein and Jersey cows make up 37 and 12% of all cows producing 4414 and 3118 kg milk at live weights of 468 and 376 kg, respectively.

In Ireland, crossbreeding is also popular because of their research results showing the benefits of crossbreeding. Their seasonal pasture-based production system demands very fertile cows, and because herd growth is limited due to farm size, up to 40% of cows in the herd are inseminated with beef sires. In this way herd size is maintained while increasing the beef production from the herd. Based on positive on-going research results, in the USA crossbreeding is also becoming popular with the percentage of crossbred cows in milk recording having surpassed the number of Jerseys, Ayrshires, and Brown Swiss.

Farmers are applying crossbreeding to increase farm profit. The Holstein breed has shown, over the recent past, a reduction in fertility with a negative effect on the longevity of cows. It is not clear whether this is a genetic or environmental effect because of the way dairy farming has changed in the recent past, i.e. an increase in cow numbers, cows producing higher levels of milk, fewer workers per cow, less attention to individual cows. Culling rates have increased and all replacement heifers are reared to replace cows being culled from the herd.

Breeding and selection programmes in dairy herds in South Africa focused mainly on the improvement of milk yield and conformation traits. This seems to have resulted in a decrease in the fertility of specifically Holstein cows. Recent research in South Africa has shown that the genetic trend for calving interval (CI), as an indicator of fertility, has shown an upward trend since 1980, being 1.25 and 0.50 days per year for Holstein and Jersey cows, respectively. The CI for South African Holsteins increased from 386 days in 1986 to 412 days in 2004. Irish research has shown that the genetic decline in fertility has been turned around by reducing the emphasis on milk yield in the genetic merit index for dairy cows.

Even though the reproductive performance of dairy cows affects herd profitability, little emphasis is being put in South Africa on the genetic improvement of fertility. At best, non-pregnant cows are culled, because of repeated reproductive failures, hormonal treatments and natural service.

Heterosis

Because of increasingly poor reproductive performance in mostly Holstein herds, farmers are considering crossbreeding to overcome this, reasoning that fertility traits are lowly heritable and should benefit from heterosis. Heterosis is defined as the increased performance of crossbred animals compared to the average of their pure-bred parents. For this reason, crossbreeding using four different, although related breeds, would give the best improvement in performance. According to Danish research, the expected F1 heterosis is about 3% for production traits, 10% for fertility and 10 - 15% for calving ease and longevity. Overall, the expected increase in total merit, due to heterosis, is about 10%. The benefit of heterosis is not transferred to the next generation.

Another factor that affects the performance of cows because of crossbreeding is complementarity. This refers to the combination of breeds that complement each other in achieving specific breeding objectives. For example, the Jersey breed is known for its high milkfat content; therefore, using Jerseys on Holsteins would result in a considerable improvement in milk fat percentage in the crossbreed.

Overseas crossbreeding studies

Most studies on crossbreeding are aimed at improving the fertility and longevity of mostly Holstein cows. Early studies in the 1970s showed greater reproductive fitness in crossbred cows than in parent breeds. In later studies, Holsteins, Brown Swiss, Brown Swiss x Holsteins and the backcross Holstein x Brown Swiss were compared in the USA. Brown Swiss x Holstein cows had 12.3 fewer days open (the interval from calving to conception) than purebred Holstein and Brown Swiss cows. This was achieved at similar milk yield levels, while fat and protein percentages were higher in crossbreds. The Californian crossbreeding studies created a large interest in crossbreeding in the USA. Seven large commercial dairies were used in the study with the aim to improve health and reproduction traits in Holstein cows. Sires from Montbéliarde, Normande, Scandinavian Red (Swedish Red and Norwegian Red) breeds were used on Holstein cows. Although the milk yield of crossbred cows were lower than that of purebred Holsteins, the number of days open was two to three weeks less than for Holsteins. In Germany, a number of crossbreeding trials have also shown improved reproductive performance, as well as fat and protein production in crossbred cows in comparison to Holstein cows.

In the seasonal pasture-based production system in Ireland, a study showed that milk yield was highest for Holsteins, intermediate for F1 Jersey x Holstein, and lowest for Jersey cows. The fat plus protein yields were highest for Jersey x Holstein, intermediate for Holstein, and lowest for Jersey cows. The reproductive performance was similar for Holstein and Jersey cows, while it was better for Jersey x Holstein cows. Overall farm profitability was the highest for Jersey x Holstein cows, intermediate for Holstein cows, and lowest for Jersey cows.

Different production systems

The climate in South Africa is different to that in New Zealand and the natural rainfall is, in most areas, low and erratic, requiring irrigation to produce sufficient amounts of grass for a year-round production system. Forages are being conserved as hay or silage. For this reason, concentrates and surplus forages have been fed to cows for many years with very few farmers making exclusive use of cultivated pasture as the main feed source. Local dairy processors also demand a year-round production system to ensure an even milk-flow through the processing plants. These factors have resulted in South African farmers using different production systems than those in New Zealand and Ireland. Local systems vary from pasture-based to zero-grazing or total mixed rations (TMR) feeding systems.

Usually, with a reduction in the pasture content of the total diet of cows, the production cost of milk increases, requiring higher milk yields to reach a break-even point of production. The cost of a zero-grazing total mixed diet making use of oats hay and concentrates may be 40% more expensive than a similar total diet using a ryegrass pasture-based system. Therefore, there is for South African production systems not such a big demand for a type of cow that fits the production system as rigidly as in New Zealand or Ireland.

Traditional crossbreeding comprises using Jersey sires on Holstein cows. The reason is to reduce body size and live weight of Holstein cows. Research in Ireland has shown the benefits of such a system. While this usually results in lower milk yield levels, fat and protein percentages increases, usually increasing milk prices. However, using Jersey sires on Holstein cows reduces beef income from the dairy herd. Although the beef production from dairy herds is not always regarded as important, in some countries this comprises 20 to 50% of the national beef supply.

Although the Irish trials show positive results with regards to crossbreeding using Jerseys on Holsteins, this does not mean it would be the best solution for South African dairy farmers as production systems and markets differ. Dual-purpose breeds have only received limited attention in this debate. Dual-purpose breeds are used mostly in Europe. The Fleckvieh breed is a Simmental derived dual-purpose breed from Germany with medium to high milk yield levels, relatively high milk components, and a high beef potential in comparison to Jersey and Holstein cows. It is the second largest dairy breed in the world. There are also a number of Simmental derived breeds like the Montbéliarde in France and the Abondance in Italy. The Montbéliarde breed (also a Simmental derived breed from France) has been used in similar crossbreeding trials on Holsteins in the USA and Ireland. Except for farmers' observations based on a few records, little scientific information is available in South Africa on the effects of using a dual-purpose breed like the Fleckvieh on Holstein and Jersey cows.

Elsenburg studies

Because farmers have requested information on the benefits and problems related to crossbreeding using specifically a dual-purpose breed, two crossbreeding studies using a dual-purpose breed as sire line have been conducted at Elsenburg since 2008. Holstein and Fleckvieh x Holstein (FxH) heifers were sourced from a large pasture-based dairy herd. Heifers were reared to first calving and their progeny has been included in the study as well. On the FxH cows Fleckvieh bulls were used on the recommendation of Bayern Genetics from Germany. For the crossbreeding study on Jerseys, the Jersey herd at Elsenburg was divided into two groups based on breeding value for milk yield and randomly allocated to be inseminated by Jersey or Fleckvieh sires. After calving, these two groups of cows were inseminated with the alternative breed. Heifers from all the different breeds were reared in the same way. They were put in a service group from 13 months of age and inseminated when observed in heat. After first calving, Holstein and FxH cows were on a total mixed ration system while Jersey and Fleckvieh x Jersey (FxJ) cows were in a pasture-based system. These cows received in addition to *ad libitum* pasture, 7 kg concentrates per day, regardless of the amount of milk cows produced. The milk yield and milk composition of cows were recorded according to standard milk recording procedures. Cows were inseminated from 60 days after calving and the reproductive performance of each cow recorded. Insemination dates of all heifers and cows were recorded as per usual for a dairy herd. From these dates, a number of fertility parameters were derived. All cross-bred cows (+ 50% Fleckvieh) were grouped together and compared to Jersey and Holstein cows within each production system.

Bull calves from both projects were reared to be marketed for either veal or for beef. Calves for veal were fed intensively up to a market live weight of approximately 200 kg, as for veal, the carcass weight of calves should not exceed 100 kg. For beef production, bull calves were castrated at three months of age and reared on rain-fed pastures to 18 and 21 months of age for Holstein and FxH steers and Jersey and FxJ steers, respectively.

Elsenburg crossbreeding results

Only a few results are provided because of limited space. The milk, fat and protein production of FxJ cows was higher, although at lower fat and protein percentages, than Jersey cows (Table 42.1). Fat and protein percentages were higher in the milk of FxH cows in comparison to Holstein cows (Goni *et al.*, 2014 and Metaxas, 2015).

Table 42.1. Milk production parameters for Jersey (J) and Fleckvieh x Jersey (FxJ) cows in a pasture-based system and Holstein (H) and Fleckvieh x Holstein (FxH) cows in a total mixed ration system

Parameters	Pasture-based system		Total mixed ration	
	J	FxJ	H	FxH
Milk (kg)	5398^{a}	6141^{b}	6240	6108
Fat (kg)	246^{a}	272^{b}	243	251
Protein (kg)	194^{a}	215^{b}	198	200
Fat %	4.61^{a}	4.47^{b}	3.91^{a}	4.13^{b}
Protein %	3.62^{a}	3.51^{b}	3.19^{a}	3.29^{b}

^{a,b}Values with different superscripts within production system differ at $P < 0.05$

As cows get older, the numbers of alveoli in the mammary gland increases, accounting for the increase in milk yield in older cows. Parity affected the production performance of breeds differently. Lactation milk yield for Jersey cows peaked in the third lactation (5674 kg), while milk yield continued to increase beyond the fourth parity in the FxJ cows reaching more than 7000 kg in fifth lactation. Similar trends were also observed in fat and protein yields with FxJ cows.

Age at first service was earlier for FxH heifers than for Holstein heifers with a larger proportion of heifers serviced by 14 months of age (Table 42.2). The interval from calving to first service was also earlier for FxH cows than for H cows with a larger proportion of cows inseminated within 80 days post partum and more FxH cows confirmed pregnant by 100 days-in-milk.

Table 42.2. The reproductive performance of Holstein (H) and Fleckvieh x Holstein (FxH) heifers and cows in a zero-grazing system (CFS = calving to first service; DO = days open; DIM = days in milk) (Muller *et al.*, 2014)

Variables	Heifers		Variables	Cows	
	H	FxH		H	FxH
Number of records	115	53	Number of records	201	108
Age first service (m)	16.0^{a}	15.3^{b}	Lactation number	1.83	1.97
First service before 14 m	0.14^{a}	0.26^{b}	Interval CFS (days)	91^{a}	85^{b}
First service before 17 m	0.75	0.85	First service before 80 DIM	0.41^{a}	0.51^{b}
Conception age (m)	17.2	17.1	Interval DO (days)	149	137
Pregnant before 14 m	0.21	0.23	Pregnant before 100 DIM	0.29^{a}	0.45^{b}
Age at first calving (m)	26.4	26.3	Pregnant before 200 DIM	0.57	0.66

^{a,b}Values with different superscripts within heifer and cow groups differ at $P < 0.10$

With regards to the reproductive performance of Jersey and FxJ heifers and cows, age at first insemination and conception age for heifers did not differ between breeds, resulting in a similar age at first calving. However, the reproductive performance of Jersey and FxJ cows showed that the interval from calving to first service was shorter for FxJ cows, i.e. 77 days compared to 82 days for Jersey cows. As a larger proportion of FxJ cows was inseminated within 80 days post calving compared to Jersey cows (70 and 54%, respectively), the proportion of cows confirmed pregnant by 100 days in milk was higher for FxJ cows than for Jersey cows, being 79 and 66%, respectively. Generally, over both studies and breeds inseminator proficiency was poor at 0.45 which could have affected the final conception results.

In closing

Crossbreeding has resulted in improved performance in a number of studies. This is probably due to the effect of heterosis. Fitness traits, like fertility, benefit more by heterosis than production traits. Overseas researchers maintain that crossbreeding in the dairy industry will increase rather than decrease. Crossbreeding studies at Elsenburg showed that FxJ cows produced more milk, fat and protein than Jersey cows. Some reproduction traits in FxJ heifers and cows were improved by crossbreeding. Smaller differences in production parameters were observed between FxH and Holstein cows with only milk composition differing significantly, being higher for FxH cows. Farmers interested in exploring crossbreeding should maintain a portion of the herd in a purebred state to enable a comparison of pure- and crossbreds. For an on-farm trial, pure- and crossbred cows should be on the same feeding level and overall management. Records on calving ease, survival of heifers and cows should also be collected as part of the evaluation. It should be kept in mind that although day-to-day observations may give some information, it is only through a proper statistical analysis that final results could give correct conclusions. This is specifically important for long term studies like crossbreeding.

CHAPTER 43

BEEF PRODUCTION FROM THE DAIRY HERD

Introduction

Beef production from dairy herds has two sources, namely, bull calves reared for veal or beef, or culled cows or heifers. Selling bull calves is regarded as a source of income, while culling cows for beef is regarded as a loss in farm income. The reason for this is that the income of cow sales is lower than the cost of raising replacement heifers. High cull rates are regarded as negative for farm profit which should be prevented. Often on pasture-based dairy farms when the maximum carrying capacity of the farm has been reached, cows are inseminated with beef sires to prevent the ever-increasing growth in herd numbers. Because of the introduction of milk quotas in Ireland, approximately 55% of all dairy cows were inseminated with beef sires with the rest of the herd bred with dairy sires. Since 2007, approximately 60% of cows have been bred to dairy bulls with the remainder to beef bulls, i.e. Angus (14%), Hereford (11%), Limousine (6%) and the rest to other European breeds. It is anticipated that in Ireland, dairy herds will increase in size, i.e. cow number; therefore, increasing the number of bull calves coming from dairy herds.

In South Africa, no information is available on the number of bull calves entering the beef production system. On most dairy farms, bull calves are marketed soon after birth as they are generally regarded as unwanted. This is because the income from beef is low in comparison to milk sales. Recently, there is an upsurge in interest in the raising of dairy bull calves. Often it is someone who wants to get into farming. Some land and/or infrastructure might be available along with access to bull calves from a nearby dairy farm. The usual reasoning behind this is that calf rearing is an easy-to-operate and well-paid venture. This is, however, not always the case with many would-be farmers failing in starting-up such an operation. New farmers with limited funds and facilities need to be very careful before venturing into this high risk operation. To be successful in bull calf rearing, specific skills and knowledge of calf rearing is required. In this chapter some aspects of bull calf rearing are briefly discussed.

1. High mortality rates

There have been numerous cases of farmers buying, from large dairies, groups of bull calves, varying in age from a few days to several weeks old, and transporting them within a few hours over long distances to a new farm. A number of these young calves get sick after arrival on the new farm, usually getting diarrhea and soon die when not treated quickly. Instances of mortality rates of up to 70% have been recorded, although a mortality rate of 25% is more common. The high mortality rate is due to a number of reasons, one being the fact that calves probably did not receive a sufficient amount of colostrum at the original farm immediately (within 6 hours) after birth. This is further exacerbated by exposure during travelling and different pathogens on the new farm, especially if housing conditions are poor. Colostrum is the first step towards protecting young calves against pathogens, as this gives them a passive immunity against diseases that the mother was exposed to. On the new farm, calves should get colostrum from a cow in the herd to provide some protection against local diseases until their own active immunity system has developed. Colostrum is a high quality feed and should be fed for as long as possible in any case, as it also provides protection in the gut of calves. Research has shown that calves with lower levels of passive immunity show reduced daily live weight gains in the first few months of their lives. Not getting enough colostrum after calving increases the health risk for calves, while mortalities add to the production cost of the operation reducing profitability. The reason for the high morbidity in bull calves resulting in a high mortality rate is usually because little effort is put into rearing bull calves, unless it is a bull calf to be reared for breeding purposes. In many cases bull calves are regarded as unwanted as they apparently contribute little to the income of a dairy farm.

2. Different rearing systems

There are different ways of rearing bull calves, e.g. for veal or beef. For white veal, bull calves are usually fed intensively in small crates on just milk or milk replacer, while for red veal, calves are fed high quality calf starter and growth meals on an *ad libitum* basis. White veal is not common in South Africa and such markets have to be developed on own initiative. It is a high cost operation and the survival of calves is very important. For veal, the carcass weight should not exceed 100 kg; therefore, the marketing age of bull calves is a live weight of about 200 kg. For beef, bull calves are usually fed intensively up to about 3 months of age, after which they will go on pasture which is supplemented with a suitable concentrate mixture. Marketing age for steers could be from 18 to 24 months of age. When no pastures are available, total mixed rations are formulated and mixed according to the nutrient requirements of bull calves within age groups. In this case, feed sourcing becomes very important as this determines the success of the venture. Profit margins are usually small because of high feed cost with mortalities having an eroding effect. For this operation, the farmer must have access to equipment such as a mixer-feeder wagon, an open camp system, feed and water troughs, etc. One should also have the knowledge and skills to formulate diets and to negotiate buying required feeds. Although the feeding cost of steers in a cultivated pasture-based system would probably be lower, the profit margin per hectare is questionable.

3. Breeds to use

Because beef production from dairy herds is unexploited in South Africa, farmers tend to disregard its contribution to herd income. For this reason, limited research has been done on this subject. In the USA, however, the beef potential of Holsteins has been demonstrated in research, with 22% of the national beef supply coming from dairy farms. In other countries cull cows and bull calves reared for beef make an even larger contribution to the national beef supply. In New Zealand, 52% of total beef produced come from dairy herds, of which 59% is used for processed grade beef for export. In Europe, the contribution of dairy farms is also more than 50% coming mainly from dual-purpose breeds and Holsteins. In South Africa, the contribution of dairy farms to the national beef supply is unknown, probably less than 15%. For Jersey farmers crossbreeding using a beef breed is one option in developing the beef component of their herds. Although Jersey steers have a poor growth rate in comparison to other breeds, the beef is of high quality with a fine texture.

4. Using dual-purpose breeds

A modeling study in Germany showed that the environmental effect of dairy farming is reduced by higher milk yields in dairy cows, because fewer cows are required to supply a specific amount of milk. However, fewer dairy cows resulted in an increase in the number of beef animals to provide in the beef demand. This increased total greenhouse gas emissions. Based on these results, researchers question the use of specialist dairy breeds. It is suggested that dual-purpose breeds would be a more viable option in reducing greenhouse gas emissions (Zehetmeier *et al.*, 2012).

Crossbreeding studies conducted at Elsenburg showed the benefit of using a dual-purpose breed for beef production in dairy herds. Fleckvieh sires, a Simmental derived breed from Germany, is being used on Jersey and Holstein cows. Although the absolute birth weight of Fleckvieh x Holstein (FxH) bull calves was higher than that of Holstein bull calves, the differences between breeds were not significant for average daily gain and age at marketing for veal and live weight at 18 months of age. For instance, the live weight of FxH steers at 18 months of age was only 5% higher, being 465 vs. 441 kg respectively. These small differences emphasise the strong beef capabilities of Holsteins as originally used in Europe and the United Kingdom. Results indicate that further studies are required to determine the optimal feeding programme to utilise the growth potential of crossbred bull calves, marketing age, and its effect on beef quality characteristics.

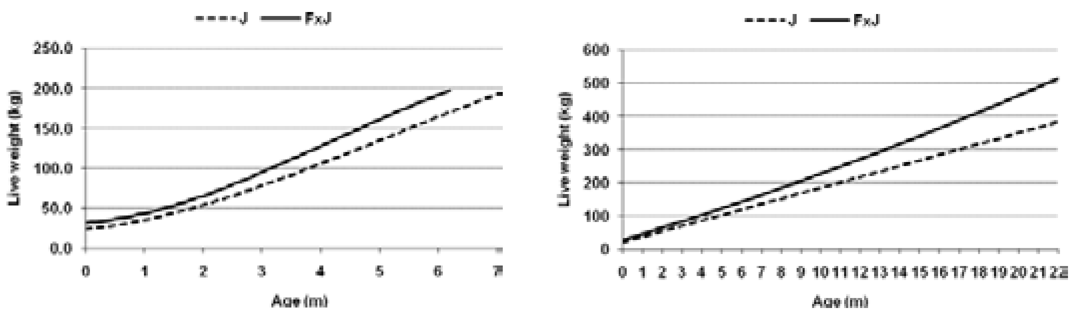
However, Fleckvieh x Jersey (FxJ) bull calves reared for veal, reached market weight (a live weight of about 200 kg) more than a month earlier than Jersey bull calves, i.e. at 6.2 and 7.3 months, respectively (Table 43.1). Jersey and FxJ steers, reared mostly on rain-fed pastures, reached live weights of 324 and 433 kg, respectively, at 21 months of age.

Table 43.1. The mean growth performances of Jersey (J) and Fleckvieh x Jersey (FxJ) bull calves reared intensively for veal and in a partially pasture-based feeding system for beef production (Goni *et al.*, 2016)

Variables	Veal production system		Beef production system	
	J	FxJ	J	FxJ
Number of records	22	39	22	25
Birth weight (kg)	27.5[a]	31.9[b]	26.4[a]	33.4[b]
End live weight (kg)	193.6	194.4	324.4[a]	433.0[b]
Marketing age (m)	7.27[a]	6.21[b]	21.06	21.05
Average daily gain (kg)	0.754[a]	0.865[b]	0.465[a]	0.624[b]
Hot carcass weight (kg)	93.2	97.9	161.1[a]	204.4[b]
Dressing-out (%)	0.48[a]	0.50[b]	0.49 ±	0.47

[a,b]Values with different superscripts within production system differ at $P < 0.05$

This is because of a higher birth weight and a higher average daily gain, i.e. 0.865 vs. 0.754 kg in FxJ bull calves. The growth curves of bull calves reared for veal and beef are shown in Figure 43.1. It is clear that differences between the breed increases with age, indicating a greater advantage at an older age.



(a) (b)

Figure 43.1. The live weight of Jersey (J) and Fleckvieh x Jersey (FxJ) bull calves reared as (a) veal and (b) beef to 21 months of age (Muller *et al.*, 2013)

Although varying over time because of supply and demand, the average selling prices for four- to five-week-old Jersey, Holstein and FxJ and FxH crossbred bull calves at weekly sales, were, respectively R80, R750, and R700 to R800 each.

Early work in the mid 1960's in South Africa showed low growth rates and efficiency of gain for purebred Jersey steers in comparison to beef x Jersey crossbred steers (Naude & Armstrong, 1967). The weight gain of Jersey bulls was improved by 39% by crossbreeding with Simmental bulls. Other researchers in New Zealand also found that the disadvantages of pure Jersey cattle are greatly reduced by crossbreeding with beef breeds. Research in New Zealand showed that beef production from Friesian cows can be increased through higher meat yields and dressing-out percentages by using suitable beef breeds, e.g. Piedmont and Belgian Blue sires. Other breeds that have been used in crossbreeding with Jersey are Belgian Blue and Chianina. Birth weights of calves from these sires were on average 34.7 and 35.0 kg, respectively, with no dystocia in either group of cows. The growth rate of crossbred steers was higher than that of purebred Jersey bulls. An alternative option would be to use a dual-purpose breed like Fleckvieh or Montbéliarde in a crossbreeding programme, as this gives the option of utilising heterosis with regards to milk yield and fertility.

In closing

For pasture-based dairy farmers using Jersey cows, herd income could be increased by using beef sires on the bottom third of the cows in the herd. This management option should, however, only be considered when (1) herd size has reached its maximum capacity for the farm and (2) the culling rate of cows is low not requiring all heifers to be reared as replacements. Crossbred bull calves and heifers must also be marketed off the farm shortly after birth to ensure that they do not compete with the dairy herd. Research is required to determine the best beef breed to be included in a breeding programme on Jersey cows. In Ireland, using a seasonal pasture-based production system, a number of specialist beef breeds are being used on Holstein cows to utilise the beef potential of dairy herds.

CHAPTER 44

IMPROVING EFFICIENCY IN DAIRY HERDS

Introduction

Feed efficiency in dairy cows is important because of the relationship between cow efficiency and income over feed cost. Gross feed efficiency is defined as the ratio between one kg of fat-corrected milk per unit of estimated net energy consumption. This may also be described as the total amount of feed required to produce a specific amount of milk. Herd efficiency could also be estimated for the total herd output vs. the total production cost. The herd output would then comprise of the herd's total milk, fat or protein yield, total beef production, and sales of surplus heifers and bulls for breeding. Comparing the feed efficiency of cows between breeds and farms is difficult as a number of factors affect production. This should only be considered within similar production systems, breeds, lactation number (age), and lactation stage. When comparing breeds, milk yield should be corrected to a similar level, i.e. energy or fat corrected milk yield. To estimate feed efficiency, an indication of feed intake is required. In a zero-grazing system feed intake could be determined by weighing the amount of feed provided on a daily basis. To be correct, the refusals of a specific day's feed allocation should also be weighed back the following day as usually in these systems, feed is provided in excess of the daily feed requirement to ensure an *ad libitum* intake. For pasture-based systems, supplemental feeds, such as concentrate and hay or silage, should be determined on a daily basis. Pasture intake should be determined from the pasture available before grazing and residual pasture after grazing. It is incorrect to use a standard pasture intake for cows under all pasture production systems. Feed efficiency is, therefore, a complex trait and its definition requires clear descriptions. Some suggest that total output in terms of farm income versus total cost is the best way to define efficiency. However, improving efficiency of different parts of the dairy herd could make a major contribution towards improving the total efficiency of a farm. In this chapter considerations for improving feed efficiency in dairy cows will be discussed.

Benchmarks for feed efficiency comparisons

Estimating the feed efficiency of cows in a dairy herd at specific points of the lactation is one way to improve feeding management. Efficiency benchmarks could be established for dairy herds to monitor management. Optimising feed intake is more important than maximising feed intake. In Table 44.1 benchmarks for feed efficiency for US Holstein cows on total mixed rations is shown.

Table 44.1. Benchmarks for feed efficiency for US Holstein cows on total mixed rations

Group	Days in milk	Feed efficiency (kg milk/kg DM of feed)
All cows	150 - 225	1.4 – 1.6
1st lactation	< 90	1.5 – 1.6
1st lactation	> 200	1.2 – 1.3
2nd + lactation	< 90	1.6 – 1.8
2nd + lactation	> 200	1.3 – 1.4
Fresh cows	< 21	1.1 – 1.2
Problem herds	150 - 200	< 1.3

The efficiency of production varies depending on lactation number and stage of the lactation, i.e. being higher in older cows and early lactation and lower in younger cows and towards the end of the lactation. Furthermore, cool weather increases feed efficiency, i.e. 1.40 vs. 1.31 on warm days. As expected, feed efficiency increases with a higher milk yield, while fibre intake and fibre level in the diet reduces feed efficiency. The genetic merit of cows also affects feed efficiency. A study in the US showed that daughters from high genetic merit bulls produce more milk than low genetic merit bulls, even though feed intake was not different, resulting in a better feed efficiency.

Cow or herd efficiency

Efficiency of production can be estimated for individual cows, for production groups or lactation stage, or for the herd. A simple way of expressing cow efficiency would be the gross margin of milk income above concentrate cost, i.e. milk yield multiplied by milk price (R/litre) minus amount of concentrate fed multiplied by concentrate cost (R/kg). This usually shows higher margins for older and early lactation cows. For a herd evaluation, the feed consumption of heifers and dry cows should be included in the efficiency estimation. The reason for including these animals is, although milk is produced by the lactating cows, heifers and dry cows are part of a dairy herd. The feeding requirements of these animals may be regarded as a maintenance cost for the herd. This might explain why efficiency differs between herds, even though the milk yield of cows is on the same level.

Herds with a smaller ratio of heifers to cows in the herd because of an early age at first calving would have a better herd efficiency than when the ratio of heifers is higher. A higher success rate in rearing heifers to first calving would also result in increasing herd efficiency because surplus heifers may be sold for breeding purpose, thereby generating an extra herd income. In herds with a low culling rate, a smaller proportion of cows need to be inseminated with dairy sires with the rest being serviced by beef sires. This would create another option for increasing herd efficiency by marketing additional beef from the herd. Most dairy farms also have an income from the sale of culled bull calves, heifers and cows for beef. In the USA, for instance, more than 20% of the national beef production comes from dairy farms while in Europe this contribution is 50%, possibly indicating that these countries are using a larger number of dual-purpose breeds for milk production. Herds with a low replacement rate of cows usually have surplus heifers for sale (which is an income for the farm), while farmers may be contracted to produce bulls for the artificial insemination industry. Other factors affecting herd efficiency may include correctly designed and maintained feed troughs (which will reduce feed wastages), better reproduction management because of an earlier age at first calving, earlier conception after calving, and fewer cows in late lactation. Production factors that will improve efficiency are milk yield levels at the start, peak, and end of the lactation, as well as the persistence of production after peak yield.

As cows consume more feed to support a higher milk yield, a smaller portion of feed energy intake is partitioned towards maintenance with a greater proportion of digested energy being used for milk production. Therefore, biological efficiency increases as milk yield increases (Figure 44.1a). Lifetime efficiency is defined as the capture of feed energy in milk and various body tissues divided by the gross energy (GE) intake during the life of a cows, starting at birth. As milk yield increases, the rate in increase in lifetime efficiency decreases (Figure 44.1b). Lifetime efficiencies were predicted assuming the average Holstein cow weighs 625 kg at maturity, and has a lifespan of 4.9 years of which 2 years is as a heifer and three lactation periods of 305 days each and two 60-d dry periods. It is expected that the conversion of gross energy to milk would not increase beyond 26%, unless major improvements occur in digestibility of feeds.

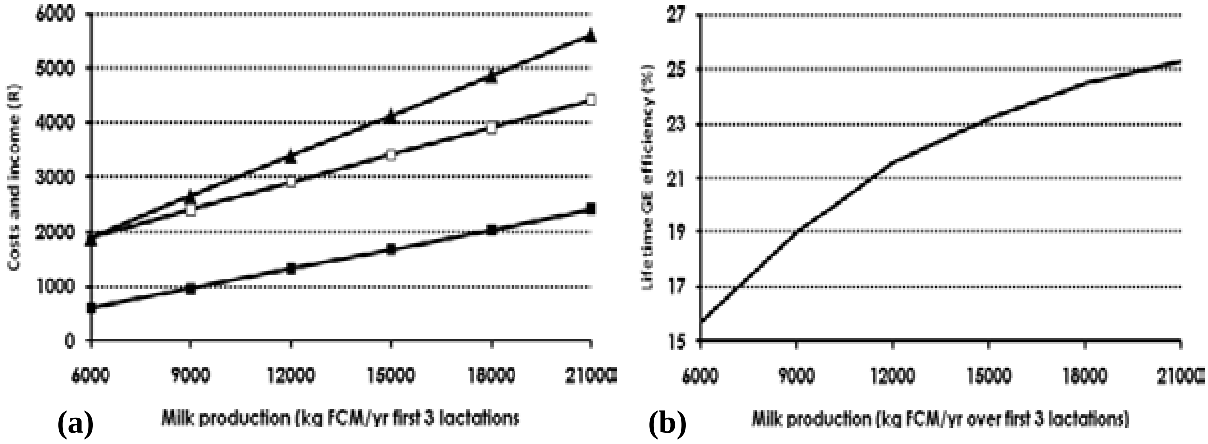


Figure 44.1. The effect of increasing milk yield on (a) predicted profitability (▲) as the difference between feed costs (■) and non-feed costs (□) and (b) lifetime gross energy efficiency for Holstein cows

Modelling lifetime efficiency showed that for cows producing at 9000 kg/yr at maturity, lifetime efficiency is predicted to increase from 17% after first lactation to 20.5% after three lactations and to 21.4% after five lactations. For cows producing less milk at maturity, lifetime efficiency is lower while requiring more lactation periods to reach maximum efficiency.

A paper published in 1953 by Leitch & Godden, although at much lower milk yield levels, showed a similar trend (Table 44.2). The study was based on estimating the energy expenditure of cows at different milk yield levels and age.

Table 44.2. The energy efficiency (%) of dairy cows as affected by milk yield per lactation and number of lactations per lifetime

Milk yield (kg)	Number of lactations – Energy efficiency (%)			
	3	4	7	10
2725	14.4	15.2	16.6	17.3
3635	17.3	18.3	20.0	20.8
4545	19.8	21.0	22.9	23.8

The whole life efficiency of cows increases with milk yield and age. However, it seems that milk yield has the largest effect on energy efficiency. The improvement with increasing number of lactations is probably related to the effect of the number of replacement heifers that have to be included in the herd. Reducing the age of cows in the herd increases the number of heifers to be reared to replace cows. Efficiency of production is negatively affected by high culling rates in dairy cows. High culling rates reduce the lifetime of cows requiring more replacement heifers.

By using specific diets for different groups of animals within a herd, the total feed consumption was estimated. This was then compared to the output required for specific milk yield levels. This showed that efficiency of production was at its highest at peak production in the lactation. The relationship between daily milk yield and total energy efficiency is described in Figure 44.2. From this it is clear that in the process of herd improvement, culling low producing cows would result in a quicker improvement in herd efficiency.

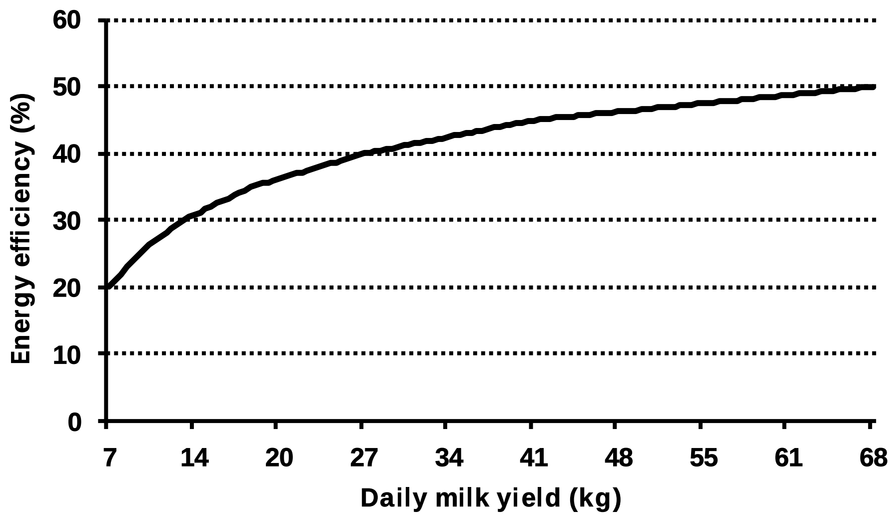


Figure 44.2. The relationship between daily milk yield and energy efficiency of dairy cows

Using cow live weight in efficiency estimation

Other factors affecting efficiency include the live weight of cows. The ratio between lactation milk yield and live weight of cows is therefore a popular trait used by farmers as an indicator of efficiency. Early research showed that the energy efficiency of milk production is independent of body weight. However, later work showed that although live weight is positively correlated to level of milk yield, body size is slightly but inversely related to biological efficiency. It is therefore expected that a cow weighing 825 kg would be expected to be less efficient than a cow weighing 625 kg, unless the heavier cow produces at least 5 kg more milk per day. However, for cows producing more than 40 kg/day, the relationship between body size and efficiency may change as the effects of nutrient partitioning decrease and the impact of digestibility increases. If, however, live weight is not related to the digestive capacity of the mature Holstein cow, a larger cow would never be as efficient as a smaller cow specifically at similar milk yield levels.

It has been suggested that the ratio between the lactation milk yield and live weight may be used as an index of merit for dairy cows. Although such an index shows a large variation among cows, this popular trait used by dairy farmers and consultants is not well-accepted by most geneticists. The reason for this is the positive genetic link between the traits affecting the ratio. This means that selecting for higher milk yields tends to increase the live weight of cows. However, the genetic correlation is not high, only about 20%, indicating that other factors affect the live weight of cows. Therefore, to improve efficiency according to the ratio between milk yield and live weight, either milk yield has to be increased while maintaining live weight, or milk yield, has to be maintained while reducing the live weight in dairy cows.

To use this trait as a selection tool within a herd would be problematic as older cows produce more milk at higher live weights than younger cows. This would most probably result in a better efficiency measure for first lactation cows because of their lower live weights. However, dairy herds do not consist of only first lactation cows which produce in most cases only about 25% of the herd's milk yield. The value of comparing the efficiency measures of cows in a herd without considering lactation number is therefore questionable. Furthermore, the efficiency merit of first lactation cows may even be higher if their actual live weights are below target breed norms. It is highly unlikely that farmers would cull cows because they are too heavy in relation to their lactation milk yield. It would further not make sense to cull cows because of body size when this trait is not included in the selection of bulls to be used in the herd. The amount of milk that is produced in a dairy herd mainly affects a dairy herd's financial sustainability and direct selection for that should be the main breeding objective. Studies showed that the genetic correlations between efficiency and production, efficiency and body weight, and body weight and production were 0.92, − 0.17, and 0.28, respectively. The heritability of efficiency was 0.46 as opposed to 0.62 for production. It was concluded that selection on the basis of yield alone would increase the genetic potential for feed efficiency.

Selecting sires for improved efficiency

Earlier studies have shown that the heritability of efficiency and milk yield differ and that a faster improvement in efficiency would be obtained by selecting for milk yield on its own. The way to improve any production trait is through sire selection. Most farmers often do not have a well-described sire selection programme and tend to use a bull-picking method based on "fixing" conformation problems in cows currently in the herd. It would be better to rank a list of bulls from best to worst for the most important trait to be improved in the herd. Preferably, a multi-trait index should be used to select bulls. In this way, different traits will be improved simultaneously. The best 5 to 6 bulls at the top of the list are picked and randomly used on cows in the herd. Alternatively, a mating programme can be used. With the large number of bulls going through bull progeny testing, it has become possible to select bulls for higher milk yields, while at the same preventing an increase in mature live weight. However, mature live weight is not currently included as a trait in most animal improvement programmes. It is recommended that body size traits be used. For bulls in the US, progeny testing programmes classification data are used to estimate the body composite trait consisting of 50% stature, 25% strength, 15% body depth, and 10% rump width.

In closing

Information on the feed efficiency of dairy cows and herds is important towards ensuring better feeding and overall herd management. Fine tuning feed efficiency requires actual feed intake figures as feed refusals should also be included in the estimation. Corrections for milk components should be included as more nutrients are required for higher fat and protein percentages. The feed efficiency of smaller cows is better, although only at similar milk yield levels. Improving reproduction management will increase herd efficiency because of fewer unproductive days.

CHAPTER 45

REDUCING THE ENVIRONMENTAL IMPACT OF DAIRY FARMING

Introduction

The image of agricultural production systems is increasingly being scrutinised by welfare organisations, activist groups, and the public. Intensive systems are getting the most attention. These so-called factory farms are being regarded by the public as not ideal for the production of basic agricultural products like milk and meat. The antagonism against these systems is based on two aspects, namely, the welfare of cows and the perceived effect of these systems on the environment. The public would prefer to see cows produce milk from green pastures as nature intended. Although pasture-based dairying systems probably provide the best living conditions for cows, except in summer when heat stress is experienced or during winter when it rains, it might not the best for the environment.

Background

Dairy cows, being ruminants, contribute directly to greenhouse gas (GHG) emissions (FAO, 2006). This is because of their unique way of feed digestion. Through a fermentation process, anaerobic bacteria in the rumen break down fibre type products in animal feeds to produce various end-products that cows use to sustain themselves. Methane (CH_4) gas, a major GHG, is produced through this fermentation process. Methane is released into the atmosphere through the natural processes of belching and breathing. The only way to reduce the CH_4 gas production from farm animals is to reduce their numbers as the fermentation process in the rumen cannot be stopped or altered significantly on a long term basis. It can only be slightly changed by using lower forage diets. The rumination process has evolved over millions of years. The implication, therefore, is that all ruminants in the world have for all times been contributing towards GHG and thus climate change. It is only recently that their specific way of converting feedstuffs has caught the attention of activist groups and eventually the attention of the public. By consuming high forage diets, which are unsuitable for human consumption, cows produce high quality food products such as milk and meat. Activists campaigning against dairy cows have not come up with alternative foods for humans to replace the high quality protein, fat, lactose, minerals and vitamins being consumed on a daily basis through milk, milk products or beef. Furthermore, the comparative impact on the environment of the production of such alternative food sources has not been modelled by activist groups.

Comparing past and present dairy production systems

By modelling it is possible to determine the effect of past and present farming systems on the environment. Capper *et al.* (2009) was reported that, in 2007, the United States (US) dairy herd consisted of 9.2 million cows producing about 84 billion kg of milk. In comparison, in 1944, 53 billion kg of milk was produced by 25.6 million cows. This means that the total US milk output has increased by 58%, while the number of dairy cows was reduced by 64%. This change in output can be ascribed to a combination of improved genetic merit of cows, better diet formulation, better herd health, and housing management aimed at improving animal care. Although producing more milk, the smaller number of dairy cows resulted in a 77% reduced feed use, 90% less land use, 65% less water use, and a 63% decrease in GHG emissions per kg of milk. To produce the same amount of milk at lower production levels, as would be expected on a high forage diet like a pasture-based system, would mean a national herd consisting of a larger number of lactating cows, more dry cows and replacement heifers. A higher milk production not only reduces the number of cows but also reduces the total feed requirement and resource use of all the animals. In this chapter, three ways to reduce the impact of dairy farming on the environment, regardless of farming system, are discussed.

Options include improving the efficiency of dairy farming by increasing the genetic merit of cows for higher lifetime milk yields, improving feed quality and feeding management, and selecting cows for reduced methane output.

1. Improving efficiency of dairy farming

The best way to reduce the impact of livestock production on climate change is by improving the efficiency of production systems (Mitloehner, 2013). This means that more milk (and beef) must be produced from the same inputs, specifically ruminant feeds. The efficiency of energy utilisation is increased with greater energy output (milk yield) by diluting the energy required for maintenance. Research showed that as milk production increased over time, total cost per kg of milk decreased, regardless of year or breed. Feed, labour, replacement and operational costs also decline at increasing milk yield levels. The reason for this is the dilution of a dairy's fixed costs. Larger dairy herds tend to have a lower cost of production and a larger milk net income per unit than small herds. Using a mechanistic model to predict the methane emission in Dutch dairies, it was shown that average methane emissions per cow per year increased from 110 kg in 1990 to 126 kg in 2010, but at the same time the average methane emissions decreased from 17.5 to 15 g per kg of milk (Bannink *et al.*, 2011).

Improved efficiency in dairy herds is not limited to higher milk yields by cows, but also includes better reproduction performance of heifers and cows. Research in Ireland showed that the growing dairy heifer represents approximately 25% of the feed costs of a dairy animal's lifetime (Berry, 2013). This means that an early age at first calving (before 24 months of age) would improve efficiency because of a reduction in total feed required during the unproductive period of a cow's lifetime. Other research in Germany showed that GHG emissions produced during the rearing phase of replacement heifers contribute up to 20% of total GHG emissions from modelled dairy farms (Zehetmeier *et al.*, 2012). The reduction in GHG emissions per kg of milk was 13% with a reduction in the replacement rate from 40% to 30%. Other researchers found that feeding lactating cows more than one ration over the lactation period improves production efficiency as it provides closer-to-requirement nutritional density diets avoiding nutrient wastes. Multiple nutritional grouping reduces the number of over-conditioned cows and excess nutrient excretions, improving income over feed costs.

Herd structure gives an indication of the fraction of animals in different parities, age, days after calving, pregnancy status, lactation status, etc. Grouping and feeding animals according to the herd structure would similarly improve herd efficiency as indicated previously. Feed efficiency is high before the peak in milk yield during the lactation; therefore, a herd with more cows early in lactation would be more efficient, because of a higher average milk yield, than a herd with more cows in late lactation. Reproduction problems result in cows being milked longer after calving therefore increasing the average number of days-in-milk for the herd. Better reproduction would therefore improve feed efficiency. As the lactation milk yield of cows increases with age (or parity), a dairy herd with more old cows, as indicated by a higher average lactation number, is more feed efficient than a younger herd. As cows are culled from the herd due to various reasons and heifers are reared to replace culled cows, the annual cow cull rate and age at first calving of heifers would have a marked effect on herd efficiency. A low cull rate results in the best whole farm efficiency, whereas a high cull rate results in the best cow efficiency but at a lower farm profit.

For dairy cows, only 26% of feed energy results in useful end-products, i.e. milk 24% and fat storage 2%. The remainder is lost as heat (33%), methane (5%), urine (3%), and faeces (35%) (Erdman, 2013). In terms of heat production, a major loss is due to the cow's maintenance requirement. This is driven by the cow's live weight; however, the increase in maintenance requirement because of an increasing live weight occurs at a decreasing rate. Therefore, while increasing size increases the cow's maintenance requirements, a smaller portion is used for maintenance allowing for a higher milk yield.

It has been pointed out that, with the increase in milk yield, fewer cows are required to produce a specific amount of milk. As a considerable number of culled cows and bull calves born in dairy herds being reared for veal of beef production, end up in the beef market, an increase in the national milk yield would mean that the beef production coming from dairies would be reduced. Research in Germany showed that while the number of dairy cows decreased from approximately 6.3 to 4.2 million, the total milk output remained constant. Because of this decrease in dairy cow numbers, gross domestic beef production was reduced by 967 million kg or 44% (Zehetmeier *et al.*, 2012). Therefore, by increasing the average milk yield of cows, the GHG emissions per kg of milk are reduced. However, when considering the beef contribution of dairy cows, the results changed, because the shortfall in beef production from dairy cows has to be made up by more beef animals. The ongoing specialisation in both milk and beef production systems is therefore questioned. The alternative would be to use dual-purpose breeds either as pure-breds or in a crossbreeding programme with specialist dairy breeds.

The Fleckvieh, a Simmental derived breed from Germany, is one such a dual-purpose breed. Other similar Simmental derived breeds are the Montbelliarde in France and Abondance in Italy. At Elsenburg, two studies using Fleckvieh bulls on Holstein and Jersey cows are demonstrating the value of such a programme. Beef production of Fleckvieh x Jersey steers is 34% higher than of Jersey steers, while crossbred calves reared for veal reached marketing age 32 days earlier than purebred Jersey calves (Muller *et al.*, 2013). The milk yield of crossbred cows is also 14% higher than purebred Jersey cows. Crossbreeding Holstein cows with Fleckvieh bulls resulted in a smaller increase in beef production, while the fertility and milk composition of crossbred cows seems to be better. The better fertility and salvage value of crossbred cows should also have a positive effect on farm income and production efficiency.

A recent study showed that the relative difference in the carbon footprint between average and high-performance dairy systems was likely to be greater than the relative difference between high-performing grass and confinement dairy systems (Capper, 2013a). This suggests that improving the productivity of a dairy system has a greater effect on the carbon footprint of milk than converting from a confinement to an intensive grass-based dairy system.

Total milk yield of cows divided by their total feed intake, up to a specific age, could be considered as an efficiency indicator for dairy cows. This means that higher producing cows calving down early and maintaining short calving intervals would be more efficient than lower producing cows or cows calving late for the first time or having longer calving intervals. As it is not practical (or possible) to determine the total lifetime feed intake of animals as heifers and cows, total lifetime milk, fat or protein yield could be considered as an indication of dairy cow efficiency. As this is related to age or productive life, the ratio between total lifetime yield and lifetime in days could be considered as an efficiency measure.

2. Improving feed quality and management

There is a perception that low-input systems have a smaller effect on the environment than high-input large production systems. However, a low-input system is also a low-yield system. Such dairy systems operate on high forage and low concentrate intakes. However, a high-fibre diet increases the CH_4 release per kg of milk in a three-fold manner: (i) by fermenting fibre, (ii) by low productivity, and (iii) by low digestibility of fibre. An increase in the use of starchy concentrates (cereals etc.) reduces the production of greenhouse gases. For high forage feeding systems, the way to reduce the effect of ruminants on the environment would be to increase the digestibility of the forage content of the diet. This implies feeding of higher digestible forages, i.e. forages harvested at an earlier growth stage.

Because of an increasing demand for milk products in the world, many pasture-based farming systems are moving towards more intensive systems. The reason for this is that the production of present day grass cultivars is not much higher than 40 years ago. This limits the milk production output from pasture-based dairy farms. To increase farm milk output, other forage crops have to be incorporated into the feeding system. A common forage crop is maize silage; produced under irrigation, increasing the carrying capacity and milk output of a farm.

Methane gas production is positively correlated to dry matter intake (DMI) and the level of production, although the percentage of dietary energy lost as methane declines with increasing DMI. A higher proportion of forage in the diet is also associated with higher enteric methane output per kg of milk than with a more nutrient-dense (or lower forage) diet. Diets that are digested faster in the rumen produce less CH_4.

Rumen distension dominates the control of feed intake in dairy cows. The filling effect of the diet, specifically the forage neutral detergent fibre (NDF) content, has a much greater effect than other fractions on feed intake. This effect varies greatly according to the digestion characteristics, fragility and particle size of the diet. The most common indicator of feed efficiency in dairy cattle is ratio of fat-corrected milk per kg of dry matter (DM) intake. In average herds, this ratio is around 1.5, while reaching 1.6 in well-managed herds (Erdman, 2013).

Major efforts have been put in reducing the loss in faecal energy by improving the digestibility of feeds. For forages, this includes the stage of maturity at harvesting (by harvesting forage crops earlier improves forage digestibility), forage species differ in digestibility, preservation method, feed ingredient selection, and feed processing. These efforts have not only resulted in improving feed digestibility, but have also increased feed intake and therefore increasing milk yield.

Reducing feed shrinkage has a major possibility in increasing feed efficiency in a dairy herd. Feed wastage occurs during forage harvest, feed delivery and storage, loading and mixing of diets, feeding-out and delivery of feeds. Dry matter loss from harvest to feed-out may range from 12 to 23% for maize silage. Cows that are fed for low refusals have greater eating rates, resulting in a greater risk of rumen acidosis. Daily feed intake is reduced by restricting the time of feed access. An on-farm case study has shown a 3.6 kg/day higher milk yield when cows experienced 0 vs. 6 hours per day of a functionally empty feed bunk. Twice daily feeding in comparison to once daily feeding results in less sorting of feed, especially against long particles during the day. However, feeding more than twice a day reduces resting time. Regular feed push-ups, especially during the hours after feeding, and consistent feed quality and quantity along the full length of the feed trough, improves efficiency with less competition among cows.

3. Selecting for lower methane producing cows

Genetic improvement in any trait is important as it is cumulative and permanent (Berry, 2013). It would therefore make sense to breed for cows that produce less methane to reduce environmental pollution by dairy cows. Genetic gain is, however, a function of the accuracy of selection and genetic variation. Large quantities of data are required to estimate reliable genetic parameters for methane production. It is expected that the accuracy of measuring the methane production of cows directly would be difficult; therefore, an indirect indicator or associated trait, like residual feed intake (RFI), would be required. The genetic correlation between direct methane production and an indicator trait would give an indication of such a possibility. The amount of methane produced by cows is correlated to milk yield levels, making it possible to select for cows producing less methane. Predicted methane emission (PME) is 6% of gross energy intake. Estimated heritability estimates for PME and RFI were 0.35 and 0.40, respectively. The positive genetic correlation between RFI and PME indicated that cows with lower RFI have lower PME values with estimates ranging from 0.18 to 0.84. It would therefore be possible to decrease the methane production of cows by selecting more efficient cows. The genetic variation suggests that reductions in the order of 11 to 26% in 10 years are theoretically possible.

Research in Australia showed that more than 90% of livestock GHG emissions are from cattle and sheep, with beef cattle contributing the most (Herd *et al.*, 2011). Little change is possible in GHG emissions by changing the diet of cattle and therefore selective breeding is the most wide-reaching tool for a lasting reduction in GHG emissions. In ruminants, there is a strong positive relationship between feed intake and methane production. This means that a breeding strategy that reduces the feed intake per unit of product production would result in a reduction in GHG emission intensity. Selecting for a lower methane production (MP), however, may result in a lower feed intake and possibly smaller or slower growing animals. Methane intensity (MI), which is methane produced per unit of bodyweight and methane yield (MY) per unit of feed intake, are two traits that measure methane output independent of cow size and feed intake. Preliminary results of Angus cows show large natural variation between animals in MP, MI and MY. Some animals produced significantly less methane per day, per kg of live weight and per kg of feed intake than the average for the sample group. Sire had a significant effect on MY and MI of animals. Results indicate that selection for a methane production trait may be possible.

Breeding objectives for dairy cattle have traditionally focused on production traits, but this has changed in recent years, leading to more balanced breeding objectives comprising a wider range of economically important traits. The measurement of traits related to animal welfare (hoof problems, lameness and laminitis), heat stress and methane emissions of dairy cows can all contribute to reducing the environmental and social impact of dairy production.

Intensive vs. pasture-based feeding systems

There is currently an ongoing debate on the effect of intensive vs. pasture-based systems on the sustainability and effect on the environment. Because of a growing demand for milk products some countries have experienced better on-farm milk prices. This has resulted in many pasture-based dairy farms increasingly incorporating feeding additional supplements, like concentrates or forage crops, as hay or silage. Supplementary feeds increases the cost of milk production, which raises the demand for cows producing at higher milk yield levels.

For intensive feeding of cows, whether as a supplement to an existing pasture system or as a fully intensive feeding system, feed troughs are required. This aspect has been well-researched and on-farm observation have shown that properly designed, built, and maintained feed troughs would reduce the environmental impact through an improvement of feed intake and a reduction in feed wastage. This, however, means that cows have to spend some time on concrete to consume supplementary feeds. Although concrete is not ideal for cows, it is better than open camps that quickly become muddy with a large build-up of manure which is difficult to remove. Concreted feed lanes keep cows clean and the manure collected on them can be removed by scraping or washing into a manure holding facility, where it can be used for a number of products, such as compost and the generation of energy through biogas systems. In a pasture-based system, only a small amount of manure, mostly around the milking parlour, can be collected. The bulk of the manure and urine is deposited on the pasture, near water troughs and on the way to the milking parlour. This creates an uneven spread of manure on the farm which in some cases could become pollution source-points.

The carbon footprint of the milk output from high-performing confinement and grass-based dairy farms was compared through a life-cycle assessment (O'Brien *et al.*, 2014). GHG emissions attributed to milk only from an Irish-type production system were 5 and 7% lower than a UK and US-type confinement systems respectively. However, without grassland carbon sequestration, all the systems had similar carbon footprints per unit of energy-corrected milk. The way emissions are estimated and the allocation of GHG emissions between milk and meat also affected the relative difference and order of carbon footprints. For instance, depending on the method chosen to allocate emissions between milk and meat, the relative difference between the carbon footprints of grass-based and confinement systems varied by 3 to 22%. However, top-performing herds have carbon footprints 27 to 32% lower than average performing dairy systems.

In closing

As dairy farmers rely on the public as consumers of the end-products of milk being produced on farms, some effort should be put into improving the image of farming systems. At the same time, farmers should demonstrate their commitment towards reducing the effect of dairying on the environment. Improving the efficiency of milk production is the best way to reduce the effect of dairy cows on the environment. This means a high milk yield for cows and good reproduction management with regards to age at first calving for heifers, short calving intervals, and low culling rates of cows. The breeding of cows to produce less methane gas is a future possibility. Using diets containing higher concentrate levels and highly digestible forages would also reduce methane production. Dairy cows produce a large amount of waste products as manure and urine. Manure has been in the past been converted into compost for the improvement of soil quality. It was only through the development of easily available, cheap sources of fertilisers as waste products from the fuel industry, that farmers have stopped using manure as natural fertilisers. In the past, the methane production potential of household waste has been used to produce heat. This was later replaced by cheap electricity. Currently developments are underway again to produce electricity from manure through bio-digesters. Generally, more electricity than is required could be produced on intensive dairy farms. Unfortunately at present, there is a limited market for excess on-farm-produced electricity while the cost of setting up such a unit is very high. The size of a bio-digester is determined by the amount of manure produced on a farm. Farms in close proximity to each other could share an anaerobic digester to reduce construction costs.

CHAPTER 46

BREEDING AND THE LIVE WEIGHT OF DAIRY COWS

Introduction

The genetic merit of a dairy herd is dependent on the average breeding value of the group of bulls that is being used to service cows and heifers in a herd. The selection of bulls has for many years been based on conformation and production traits. Some farmers regard conformation traits of the daughters of bulls to be more important than the production performance of cows. This is an anomalous way of reasoning because cows are kept primarily for the production of milk containing high fat and protein percentages while showing cows would be regarded as an optional secondary reason. This is probably because of pressure from breed societies emphasising the conformation of dairy cows. Although conformation traits are important with research showing that cows with longer productive lives, have specific traits such as high milk yields, good feet and legs, compact udders with teats directly under the udder, and not extreme on size. This, however, does not imply that selecting for those traits would also result in high milk yield levels. Research has shown that the relationship between milk yield and general conformation is about 5% which indicates that the conformation of cows would not decline when sire selection is mainly based on production.

Cow size or live weight of dairy cows is one such a conformation trait that receives a lot of attention, as many dairy farmers believe that it affects milk production profitability. Mostly pasture-based dairy farmers want cows to be as small as possible and may even forfeit production performance in an effort to reduce the size of cows. The dilemma for South Africa dairy farmers is that no research has been done locally to determine the effect of cow size or live weight on the production performance of dairy breeds. Dairy farmers using Holsteins are considering doing crossbreeding with Jersey sires to reduce the size of cows. Similarly, studies on crossbreeding using these two breeds have not been conducted in South Africa. A number of farmers have tried crossbreeding, although seemingly with varying success. Research conducted overseas gives some indication of the outcome of such drastic actions, although results might differ because of different production systems being employed.

Differences in live weight and production systems

While Holstein cows are mainly black and white, the difference in live weight and size within the breed is large, probably affected by the production system being used. In the USA, dairy cows are mostly fed total mixed rations (TMR) and cows are large, weighing on average 650 kg. On the other hand, in New Zealand, dairy cows are kept on pasture and are fed limited amounts of supplemental concentrates and other roughages. Cows are mostly small, e.g. Jersey, Holstein and Holstein x Jersey (Kiwi-cross) cows weighing about 375, 470 and 450 kg, respectively. In New Zealand a seasonal calving pattern is used, while in the USA calving is on a year-round basis. Traditionally, in the USA, there has been a strong emphasis on size, as large cows do well in the show ring.

Although the number of pasture-based dairy farms has increased recently, dairy farmers in South Africa mostly make use of zero-grazing systems. The reason for this is due to the low and erratic rainfall during most times of the year. Cultivated pastures have to be irrigated to supplement the natural rainfall to ensure a year-round pasture production. Even in pasture-based systems in South Africa, it is common for dairy cows to receive varying amounts of concentrates and additional hay or silage resulting in cows consuming less than 50% of their total daily diet as pasture. For instance, Jersey cows on pasture usually receive about 6 kg concentrates per day, while also receiving 2 - 4 kg of hay or silage. For a total daily dry matter (DM) intake of about 15 kg/day, this results in a pasture intake of 7.8 and 6.4 kg DM per day, which is 52 and 46%, respectively, of the total daily intake. Cows have to receive less than 5 kg of concentrates per day and no supplementary hay or silage to have a high (more than 60%) pasture intake. However, feeding high levels of concentrates and supplementary hay or silage increases the carrying capacity of farms, while also protecting the system against seasonal droughts. A seasonal calving pattern is also not an option for dairy farmers in South Africa, as processors require a year-round even milk flow to ensure processing plants operating at full capacity for most of the year. Because of these reasons, there has not been a strong emphasis on "fitting" the cow to the system as is the case for mainly pasture-based seasonal calving systems in countries like Ireland and New Zealand. In South Africa it is on some farms rather a case of fitting the system to the cows.

Genetic implications of live weight

The heritability of live weight in dairy cows is high, about 45%, which means that this trait, together with body size, could easily be changed genetically. It should, however, be kept in mind that there is positive genetic correlation between milk yield and live weight. This means that when selection is aimed exclusively at increasing milk yield, live weight would increase, although the opposite can also happen. The result of selecting for smaller cows would reduce the milk yield of cows. A further problem is that in most bull progeny testing programmes, no breeding values are estimated for the live weight of the progeny of dairy bulls. This is because of a lack of data, as cows are not regularly weighed, while live weights change over the lactation period. However, as an alternative to live weights, body size traits could be used in a breeding programme to change the body size and live weight of dairy cows.

In 1966, a study was started in the USA to compare large and small cows in a TMR feeding system (Hansen *et al.*, 1999). Sires were selected on predicted transmitting ability (PTA) for stature, strength and body depth using an index consisting of (0.5 x stature) + (0.25 x strength) + (0.25 x body depth). Three sires with the most extreme PTA index for small and large body size were selected each year. Cows were randomly mated by sires within each group. Although live weight and body measurements of cows differed significantly between sire groups, there was a large overlap of body size across the two genetic lines. Some results from this study are shown in Table 46.1, showing differences between sire groups over lactations. Despite high heritability estimates for traits related to body size, cows in the two genetic lines differed only slightly in the early generations of the trial. This is probably an indication of the slow additive effect of genetic change. The distributions of phenotypes for the two lines continue to overlap considerably following more than 30 years of intensive selection for body size.

Across years of the study, the body weight of cows did not change for the small line although increasing significantly for the large line. This indicates that the body size of the small line did not change over time although cows in the large line had become larger. The small line reflects Friesian cows used earlier while the large line followed the trend set out by the USA Holstein Association. More importantly is that milk, fat and protein production did not differ between small and large lines. This resulted in a higher income above feed cost for the small line. Although reproduction parameters only differed significantly for services per conception for first lactation cows, all trends favoured the small line. The birth weights of calves were higher for the large line, being 42.0, 44.7 and 45.5 kg vs. 39.4, 42.4 and 43.05 kg for first, second and third lactation small cows, respectively. This, however, did not affect calving ease which did not differ between the two lines. Based on these results, the continuing emphasis on large Holstein cows is being questioned. However, putting a negative weight on body size in a selection index might restrict the increase in production. Traits aimed at improving production and efficiency should be included in selection goals.

Table 46.1. The mean, range live weight, production and some reproductive traits for Holstein cows in different parities on a total mixed ration diet (Hansen *et al.*, 1999)

Traits	Parity	Small line	Range (min-max)	Large line	Range (min-max)
Postpartum live weight (kg)	1	558[a]	416 - 720	609[b]	450 - 822
	2	596[a]	488 - 731	664[b]	514 - 834
	3	641[a]	515 - 784	720[b]	580 - 885
Live weight 1 month post partum (kg)	1	507[a]	398 - 683	559[b]	434 - 722
	2	555[a]	429 - 667	625[b]	503 - 748
	3	584[a]	499- 694	672[b]	553 - 780
Milk (kg)	1	8535		8492	
	2	9820		9578	
	3	9687		9954	
AI's/conception	Heifers	1.54		1.67	
	1	1.79		2.08	
	2	1.91		2.08	
	3	2.02		2.24	
Calving ease	1	3.16		3.08	
	2	1.51		1.43	
	3	1.36		1.45	
Productive life (days)	84 mo	712.5		624.0	
	72 mo	658.3		570.6	

[a,b]Values with different superscripts between small and large lines differ at $P < 0.01$; mo: Month

Because of the slow response in changing the body size of dairy cows, a faster response would be obtained by crossbreeding using a smaller breed like Jerseys.

Local research

Genetic parameters for live weight and condition score were estimated for dairy cows using records from the Elsenburg Holstein herd. Cows were weighed once a month and their body condition scored. This is an indication of their body fat reserves. These records were analysed together with the cows' milk yield records. The average live weight of cows was about 533 kg, ranging from 330 to 780 kg. This large variation in live weight was due to live weights being recorded at different stages of the lactation period and over all lactations from first to third lactation. The live weight of cows followed a distinct pattern over the lactation period, i.e. after calving, cows lost weight to about 60 days after which live weight increased to the end of the lactation period. Live weight increased with lactation number, with first lactation cows weighing approximately 500 kg, while cows in third lactation weighed about 590 kg. The increase in live weight from first lactation is primarily due to cows growing to reach a mature live weight at about third lactation. The heritability of live weight was 0.65, which is higher than literature values, although still within the expected range. Although all the milk yield traits were positively related to live weight, only the genetic correlation for protein and fat yield reached significance. The lack in statistical significance is probably related to the limited number of records available for this study. It is suggested that the change in condition score would affect live weight and therefore genetic correlations. International studies have also shown that the genetic correlations between body weight and milk yield have not been consistent. This seems to be affected by the time when live weights were recorded, i.e. + 0.29 in week 3 and - 0.25 in week 13 of the lactation period, respectively. An Irish study showed that body weight throughout the lactation had a moderate positive genetic correlation (0.22 to 0.34) with milk yield at 60 days in milk. The present study showed negative correlations between yield traits and condition score. It was further suggested that body size traits would be more suitable than live weight as it is affected by milk yield and condition score. Body size traits, like chest circumference or shoulder height, could be used as indicators of live weight and feed intake. Genetic correlations between chest width and body depth to feed intake were low to moderate.

An earlier study showed that, although the milk yield of the Elsenburg Holstein and Jersey herds increased from 5112 and 3892 to 7816 and 5411 kg per lactation respectively, the live weight of cows in both breeds did not change significantly. Presently, after more than 30 years of genetic improvement for milk yield, the live weights of Holstein and Jersey cows in the Elsenburg herds are 595 and 415 kg, respectively. It is therefore possible to increase the genetic merit of a dairy herd for milk production without increasing the live weight of cows.

However, in contrast to this, the live weights of Holstein and Jersey cows in an Irish study, comparing purebreds to Jersey x Holstein crossbred cows, were 523, 387 and 466 kg, respectively. These cows were in a pasture-based seasonal calving system, receiving only small amounts of concentrates.

No research has been conducted locally to give farmers any scientific support with regards to the effect of live weight on milk yield and lifetime performance of Holstein cows specifically. Some local farmers have adopted corrective breeding programmes either by crossbreeding, using Jersey sires on Holstein cows, or by selecting Holstein sires to produce smaller progeny. Breeding towards smaller cows without considering the genetic merit of sire for milk yield has had, in some cases, an expected, negative effect on the milk yield of dairy cows.

A study has recently started at Elsenburg to compare the effect of sire selection specifically aimed at reducing the body size of Holstein cows on their live weight, body size, milk yield performance, feed efficiency, reproductive performance and longevity in comparison to cows selected for higher fat and protein yield. Progeny of sires selected for high milk yield or low stature is to be compared in a pasture-based feeding system.

Every year when new genetic information of Holstein bulls becomes available, two groups of bulls aimed to decrease the stature (body size) of cows and to improve fat and protein yields will be selected and used on cows using a mating programme.

In Table 46.2 the average genetic merit of the two groups of bulls to be used in the study is presented. Better genetic merit values for specific traits are shown in bold. As expected, milk yield traits were higher in the production group of bulls while selecting bulls to breed for smaller cows should result in cows being smaller with regards to stature and body composite while the fat and protein percentage of the milk would be higher although at a lower milk yield. The productive life of cows resulting from the group of bulls selected for smaller cows would be higher which should make up for the lower milk yield over the long term.

Table 46.2. The average genetic merit of Holstein bulls selected for fat and protein yield and for smaller cows (PTA: Predicted transmitting ability)

Traits	Milk yield	Smaller cows
PTA milk (kg)	**2050**	1382
PTA protein (kg)	**62**	51
PTA fat (kg)	**79**	62
Protein (%)	- 0.002	**0.035**
Fat (%)	0.02	**0.047**
Productive life (months)	1.67	**3.27**
Stature	1.38	**0.35**
Body composite	1.20	**0.18**

In closing

Sire selection has a long-term effect on the genetic merit of a dairy herd. To correct specific traits usually takes time because of the long generation interval in dairy cows. Reducing the live weight of cows could have a negative effect on milk yield although this could be prevented by correct sire selection. Direct selection for single traits should be avoided because of possible negative correlations with other traits. Because of the large amount of genetic information that is available for dairy sires, an index of a combination of a number of 10 traits should be used instead. Economic weights for each trait are used to construct such a selection index.

CHAPTER 47

FACTORS AFFECTING THE MILK PRICE OF DAIRY COWS

Introduction

In South Africa, milk prices for dairy farmers were initially controlled by the Dairy Board. Prices were dualistic with a higher price being paid for so-called fresh milk than for industrial milk, i.e. milk being used to produce dairy products like cheese and milk powder. The rationale behind this system was because large herds were mostly producing milk from zero-grazing or total mixed ration (TMR) systems at a higher feeding cost which demanded a higher milk price to remain profitable. In contrast, pasture-based dairy farmers, in the early days, had small herds which were operated at very low input costs. This meant that they could be profitable even at low milk prices.

In 1983, the slogan "Milk is Milk" was adopted in an effort to pay all farmers a uniform price for milk. However, this did not really materialise and current milk prices are determined by the milk processors themselves, resulting in various milk pricing structures. Farmers tend to compare milk prices between farms directly. This is, however, not correct, as milk prices would always differ because of the difference in the fat and protein percentages in milk, the amount of milk each herd produces, and its end use or processor. Milk pricing structures should further differ between processors because of their own production cost of milk products and profit margins.

Producers are presently, in most cases, paid according to fat and protein yields. The value (price) for fat and protein varies, usually with a higher emphasis on protein. In some cases an additional premium may be paid for protein to stimulate production. However, most dairy processors also provide fresh milk to the supermarkets. Very few processors buy milk for fresh milk only. Milk used for fresh milk has to contain minimum levels of fat and protein percentages.

Despite all efforts to improve milk pricing systems for dairy farmers, there are still real milk price disparities among dairy farmers. Often dairy farmers who are in close proximity to major markets have to close down, because they are forced to use more expensive feeding systems because of a lack of water for pasture production. The cost of milk production from pasture-based systems could be 40% lower than that of a zero-grazing system, although in many cases production areas are further away from the market incurring high transport costs.

Fat and protein yield

Some dairy processors have found, over time, an increase in the fat and protein percentage of the milk being collected on farms. This is unexpected, as the payment system is based on fat and protein yields. This provides little incentive to improve the fat and protein percentage in the milk. Even though there is a positive correlation between milk yield and fat and protein yields, the correlation between milk volume and fat and protein percentages is negative. This means that an increase in milk volume by cows producing at a higher milk yield level, through better feeding, breeding and management, should be followed by an increase in fat and protein yields, although at declining fat and protein percentages. This means that farmers have, possibly, through sire selection, breed changes or changes in feeding programmes, managed to improve the fat and protein percentage of milk collected by dairy processors. Increased volumes of milk being picked up could also be the result of a larger number of cows being milked rather than increasing the milk yield of individual cows. It would be advantageous for processors to receive milk containing higher levels of fat and protein percentages as that would reduce the production cost of milk products.

In cases where fat and protein percentages have declined in milk being collected, it would be a problem for dairy processors, as this would result in an increase in the production cost of dairy products like yoghurt and cheese. The increase in production costs for dairy products is related to the higher transport and handling costs of milk, with a lower solids content as more litres of milk are required to produce specific amounts of a specific product. Tankers transporting bulk milk have specific capacities, while batch tanks used for cheese production, similarly, also have specific capacities. Fat and protein yields are determined by both the volume of milk cows produce daily and the fat and protein percentage in the milk (Table 47.1).

Table 47.1. The effect of volume of milk produced and fat or protein percentage on fat or protein yield

	Milk yield (litres/cow/day)						
	12.1	14.6	17.7	21.4	25.9	31.4	38.0
Fat/ Protein%	Fat/protein yield (kg/cow/day)						
3.0	0.36	0.44	0.53	0.64	**0.77**	0.94	1.14
3.6	0.44	0.53	0.64	**0.77**	0.93	1.13	**1.37**
4.4	0.53	0.64	**0.77**	0.94	1.13	**1.37**	1.67
5.3	0.64	**0.77**	0.94	1.13	**1.37**	1.66	2.01
6.4	**0.77**	0.93	1.13	**1.37**	1.66	2.01	2.43

From Table 47.1 it is clear that higher fat or protein yields are obtained by increasing the volume of milk produced and/or the fat and protein percentages in the milk. Milk pricing structures based on payment for fat and protein yields, therefore, result in contrasting emphasis for producers and processors. Because the same price is being paid per kg fat or protein irrespective of the component percentage, dairy farmers tend to increase milk volume ensuring a higher income. This is done by milking more cows or increasing the average milk yield in the herd by better feeding using higher quality roughages or more concentrates.

Dairy processors, on the other hand, would prefer milk containing a higher fat and protein percentage in an effort to keep the production cost of dairy products at a minimum level. The problem is that in processing plants less cheese is made per batch when using milk containing a lower milk solid content. This increases the cost of cheese production. For example, the predicted Cheddar cheese production from 100 kg of milk increases from 9.5 to 13.7 kg when the fat and protein percentage of milk increases from 3.50 and 3.00%, respectively to 5.50 and 4.20%. Because of the higher fat percentage, some 0.35 kg extra fat is also produced for butter.

Milk prices should encourage farmers to supply sufficient volumes of milk, while maintaining or increasing fat and protein percentages. Dairy farmers will only do this if there is a financial incentive to provide the quality of milk that processors require.

Penalising volume

Some countries have a milk pricing system based on prices paid per kg fat and protein with a penalty (a negative value) on the volume of milk produced. This is done presumably in an effort to encourage the production of milk containing a higher level of milk solids. It is, however, doubtful whether this practice will produce the desired results. In Table 47.2, the effect of a specific milk pricing structure with a penalty on milk volume for a dairy herd producing milk at different levels is shown.

Table 47.2. The effect of a specific milk price structure on the lactation income of a Holstein herd that have shown an increase in production over time

Parameters	Milk price structure	Production year 1984	Production year 1998	Change (%)
Milk (kg)	- 5c/liter	5112	8360	+ 64
Fat (kg)	R5/kg	189	293	+ 55
Protein (kg)	R12/kg	172	269	+ 56
Income (R)		2753	4275	+ 55

From 1984 to 1998, the average milk yields per lactation of cows in this herd increased by 64% from 5112 to 8360 kg per lactation. As expected, the fat and protein yields also increased, although at a smaller margin, i.e. at 55%. The reason for this is a reduction in the fat and protein percentages of the milk, i.e. from 3.70 to 3.50% for fat and 3.36 to 3.22% for the protein content. The ratio of fat to protein yield did not change and was 1:0.91 in 1984 and 1:0.92 in 1998.

Because the milk price structure is based on fat and protein yields, the income per lactation for cows in this herd increased regardless of the penalisation on milk volume. This resulted in milk being produced containing lower fat and protein percentages. This change would be a problem for the processor as this would increase the cost of processing milk into different products. The only benefit for processors would possibly be a saving on the transport cost of milk because a larger quantity of milk is available for collection at the same farm. A higher volume of milk could also be produced by milking a larger number of cows. For the farmer, a penalty of 5 c/ litre on the volume of milk did reduce income, although the negative effect on the income per lactation was small in comparison to the improvement in milk yield. A penalty on volume of more than 24 c/ litre would be required to produce a similar income as in the 1984 production year.

Therefore, although penalising volume resulted in reducing income per lactation, this comes at a penalty for the processor collecting milk containing less milk solids. The smaller farm income in relation to the improvement in milk yield is probably not sufficient to stimulate the production of higher solids milk. To stimulate the production of milk containing higher levels of fat and protein, milk prices should be structured on the volume of milk produced, as well as the percentage of fat and protein in milk.

Increasing milk prices

Milk pricing structures vary between different milk processors. The current milk pricing structure at Elsenburg has a base price for milk containing 3.3% fat and 3.0% protein. For each 0.1% increase in fat percentage above 3.3%, the milk price increases by 2.1 cents per litre. For a similar increase in the protein percentage, the milk price increases by 3.13 cents per litre. This means that a higher emphasis is put on protein production, the ratio between fat and protein being 1:1.5. For each 0.1% decrease in fat and protein percentages, milk prices are reduced by 2.4 and 3.60 cents per litre, respectively. This means that farmers are encouraged to produce milk at higher fat and protein percentages while producing milk containing low fat and protein percentages is discouraged by bigger penalties than premiums for higher fat and protein percentages.

Increasing the volume of milk

The variation between cows in milk yield is large and high milk yield levels are possible. Increasing the milk yield of cows is usually easy, because it mainly involves feeding more and higher quality feeds. The amount of milk dairy cows produce is dependent on their total energy intake. The amount and quality of the forages (pasture, hay or silage) and supplementary concentrates determine the total energy intake of cows. The condition of the cows at calving also affects the amount of milk cows produce.

Increasing the milk composition of milk

It is difficult to increase the fat and protein percentages of milk by feeding at the same time, as it involves contrasting feeding programmes. To increase the protein percentage in the milk, more energy in the diet is required. This is usually supplied by feeding more or a higher quality concentrate mixture. By increasing the amount of concentrates in the diet, cows may start to ruminate less because of a shortage of fibre. This reduces the saliva production of cows resulting in a more acidic rumen. This reduces the number of acetic acid producing bacteria in the rumen and that results in milk having a lower fat percentage. Artificial buffers must then be included in the diet to protect the rumen against high acidity levels and a drop in fat percentage.

The total diet of dairy cows should always contain a minimum roughage level. For higher fat percentages more roughages or artificial buffers must be included in the diet to keep the acidity level in the rumen low. This effectively puts a limit on the maximum amount of concentrates in the diet. For cows on pasture, additional roughages like hay or straw are sometimes fed in an effort to increase rumination and to maintain or improve the fat percentage in the milk. This, however, could lead to a lower total feed and energy intake with a reduction in the milk yield and protein percentage. This could ultimately result in a reduced milk price and therefore milk income. According to the milk production results in a study where straw was fed additionally to cows on pasture, the net improvement in the milk price was small (less than 1 c/ litre) without regarding the extra cost of feeding the straw.

Sire selection

Based on heritability estimates, the genetic effect on milk production and milk composition in dairy herds is medium to high. The genetic relationship between milk volume and fat or protein yields is high and positive, while the relationships between volume and percentages are negative. Emphasising the volume of milk would result in milk containing less milk solids. This would be to a disadvantage for dairy processors. With a high emphasis on fat and protein percentages, the volume of milk could be reduced to the disadvantage of farm income. A payment system based on prices paid per kg fat and protein provides little financial incentive to produce high solids milk. Sires are often labelled as high volume or high component bulls. Ranking sires according to their genetic income (based on a payment system for kg fat and protein), it is often found that high components bulls rank lower than high volume bulls. This is because of lower fat and protein yields. Changing the genetic status of dairy cows in terms of milk volume and components is possible but difficult. This is dependent on a long term strategy and different sire selection criteria are needed both on farm and by AI companies.

In closing

A milk pricing structure based on fat and protein yields, results in an increase in the volume of milk. This is in contrast to the requirement of dairy processors who need milk of high fat and protein percentages. A penalty on milk volume does not always provide enough financial incentive to select for higher fat and protein percentages in milk. The financial implications of feeding supplementary roughages or concentrates to change the fat or protein percentage in milk should be considered carefully. There is little incentive to feed straw to cows on pasture to improve the fat percentage in the milk, if that results in less milk and a lower protein percentage and therefore a reduction in milk income. Milk pricing structures of dairy processors should include the volume of milk produced and the percentages of fat and protein in the milk. A sliding scale should be used, emphasising higher fat and protein percentages. This will provide the financial incentive to farmers to adopt appropriate feeding, breeding and management strategies to supply a product that accords with the requirements of dairy processors.

SECTION 5

MILK PRODUCTION and QUALITY

CHAPTER 48

ANATOMY AND PHYSIOLOGY OF LACTATION

"Remember a cow is a mother and her calf is a baby"

Introduction

Very early in the development of the dairy industry in Britain, the way to treat cows for milking was described as follows:

"…She shall then milk the cow boldly, and not leave stretching and straining of her teates, till one drop of milk more will come from them; for the worst point of housewifery that can be, is to leave a cow halfe milkt; for besides the losse of milk it is the only way to make the cow dry, and utterly unprofitable for the dairy. The milkmaid, whilst she is milking, shall do nothing rashly or suddenly about the cow which may afright or amaze her; but as she came gently, so with all gentleness she shall depart." From C. Markham (1660). The English housewife – a way to get wealth.

The same principles still apply for present-day dairies using modern equipment.

Anatomy of the udder

The udder of a mature dairy cow normally weighs about 10 to 25 kg and consists of four individual glands, also referred to as quarters. Each quarter is drained by a teat at the bottom of the quarter. There is no flow of milk between quarters. The total milk storage capacity of the udder may be as high as 35 kg.

The udder is a skin gland connected to the abdominal cavity through the inguinal canal. Blood and lymph vessels, as well as nerve fibres, enter the udder from the abdominal cavity through this canal, which forms a tube about 10 cm long.

Seen from the back, the udder is divided into a right and left half by the udder or intermammary groove. From a side view, the fore and rear quarters are more smoothly joined together not having such a distinctive groove. The hind quarters are usually larger than the fore quarters and may secrete 25 to 50% more milk than the fore quarters with the ratio between back and fore quarters being 60 to 40%.

The udder is attached to the body by the following ligaments:

1. The medial suspensory ligament, which divides the udder into a right and left half (Figure 48.1), and
2. The lateral suspensory ligaments, which form a fibrous layer around the outside of the glands joining the medial suspensory ligaments on the lower surface of the glands.

The lateral suspensory ligaments are chiefly fibrous, whereas the medial suspensory ligaments are more elastic fibres. Filling the udder therefore stretches the medial ligaments to enlarge the storing capacity of the udder. When these ligaments weaken, the udder tends to separate from its close adherence to the abdominal wall and the udder is described to be breaking away. Connective tissue penetrates and traverses each quarter, thus giving shape and further support to the udder. A big udder may contain a large volume of connective tissues and little gland tissue; udder size is, therefore, not always a true indication of the productive ability or capacity of a cow.

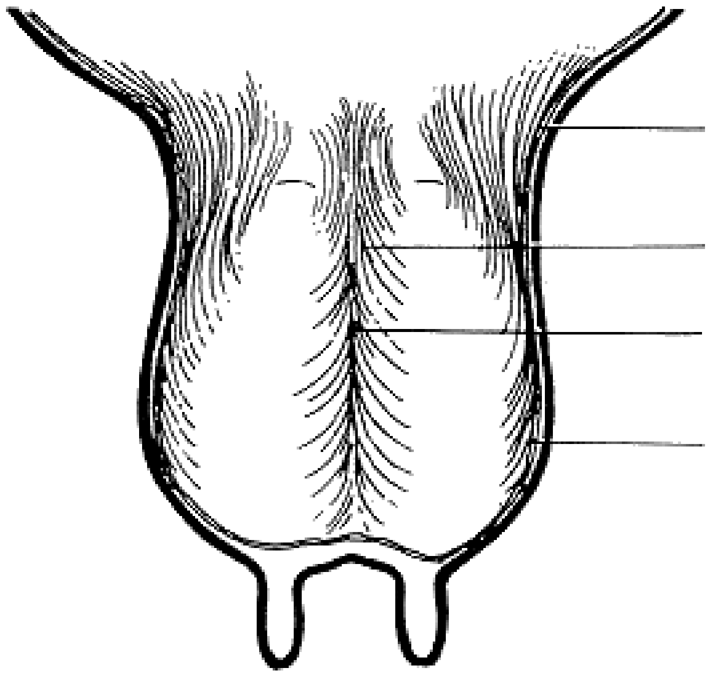


Figure 48.1. The suspensory apparatus of the udder of a dairy cow

The udder should ideally shrink during the milking process and must therefore be completely elastic when empty.

It is important for the udder to extend well forward for the maximum utilisation of the space available underneath the body. This feature is essential, since the udder must be large enough to contain all the milk that may be secreted between milking sessions. This results in the udder expanding, i.e. becoming larger, by about one-third of its normal size. This expansion increases the milk-carrying capacity of the udder by approximately 60%, while the remaining 40% of the milk secreted can be accommodated in the natural storage spaces of the udder.

The shape and size of the teats that drain the four glands are independent of the shape and size of the udder. In addition to the four normal teats, about 40% of cows have one or more supernumerary teats, usually without the presence of glandular tissue. These teats usually occur behind the rear teats.

Milk collecting system

The teat opening, or streak canal, is situated in the lower end of the teat and is surrounded by a sphincter muscle. This muscular walled canal, which is 0.5 to 1.0 cm long, prevents dirt entering the udder and milk escaping before milking commences. The diameter of the streak canal and the tonus of the sphincter muscle determine the ease of milking a cow. At the upper end of the streak canal loose folds of tissue, called the Furstenberg's Rosette, press down against the opening of the streak canal and assist in preventing the escape of milk from the udder.

The teat cistern has a diameter of about 1 cm with a capacity of 30 to 50 mℓ of milk immediately above the teat opening. In the teat cistern, several fairly well-defined circular membranes are found. This may sometimes form a septum across the teat, preventing the flow of milk. If this happens, the septum has to be pierced with a special needle to enable normal milk flow.

The udder cistern, also called the lactiferous cistern, with a capacity of 100 to 400 mℓ of milk, follows immediately beyond the teat cistern and is situated in the udder. There is no definite separation between these two cisterns resulting in their being more or less continuous. From the gland cistern five to 20 large milk collecting ducts branch and rebranch into very small collecting tubules, each eventually ending in an alveolus (Figure 48.2).

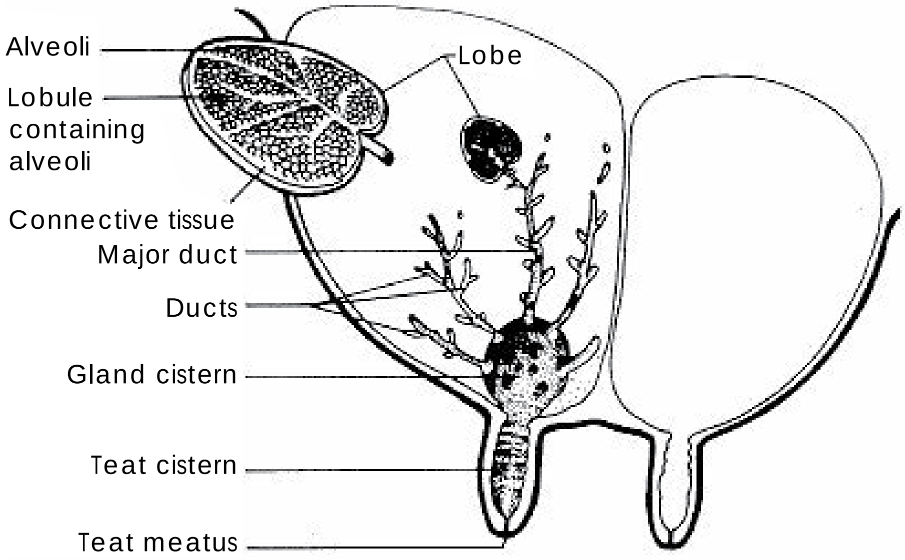


Figure 48.2. The milk collecting system

An alveolus consists of a single layer of milk producing cells attached to the inside of a spherical basement membrane. This cell layer of epithelial cells surrounds the lumen, the hollow inside of the alveolus into which the milk is excreted. A dense myoepithelial (muscle tissue) and vascular (blood-vessel) network surrounds the alveolus (Figure 48.3). Each lumen drains into a small milk-collecting tubule. These small tubes flow together forming larger milk ducts.

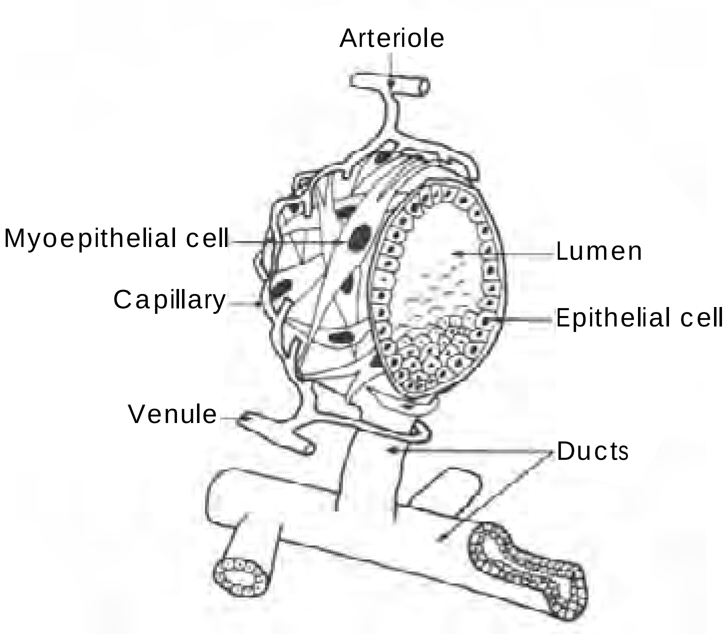


Figure 48.3. The alveolus

The alveoli occur in large numbers in the udder and have a diameter of 0.1 to 0.3 mm. They are grouped together in lobules by connective tissue; each lobule containing about 200 alveoli. All the lobules draining into the same milk duct are described as a lobe.

Milk secretion

Each alveolus is surrounded by a dense network of fine blood-vessels which provide the milk synthesising cells with a continuous supply of nutrients for the synthesis of milk. There are three phases identified during milk secretion:

- Synthesis by the cells of the alveolar epithelium;
- Discharge from the epithelial cells into the alveolar lumen; and
- Storage in the alveolar, ducts, and cisterns.

Directly after milking, the lumina are almost empty, the epithelium folded, and the cells themselves are largely devoid of any secretion. As the producing cells draw the raw materials for milk synthesis from the blood, synthesised secretory products fill the interior spaces of the cells before leaving through the walls of the apex to fill the lumen with milk.

About 500 kg of blood pass through the udder during the production of one kg of milk. Some milk constituents move unchanged from the blood to the milk, while others are synthesised by the epithelium. Casein and lactose, for example, are found only in milk, while milk fat comprises glyceride combinations not found elsewhere in the body.

Udder pressure and secretion rate

Changes in the secretion rate and intramammary pressure in the udder during milk secretion as affected by milking interval are shown in Figure 48.4.

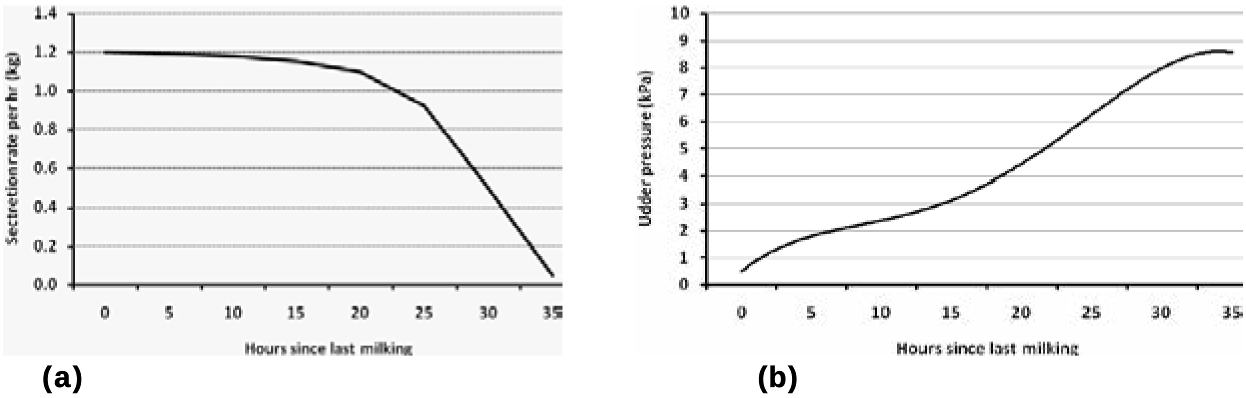


Figure 48.4. The decrease in milk secretion rates (a) and increase in udder pressure (b) as affected by the length of the milking interval

Milk is continually synthesised at a rate of about 1 to 2 mℓ/g glandular tissue per day. At the completion of milking, when all available milk has been removed, pressure within the teat cistern is at atmospheric levels, but within an hour after milking, pressure within the udder increases by about 1 kPa as milk residues fill the collapsed teat and udder cisterns. Thereafter, pressure initially increases slowly for 5 to 6 hours, and then more rapidly at 2 to 4 kPa at the end of normal milking intervals. The pressure at this stage depends on the length of the interval between milking sessions, udder capacity, and the yield of cows. The pressure in the udder is also greater in the hind quarters than in the front quarters, as well as in early lactation.

Milk is secreted at an inverse rate to mammary pressure. This relationship is, however, virtually linear for the first 10 hours. Thereafter, with an extension of the interval, the rate of synthesis slows down, showing a marked reduction after about 24 hours. After about 36 hours, when udder pressure may be as high as about 7 kPa above atmospheric pressure, milk secretion stops altogether.

There are indications that the apparent decline in secretion rate of most of the milk constituents, as the milking increases, is due to their absorption during storage, rather than a true decline in secretion rate.

Once the rate of milk secretion has been depressed by delaying milking, it does not immediately revert to normal when milking resumes. For example, the yield obtained in an 8-hour interval following a 24-hour interval, is 25% less than when the 8-hour interval was preceded by another normal 8-hour interval.

Milking frequency and milk production

Long intervals between milking sessions cause the udder pressure to increase to high levels, slowing down the secretion rate. By shortening milking intervals, an increase in daily production is possible.

The interval between milking sessions is a critical element of dairy management as both the number of milking sessions in a 24-hour day and the duration of the intervals between milking sessions are important. At high milk yields and lower storage capacity in the udder, milk must be removed more frequently from the udder to avoid a reduction in the milk secretion rate. Intervals longer than 12 hours between milking sessions should be avoided.

In South Africa, at least 90% of cows are milked twice a day. Milking at exactly equal intervals of 12 hours is ideal, but is rarely practiced because of the unsocial hours which it imposes on the milkers and management. The average intervals for large herds are usually about 14 and 10 hours, i.e. at 05:00 and 15:00 per day. However, based on research results, a ratio even as wide as 16 to 8 hours does not reduce milk yield by more than 4%. This means that the lower milk yield could be weighed up against milking at more sociable hours, for instance to start milking at 07:00 and 15:00 every day.

Milking cows three times instead of twice a day increases milk yield by 5 to 25%, provided cows are fed adequately. When no extra feed is provided to compensate for the higher milk yield, cows will lose body condition (live weight), which would affect the milk yield of cows in the following lactation negatively. Increasing the number of times cows are milked per day, results in higher production increases in older cows in comparison to first lactation cows. A decrease in udder pressure is often only partly responsible for the higher milk yield, because better feeding and management may also contribute.

No conclusive proof is available that milking frequency influences the composition of milk produced daily. Some research showed a slight decline in fat percentage in milk when cows are milked thrice instead of twice a day. This is probably because of the higher milk yield.

Milking cows four times per day may lead to an increase in milk yield of 5 tot 10% higher than that of cows milked three times per day. This increase is mainly due to better feeding and overall management.

Milking cows only once a day throughout the lactation reduces lactation milk yield by 5 to 10% in comparison to twice a day milking. Once-a-day milking is often applied under pasture-based conditions when pasture production is limited or when cows are at the end of the lactation period when milk yield is at a low level.

The milk let-down reaction

The largest percentage of milk in the udder is stored in the lumen of the alveoli and in the small milk ducts. Due to the small diameter of these ducts, capillary forces prevent the drainage of the milk.

Milk in the alveoli and ducts cannot be removed from the udder using normal means without the cooperation of the cow. Only the small quantity of milk present in the teat and udder cisterns and in the larger milk ducts can be removed. This milk is described as the fore-milk and is only a small percentage of the total milk stored in the udder.

At the commencement of milking, only the fore-milk is therefore immediately available. Hereafter an interruption of milk flow usually occurs. This is especially noticeable in cows that have not been stimulated correctly before milking has started. Before the initiation of the main milk flow, i.e. before milk let-down occurs, the nervous system of the cow must first be stimulated to let milk down.

The nervous reflex responsible for milk let-down begins with the stimulus produced by the suckling of the calf, or the presence of milkers, or the sounds of the milking machine. In normal milking routines, udder washing at the beginning of the milking process usually serves as the stimulus for milk let-down.

The teat base, i.e. where the teat joins the udder, is richly supplied with nerve centres and a massage (when being washed) or suckling action on this area produces a strong stimulus. The nerve impulse travels to the hypothalamus of the brain, which activates the pituitary gland to release the hormone oxytocin into the blood which carries it to all parts of the body. When it reaches the udder, it causes the myoepithelial cells surrounding each alveolus to contract, decreasing the size of the lumen of the alveolus, forcing milk out of the ducts. The small ducts also shorten and widen to facilitate the movement of milk from the alveoli into the larger ducts. As a result of the above, the teat and udder cisterns, as well as the larger milk ducts, become distended with milk, resulting in the hardening of the udder and teats and an increase in intra-mammary pressure. Milk let-down has occurred and the cow can now be milked. A period of 45 to 60 seconds elapses between the time when oxytocin is released into the bloodstream and when it arrives in the udder.

About 15% of the initial milk volume cannot be removed from the udder during a thorough, normal milking process and is known as residual milk. Removal of residual milk is, however, possible by the injection of oxytocin. This procedure is of no practical use as the residual milk does not affect the daily milk yield of cows.

Oxytocin levels in blood serum

The average oxytocin level in the blood serum of dairy cows is about 8.0 ± 0.11 µU/ml. As a result of cow stimulating cows increases the level of oxytocin which reaches a peak concentration of about 25 µU/ml within two minutes. The peak concentration may vary considerably, e.g. from 11 to 65 µU/ml between cows. After peak, the concentration of oxytocin declines sharply, reaching pre-stimulation levels within about four minutes.

The maximum concentration obtained and the time required to reach this peak is dependent on the following factors:

- **Type of stimulus**
  Hand stimulation, e.g. a 30-second udder wash, is a strong stimulus and results in maximum oxytocin levels in the blood within 1 to 2 minutes. The normal pulsator action of the milking machine causes a more gradual increase and a lower peak concentration. The peak is obtained in about double the time than with hand stimulation (Figure 48.5).

- **Breed of cow**
  Holstein-Friesian cows are easier to stimulate than Jersey cows.

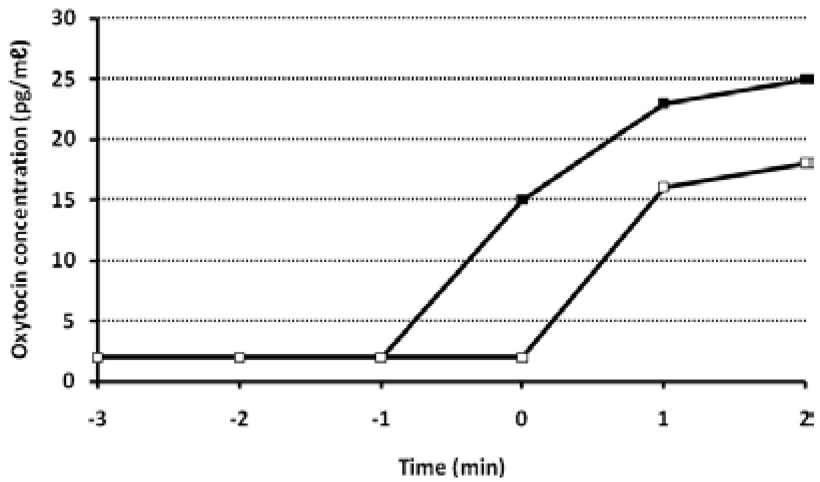


Figure 48.5. The oxytocin concentration before, during and after manual (■) and milking machine (□) stimulation

Oxytocin concentration and milkability

During the 1960's, researchers in New Zealand found that hand-stimulated cows, i.e. a 40-second udder wash immediately prior to machine-milking, resulted in 16% more milk and 32% more fat yields than cows not stimulated by hand. Low producing Jersey cows were used in the study. These results contributed to the conclusion that high oxytocin levels, as a result of the strong milk let-down reaction, also cause a high pressure in the udder which is required for the complete removal of milk. Since the oxytocin levels in the blood and udder pressure start to decline within minutes after stimulation, it is accepted that to ensure optimal milk flow that the milk process should start within one minute after stimulation.

The results of more recent research, using high performing Holstein cows, showed that production increases because of hand-stimulation, to be about 0 to 2%. This small beneficial effect does not contradict the necessity of stimuli and circumstances contributing to a strong milk let-down reaction. It is, however, evident that the degree of stimulation necessary to ensure complete milking is dependent on factors such as breed, production level and stage of lactation. The conclusion is that in the case of a modern, high genetic merit, high producing dairy cow, the stimuli from the normal milking parlour routine are sufficient to ensure a satisfactory milk let-down reaction and that deliberate stimulation would not be required.

Reasons for this change in emphasis on the necessity for the specific stimulation action include the following:

- High producing dairy breeds and cows are stimulated more easily.

- Due to the culling of cows from the herd on the basis of milk production, it follows that those cows which do not respond adequately to the particular milking parlour routine for a specific dairy will be culled because of low milk yields. The evolution of modern milking machines and methods thus resulted in the selection for animals requiring a minimum of stimulation.

Effect of time interval between stimulation and milking on milk characteristics

High oxytocin levels are maintained in the blood for only a short period. The duration of the milk let-down reaction is therefore also short. Research has shown that the half-life of oxytocin is about 3 minutes. Because optimum milkability is only obtainable when both oxytocin levels and udder pressure are high, it is important that the milking unit is attached to the udder before the oxytocin concentration in the blood starts to decline, which is usually within one minute after stimulation. When the interval between stimulation and the attachment of the milking unit is delayed, milk characteristics are adversely affected (Table 48.1).

Even short delays between stimulation and the start of milking may have the following results:

- a decrease in milk yield,
- a higher stripping volume,
- a longer machine-on time,
- a decrease in the maximum milk-flow rate,
- a longer time to reach peak-flow rate,
- a lower fat percentage in milk, and
- shortening the lactation period because of earlier drying up.

Table 48.1. Milking characteristics caused by delays between pre-stimulation and the start of the milking process

Parameters	Delay (min)		
	0	3	15
Total milk yield (kg)	11.2	10.7	10.5
Stripping (kg)	0.2	0.2	0.4
Total machine-on time (min)	7.6	7.7	7.8
Peak-flow rate (kg/min)	2.7	2.4	2.4
Time to reach peak flow rate (min)	1.9	2.1	2.5

Inhibition of milk let-down response

Inhibition of the milk let-down response has been observed in a number of species as the result of emotional disturbances, such as cows being frightened, in pain, anger, etc. The immediate cessation of the milk-flow is caused as a result of a nerve stimulus causing the adrenal gland to liberate the hormone adrenaline (epinephrine) into the blood stream. The mechanism by which adrenaline causes the inhibition is not absolutely clear. It is, however, known that adrenaline causes the constriction of the blood vessels in the udder. Another possibility is that adrenaline prevents the release of oxytocin.

Blood circulation through the udder

The quantity of blood in the body of cows varies from 5.8 to 8.5% of live weight. In young cows and dry cows, the percentage is lower than in older cows and in cows in milk. It is known that for each 1 kg of milk secreted, 150 to 500 kg of blood must pass through the udder.

To maintain a high secretion rate, an adequate vascular system supplying and draining blood to and from the udder is essential. All the blood vessels to and from the udder occur in pairs, one vessel for each half of the udder. The arteries carrying blood to the udder include the following:

- **The external pudic artery**
  This is the most important artery carrying blood to the udder. It enters the udder through the inguinal canal and is then known as the mammary artery.

- **Perineal artery**
  This artery reaches the udder through the pelvis and supplies blood to the posterior dorsal part of the udder.

The blood leaves the udder through the following veins:

- **The external pudic vein**
  This leaves the udder through the inguinal canal

- **Subcutaneous abdominal vein**
  This vein flows from the udder under the abdomen and enters the body cavity through the milk-well, posterior to the sternum.

Elements of the milking routine

An efficient and fixed milking routine, which is understood by the milkers and which cows are used to, is a very important component of milk production. Low milk yields, low fat tests, short lactations and the spread of mastitis, often result from an inefficient milking routine.

The basic steps in the milking routine are as follows:

i) Washing the udder
Proper washing of teats and udders before milking (Figure 48.6) serves a three-fold purpose
- controlling bacterial contamination of the milk,
- stimulating milk let down, and
- protecting against mastitis.

Figure 48.6. Hand washing of the udder and teats using running water

Dirt and manure clinging to the cow's udder and teats contain many millions of bacteria per gram of dirt. To prevent this dirt and bacteria from being washed into the milk during milking, it is essential that the lower part of the udder, and especially the teats, are thoroughly washed before milking. Water at room temperature, luke-warm water (approximately 40°C) or, preferably, water containing a disinfectant, should be used for this purpose. The following methods could be used:

- **Bucket method:** This is a method commonly used in small-scale dairies but is, from both a hygienic and a convenience point of view, not recommended to be used. The disadvantages are that, unless individual washing-cloths are being used for each cow, both the washing-cloth and water in the bucket become a source of bacterial contamination, increasing the possibility of spreading mastitis among cows.

- **Hose with spray nozzle:** This method is hygienic, convenient and practical, especially in milking parlours. The washing action can either be done with the bare hand or with a single-service washing-cloth (one cloth per cow). Devices which measure disinfectant into the water-line are available.

- **Automated udder washing:** This can be done either in the milking-parlour or in a preparation stall. A water sprayer located on the floor or a preparation stall is automatically turned on by the cow entering the stall.

The effectiveness of udder washing is affected by:

- the thoroughness of dirt removal from the teats and lower part of the udder,
- preventing the unnecessary wetting of the upper parts of the udder as well as the groin area of the cow, and
- drying the teats and udder before commencement of milking, preferably with a single-service paper towel (Table 48.2).

Table 48.2. The effect of different udder washing procedures on the bacterial content of milk

Washing procedure	Bacteria per mℓ of milk			
	Clean udders		Very dirty udders	
	Average	Range	Average	Range
None	5120	1010 – 16900	7530	1550 – 28350
With water, no drying	8840	1550 - 28350	18540	1750 – 111000
Water and drying	3 160	750 – 15000	14400	2660 – 54000
Disinfectant, no drying	2 150	405 – 18750	11250	825 – 64200
Disinfectant and drying	750	172 – 4605	1930	115 – 15740

Udder washing usually serves as a stimulus for the milk let-down reaction and should begin about one minute before applying the milking machine.

ii) Testing for mastitis

This involves squeezing a small quantity of milk from each teat, either onto a stip cup or into the paddle which is used for performing the California Mastitis Test (CMT). This action allows the milker to ensure that the teat orifice is not blocked and to check for mastitis, blood and other abnormalities in milk (Figure 48.7).

Figure 48.7. Testing of fore-milk for mastitis before attaching clusters on the teats

iii) Attaching the teat cups (or milk cluster)

The teat cups should be attached as soon after udder preparation as possible (Figure 48.8). After stimulation, the milk let-down reaction wears off within minutes, and if the cow is not completely milked within this time, the volume of residual milk will increase.

Figure 48.8. Attaching the teat cups on the teats

iv) Stripping

This is the term given to the methods used to remove more milk after normal milk flow has ceased. Hand stripping gave way to machine stripping, usually achieved by downward pressure on the claw and by massaging the udder (Figure 48.9).

Figure 48.9. Stripping of milk from the udder

The purpose of stripping is to ensure that all the available milk is removed from the udder. Various research reports have indicated that a higher yield is obtained when stripping is included in the milking routine. In a trial conducted in Germany, in which only the right half of the udders of first lactation cows were stripped after milking, those halves produced 6.8% more milk and 9.2% more fat per lactation than the unstripped halves of the udders.

The necessity and advantage of stripping depend largely on the thoroughness of stripping cows after milking. Complete milking-out is largely dependent on:

- effectiveness of stimulation,
- timely utilisation of milk let-down reaction, and
- efficiency of the milking machine.

To cease machine stripping does not normally have a detrimental effect on udder health, although air rushing in when machine stripping is done, may increase the risks of mastitis.

Stripping, being time-consuming, is often not done at the end of the milking routine. The responsibility to ensure that the cows are thoroughly milked out should, however, not be neglected.

v) Removing the milking unit

The milk clusters can be removed once the milk-flow rate has dropped to below about 20 mℓ/min. This is done by cutting off the vacuum from the clusters and by gently drawing the teat-cups off the udder (Figure 48.10). Continuing to milk cows after the milk flow has dropped results in over-milking with the following disadvantages:

- increases the erosion of the teat orifice,
- this may increase the number of new mastitis infections, while
- available machine-time is wasted.

Figure 48.10. Removal of the milking cluster from the teats

vi) Rinsing the milking units

Although very often omitted from the milking routine, the milking units, in an effort to minimise the spread of mastitis organisms from cow to cow, may be rinsed between cows. This can either be done by dipping the teat cups first in a pre-rinse (water) and then in a sanitising solution, or by back-flushing with water which may contain a disinfectant.

The effect of cluster flushing on new mastitis infection rates is not clear. It is, however, known that the bacterial population on liners can be reduced, although not eliminated, by flushing, for example, with water at 85°C for 5 seconds, or by back-flushing with either cold or hot water which may or may not contain a disinfectant, such as hypochlorite or iodine.

Indications are that back-flushing, even with cold water, reduces new infection rate as caused by streptococcal but not by staphylococcal mastitis. There is, however, also evidence that inter-cow cluster pasteurisation, which is much more effective than any type of cluster flushing, will only give moderate reductions in new infection rates when teat disinfection is practiced.

vii) Teat disinfection

The most effective single element in the control of new udder infection among lactating cows is teat disinfection immediately after milking (Figure 48.11). Teat dipping (disinfection) can be done by either dipping the teats or by spraying the disinfectant on the teats.

Teat dipping has the following advantages:

- destroys bacteria left on the teat at the end of milking,
- eliminates and prevents colonisation of the teat orifice by pathogenic bacteria, and
- assists in the prevention and healing of teat lesions, particularly when emollients such as glycerol are included in the formulation.

This practice can reduce new mastitis cases by approximately 50%. A range of disinfectants, including sodium hypochlorite, iodophors, chlorhexidine, dodecyl benzene, sylphonic acid and others, are employed for this purpose.

Figure 48.11. Teat disinfection using a spray method after milking and the removal of the milking clusters

As with teat dipping, the amount of disinfectant used and the efficiency of teat coverage by spraying depend primarily on the skill of the operator. If care is taken to cover the teats, the time to spray teats will be longer, while using more disinfectant than teat dipping.

The effectiveness of germicidal teat dips in reducing new infections caused by *Streptococcus agalactiae* and *Staphylococcus aureus* is well-documented. The majority of these teat dips are, however, not very effective in eliminating new coliform infections. The use of latex teat dips, which were designed to form a physical barrier over the teat opening to prevent environmental bacterial contamination between milking sessions, may be more effective against the latter organism. A reduction of for example 76% was found in the number of new coliform infections when an acrylic latex teat dip without germicide was used.

In closing

Milk production is a continuous process in the udders of dairy cows until all the alveoli and ducts are filled up. Removal of milk by milking cows initiates milk synthesis. The milk let-down is affected by the release of oxytocin, while it is blocked by the secretion of adrenaline. Treating cows calmly before and during milking will result in high milk let-down and milk production. The interval between udder stimulation and milking unit attachment should be within one minute, as high oxytocin levels are maintained in the blood only for a short period. High producing dairy cows are stimulated more easily. First lactation cows not adapting well to the milking parlour management will be culled early as their milk yields will be affected negatively.

CHAPTER 49

THE COMPOSITION OF MILK

Variation is the only constant characteristic of milk composition

Introduction

Milk is defined as the undiluted, fresh lacteal secretion obtained by the complete milking of one or more healthy cows, excluding colostrum, which is secreted within 15 days before and about 5 days after calving down.

Bulk milk obtained from different sources may differ widely in composition. Even milk from an individual cow may vary from one to another milking session, e.g. such as morning and evening milking, as well as the total milk from day to day. The variation in milk composition is a result of the influence of a long list of physiological, inherited, and environmental factors.

The gross composition of milk based on a large number of milk samples collected from a variety of sources and including different breeds is presented in Table 49.1.

Table 49.1. The gross composition of cow's milk

Component	Content (%)	Total solids (%)	Solids not fat (%)
Water	87.2	-	-
Fat	3.7	3.7	-
Proteins	3.5	3.5	3.5
Lactose	4.9	4.9	4.9
Minerals	0.7	0.7	0.7
Total	100.0	12.8	9.1

The components, other than water, are known as the total solids (TS) and the total solid minus the fat content is the solids-not-fat (SNF). In average milk, these two groups of components amount to about 12.8% TS and 9.1% SNF. All milk contains the same gross components, although in varying proportions (Table 49.2).

Table 49.2. The average composition of the milk of various mammals

Species	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Minerals (%)
Woman	87.4	3.8	1.6	7.0	0.2
Cow	87.2	3.7	3.5	4.9	0.7
Goat	87.0	4.3	3.5	4.3	0.9
Ewe	80.7	7.9	5.2	4.8	0.9
Buffalo	82.8	7.4	3.6	5.5	0.8
Camel	87.6	5.4	3.0	3.3	0.7
Mare	89.0	1.6	2.7	6.1	0.5
Ass	89.0	2.5	2.0	6.1	0.4
Reindeer	63.3	22.5	10.3	2.5	1.4

Since different batches of milk may differ noticeably as it is affected by a number of biological factors, and to ensure that buying and selling of milk in the trade is conducted on an equitable basis, the composition of any batch of milk should be known. Knowing the composition of milk is important for the following reasons:

- The composition of milk determines the yield and composition of manufactured dairy products. For example, the Cheddar cheese yield from 100 kg milk containing 3% fat is about 8 kg in comparison to about 10 kg from milk containing 4% fat.

- Milk in the so-called fresh-milk trade must comply with specific minimum requirements. Although these may vary, depending on the controlling authority, the minimum requirements for full-fat fresh milk according to the Act on Agricultural Product Standard (Act 119 of 1990) should be:

  - Fat : minimum 3.3%
  - SNF : minimum 8.3%
  - Protein : minimum 3.0% (on fat-free basis)

- The composition of milk is a component in the breeding programme of a dairy herd. Total milk production is negatively correlated to fat and protein percentages. This means that fat and protein percentages decrease when milk yield increases. While it is important to increase the total milk yield of dairy cows, the ultimate aim in breeding should be to increase the fat and protein yield per lactation of dairy cows.

- In most quality payment schemes, the fat and protein content of milk determines about 80% of the farm-gate price.

The individual milk components

Water content

Milk is a natural liquid food containing about 86 to 88% water. Water gives bulk to milk and is the medium in which all the components of milk are dissolved or suspended. A small percentage of the water in milk is hydrated to the lactose and salts and some is bound in the proteins.

The concentration of soluble salts, mainly lactose and chloride, in the watery phase, determines the freezing point of milk. The freezing point of milk varies between - 0.512 to - 0.541°C is the most constant physical property of milk. The secretory processes of the mammary gland are such that the osmotic pressure of milk is kept in equilibrium with that of the blood. Any depression of the synthesis of lactose, e.g. in mastitic udders, is compensated by increases in the sodium and chloride contents in milk. Adulteration of milk by the addition of water lowers the concentration of soluble salts and causes the freezing point of milk to increase above - 0.512°C.

The freezing point of milk is therefore a reliable and convenient method for the determination of the adulteration of milk with water. Each 0.001°C increase in the freezing point above - 0.512°C is equivalent to the addition of about 0.2% water.

Milk fat

a. Physical characteristics

The percentage fat in bulk milk varies between 3 to 5%, although the variation may be wider in the milk of individual cows. The fat in milk exists in the form of small globules, averaging in size from about 0.001 to 0.005 mm in diameter. The surface of these globules is coated with an absorbed layer of phospholipids and proteins. This layer is commonly known as the fat globule membrane and plays an important role in preserving the individual identities of the globules. About 1.5 to 3.0 billion of these tiny globules may occur in 1 mℓ of milk. The size of the globules is dependent on the following factors:

- **Breed of cow:** The fat globules in the milk of dairy breeds with higher fat percentages, like Jersey and Guernsey, are larger than those in the milk of breeds with lower fat percentages like Holstein-Friesians. The average fat globule in Guernsey milk is 80% larger than that of Holstein milk. Variation in globule size does not cause the daily variation in the fat test of the milk of individual cows.

- **Stage of lactation:** Cows later in lactation have smaller fat globules in their milk. The fat globules are usually the largest during the first two weeks of the lactation with the most rapid rate of decline occurring during the next two months of the lactation. Thereafter, the rate of decline is slow, although continuing to the end of the lactation. This decline in globule size is an important factor as late lactation milk is more susceptible to the development of a rancid taste.

- **Individual cows:** The size of globules from different cows from the same breed may vary to a great extent.

Fat globules float around in the milk in a true oil-in-water emulsion with the fat being the dispersed phase. Fat globules are kept apart by:

- The viscosity of milk.
- The fat globule membrane – this membrane has to be removed or broken before two fat globules can unite. Agitation, as in churning, breaks the membrane and the globules coalesce to form butter granules.
- A negative electric charge that is present on the globules.

Due to the difference in the specific gravity (SG) of milk fat (SG of 0.93) and skim milk (SG of 1.036), the globules in undisturbed milk will, with time, rise to the surface to form a cream layer on top of the milk. Due to this, it is of utmost importance to stir milk thoroughly before a sample of bulk milk is collected for analysis. Sampling from a bulk tank should be preceded by at least five minutes of stirring.

b. Chemical composition

Milk fat, like the majority of animal fats, consists chiefly of triglycerides of fatty acids. It also contains varying quantities of other components as indicated in Table 49.3.

Table 49.3. The components of milk fat

Components	Content in fat(%)
Triglycerides	98 - 99
Phospholipids (lecithin)	0.2 - 1.0
Sterols (cholesterol)	0.2 - 0.4
Free-fatty acids	Trace amounts
Fat-soluble vitamins	Trace amounts

A triglyceride can be defined as an ester (combination) of one glycerol molecule with three molecules of fatty acids. A triglyceride can thus be represented as follows:

Glycerol + fatty acid 1 + fatty acid 2 + fatty acid 3 = triglyceride + H_2O

At least 18 different major fatty acids, some of which are shown in Table 49.4, are found in milk fat.

Table 49.4. The chemical formula, melting points and content of some major fatty acids in milk fat in comparison to soy beans

Fatty acid	Formula	Melting point	Content in milk fat (%)	Content in soybeans (%)
Butyric	C_3H_7COOH	- 8°C	2.9	-
Capric	$C_7H_{15}COOH$	16°C	0.8	-
Stearic	$C_{17}H_{35}COOH$	69°C	15.0	-
Oleic	$C_{17}H_{33}COOH$	14°C	31.9	25
Linoleic	$C_{17}H_{31}COOH$	- 31°C	4.5	55

Butyric acid (CH_3 - $(CH_2)_2$ - COOH) is an example of a volatile fatty acid. Being volatile, it is partly responsible for the pleasant aroma given off when butter is heated.

Stearic acid (CH_3 - $(CH_2)_{16}$ - COOH) is an example of a saturated long-chain fatty acid and is described as a hard fat with a melting point of 69°C.

Oleic acid (CH_3 - $(CH_2)_7$ - CH=CH - $(CH_2)_7$ - COOH) has the same amount of carbon atoms as stearic acid, but contains 2 hydrogen atoms less. It is therefore classified as an unsaturated fatty acid and has a lower melting point (14°C) and is thus a soft fat.

Linoleic acid (CH_3 - $(CH_2)_5$ - CH=CH - $(CH_2)_2$ - CH=CH - $(CH_2)_5$ - COOH), similar to stearic and oleic acids, also contains 18 carbon atoms, but has 4 hydrogen atoms less than stearic acid, as well as two unsaturated bonds. Because this type of fatty acid contains more than one double bond, it is termed a poly-unsaturated fatty acid. Linoleic acid has, because of its unsaturation, a very low melting point and is therefore classified as a very soft fat.

Any three fatty acids, or even three molecules of the same fatty acid, may combine with a single glycerol molecule to form a triglyceride. A wide variety (theoretically 18^3 = 5832) of different triglycerides may thus appear in milk fat. All different triglycerides would be in an individual milk fat globule.

The fat percentage in milk is currently determined by means of infra-red analysers. This method is based on the absorption of the infra-red light by specific chemical bonds in the triglycerides.

It is important to indicate that the fatty acids in normal milk are chemically bound to the glycerol molecule and thus do not contribute to the acidity of milk. When milk, however, turns rancid, fatty acids are hydrolysed (set free) from the glycerol molecule by the enzyme lipase. Free fatty acids responsible for the rancid taste then appear in the milk contributing, although to a very minor extent, to the acidity.

The percentage of the different fatty acids in milk differs as a result of the following factors:

- **Breed:** In the milk of breeds producing high fat milk there is a smaller percentage of low melting point fatty acids, e.g. butyric and oleic acid, resulting in Jersey cows producing fat that is usually firmer than that of Holsteins.
- **Feed:** Feeds, like green pasture and linseed oil, containing a high percentage of low melting point fatty acids, e.g. oleic and linoleic acid, result in a soft fat, whereas dry roughages produce a firm fat.
- **Stage of lactation:** Fatty acids are affected by lactation stage, e.g. butyric acid has a maximum value during the first month of lactation and decreases during succeeding months, reaching a minimum at the end of the lactation. Stearic and oleic acids are high in early lactation, while it decreases until mid-lactation and increases again to the end of the lactation period.

Higher levels of low melting point fatty acids in milk result in softer fat, thereby improving the spreadability of the butter made from such milk.

c. The precursors of milk fat

Propionic acid is indirectly the main glycerol precursor. In cows, it is converted into glucose outside the mammary gland. The glucose is converted into glycerol inside the gland. Fatty acids may result from the following three sources:

- **Short chain organic acids:** Acetic acid makes the most important contribution to the synthesis of fatty acids in the mammary gland. Acetic acid results from the fermentation of digestible carbohydrates, e.g. hemi-cellulose which occurs in high concentrations in fibre-rich feeds in the rumen. A certain amount of roughage in the diet is required to stimulate this fermentation process and to maintain the normal fat percentage in milk.
- **Fat depots in the animal body:** this is a major source when cows are underfed.
- **Ingested fats:** Fats in the diet contribute approximately 25% of the milk fatty acids.

d. The role of milk fat in milk and milk products

Fat is probably the most important component in milk. Its effect is seen mainly in four categories, i.e. the economy of milk production, human nutrition, food flavour, and the physical properties of milk products.

In the past, most payment systems for milk were based largely on the fat content of milk. In South Africa, payment for protein was incorporated into the payment scheme in 1983. Since milk fat is still relatively expensive compared to other milk components, it is obvious that the cost of dairy products depend on their fat contents.

Milk fat, as with other fats, is a rich source of energy, yielding approximately 9 Kcal/gram (1 cal = 4.185 Joules). Secondly, it serves as a carrier of the fat soluble vitamins A, D, E and K, and thirdly, milk fat contains significant amounts of the so-called essential fatty acids i.e., linoleic acid and arachidonic acid.

The most distinctive role that milk fat fulfills in dairy products concerns the flavour of foods. Milk fat is responsible for the rich, pleasing flavour of many dairy products such as butter, cheese, and ice cream. On the other hand, it is also notable that the milk fat is significant in many flavour problems, such as rancidity and oxidised flavours, which may occur in dairy products.

The fine body and texture in most dairy products is determined in many instances by milk fat.

1. Milk protein

The average protein content of bulk milk is about 3.5%, although varying between 2.8 and 4.0%. The variation in the protein content of milk, on a daily basis, is much less than that of fat. The protein to fat ratio in bulk milk in high fat producing breeds varies from approximately 0.8 to 1.0, while for lower fat producing breeds, the ratio may be almost 1 to 1.

Proteins are polymers of amino acids. Certain essential amino acids, such as tryptophan and lysine, cannot be synthesised in the human body. These, however, are all present in milk proteins. Of the 20 amino acids occurring in proteins, all are found in milk protein.

Milk contains a number of protein components which differ in composition and properties. The major groups are indicated in Table 49.5.

Table 49.5. The distribution of protein in bulk milk

Protein fraction	Content in milk (%)	Average of total N (%)
Casein	2.7	76 - 79
Albumin	0.3	9
Globulin	0.1	3
Proteose-peptone	0.1	4
Non-protein nitrogen	0.2	5
Total protein	3.5	100

2. Casein

Casein is defined as the protein fraction that precipitates from skim milk when the pH decreases by acidification to a pH of 4.6 to 4.7.

The casein content in milk varies from 2.3 to 3.8%. It is the main protein fraction of milk and is not produced anywhere else in nature. In milk, casein occurs as a fine colloidal suspension in combination with calcium and is often termed calcium caseinate. The colloidal particles have a diameter of approximately 0.0001 mm, being 10 times smaller than the fat globules in milk.

Casein is precipitated in milk by:

- Acids: This usually happens when the normal pH of milk of about 6.6 sours to a pH level of 5.2 to 4.5. It is this precipitation of the casein that causes sour milk to thicken or coagulate.
- Alcohol: When milk and 68-70% alcohol are mixed in a 1:1 ratio, the casein precipitates if acid development has already occurred. This is the basis for the well-known alcohol (Alizarol) test by which raw milk is graded before being picked up on the farm.
- Rennin: The enzyme rennin used in cheese-making coagulates milk at a normal pH-level within a short time frame.
- Heavy ions: The presence of an excess of

heavy ions, e.g. Ca++ and Mg++, causes the coagulation of casein.

Casein, being a high quality protein as it contains all the essential amino acids, is very much in demand in the food industry. Dairy products, such as cheese and milk powder, contain a high percentage of casein.

Casein also has a number of non-food uses and is being used in the paper coating, glue, plastic, paint, textile, and leather industries.

3. Albumin and globulin

These two proteins are in true solution in milk and are not precipitated by rennet or by normal acidification to a pH level of 4.7. During the cheese-making process, they are thus not coagulated and remain in the whey. For this reason these proteins are called the soluble or whey proteins. Their total percentage in milk is about 0.5 to 0.7%.

Both albumin and globulin are precipitated by heat (about 68°C or higher). This is the reason why colostrum, which may contain up to 10% of these proteins, thickens when it is heated.

Immunoglobulin (IG), a fraction of globulin, is present in normal milk in low concentrations, while occurring in colostrum in much larger quantities. These proteins are of unique importance for the new-born calf, because they are absorbed into its circulation system where they fulfill temporarily the immunological functions of blood gamma-globulin. Immunoglobulins (or antibodies) can be absorbed through the intestinal wall only during the first 24 to 36 hours of life, with the maximum amount being absorbed during the first hour. After calving, the concentration of IG in colostrum declines sharply, i.e. from 130 mg/mℓ of milk at 2 hours to 26 mg/mℓ of milk at 24 hours. For these reasons, it is of utmost importance that a new-born calf should receive about 5% of its birth weight in colostrum within the first half-hour after birth.

4. Precursors of milk proteins

Casein does not occur in the blood but is synthesised in the udder mainly from the free amino-acids which are absorbed from the blood. Some of the non-essential amino acids are, however, also synthesised in the udder.

The immunoglobulins and certain albumin fractions are identical to the protein of blood. These are transferred directly from the blood to the milk. The other whey proteins are, however, synthesised in the udder.

5. Lactose (milk sugar)

Lactose is found in high concentrations in milk only while very low levels appear also in blood and urine. Lactose is the only carbohydrate in milk. Milk from some mammalian species, such as sea lions and some seals, does not contain any lactose.

Lactose is a disaccharide, being a compound consisting of a molecule each of galactose and glucose. The average percentage of normal cows' milk generally ranges from 4.6 to 5.2%. This usually amounts to about 50% of the total solids in skim milk.

The osmotic pressure of milk is essentially similar to that of blood and is maintained by the balance of concentration of lactose and soluble mineral matter, mainly chlorides. Thus any variation in lactose concentration is counterbalanced by one in sodium chloride (NaCl) in the opposite direction. The smaller molecular weight of NaCl and its complete dissociation means that a slight increase in chloride concentration is counterbalanced by a much greater decrease in the lactose content of milk.

In a mastitis-infected udder, the permeability of the epithelium cells increases with the result that more blood substances enter the lumen and thus the milk. As the chloride content of blood (about 0.3%) is about three times that of milk, the chloride content of mastitis milk increases from about 0.09 to 0.14%, whereas the lactose content of milk decreases from about 4.9 to 4.6%. Low lactose values in milk samples from individual cows are, therefore, a fair indication of a mastitis infection.

Lactose fulfills an important role in nutrition as it serves as a source of energy providing 4 kCal per gram of milk, while it aids in calcium and phosphorus assimilation and also in the intestinal synthesis of vitamins, e.g. vitamin D in some species.

The primary uses of lactose are the following:

- As an ingredient in infant foods and in special dietary products;
- In the formulation and standardisation of pharmaceuticals, tablets and pills; and

- In the production of caramelised dairy products.

Lactose is fermented by bacteria to lactic acid and is therefore of utmost importance in the manufacturing of fermented and ripened dairy products. It also plays an important role in the texture, taste, and solubility of a wide range of dairy products.

The precursor of lactose is blood glucose. Some glucose is converted in the udder to galactose and with both sugars present, lactose is formed.

The contents of the main milk constituents, namely, milk fat, total protein and lactose, are currently determined by means of infra-red analysers. The principle on which these analysers operate is based on the absorption of infra-red light by specific chemical bonds in the milk constituent to be determined.

6. Minerals (milk salts)

The minerals that occur in milk are listed in Table 49.6.

Table 49.6. The mineral content of normal milk

Minerals	Content in milk (%)
Calcium (Ca)	0.12
Magnesium (Mg)	0.01
Phosphorus (P)	0.09
Sodium (Na)	0.06
Potassium (K)	0.14
Chloride (Cl)	0.11
Sulphur (S)	0.03
Citric acid	0.16
Total	0.72

Although the mineral content of milk is less than 1%, minerals have a marked effect on the nutritive value, heat, and alcohol stability of milk. Minerals also affect the age, thickening of evaporated and condensed milk, the feathering of cream in coffee, the coagulation of milk by rennet, and the clumping of the fat globules during homogenisation.

Potassium, sodium and chloride are entirely in solution. Phosphate, calcium, magnesium and citric acid are partly in solution and partly in suspended (colloidal) combinations.

In addition to the elements that occur in milk in relatively large proportions, there are a large number of elements usually measured in parts per million (ppm) or micro-grams per ℓ. These are referred to as trace elements (see Table 49.7). The fact that they are present in very small amounts does not detract from their importance since many of these elements are known to have remarkable physiological, catalytic, and nutritional qualities.

Table 49.7. The trace element content (microgram/litre, mg/ℓ) of standard milk

Elements	Concentration (mg/ℓ)
Aluminum	460
Arsenic	50
Boron	270
Cadmium	26
Chromium	15
Copper	130
Iodine	43
Iron	450
Lead	40
Manganese	22
Molybdenum	73
Nickel	27
Rubidium	2000
Selenium	40
Silver	47
Strontium	171
Zinc	3900

It is well-accepted that more trace elements occur in milk. The minerals and their concentration values in Table 49.7 have been selected to give a general indication of their proportions in milk. A higher intake rate of most of these elements should increase their content in milk.

7. Vitamins in milk

Milk is a good source of a number of vitamins, such as riboflavin (vitamin B2), while contributing significantly to vitamins A and B1 requirements. Milk has inadequate levels of vitamin C (ascorbic acid) and is a poor source of vitamin D. The most important vitamins in fresh milk are shown in Table 49.8.

Table 49.8. The most important vitamins in fresh milk

Vitamin	Content (mg/mℓ)	Characteristics
A	136 - 176	• Precursor is carotene which occurs in certain plants • Promotes growth and health • Prevents night blindness and hardening of epithelium tissue (e.g. in the respiratory and reproductive tracts) • Heat stable • Prone to oxidation
B_1 (Thiamine)	0.02 - 0.08	• Prevents beri-beri • Partially destroyed by pasteurisation
B_2 (Riboflavin)	0.08 - 0.26	• Sustains normal growth and skin health • Destroyed by direct sunlight
C (Ascorbic acid)	1.57 - 2.75	• Prevents scurvy • Promotes healthy teeth, bones and blood vessels • Destroyed by heat and sunlight

8. Gasses

Milk directly from the udder contains about 8% (by volume) of dissolved gasses. When coming in contact with the atmosphere, the percentage of carbon dioxide (CO_2) decreases, while there is a gain in oxygen (O_2) and nitrogen (N_2). Milk, as delivered to the consumer, contains about 0.5% O_2, 1.3% N_2, and 4.5% CO_2 by volume.

9. Enzymes

Milk contains a number of enzymes as they are components and products of the mammary gland. Certain enzymes can, however, result from bacterial growth in milk. The main enzymes natural to milk include catalase, phosphatase, lipase and reductase:

- **Catalase:**
  It decomposes hydrogen peroxide as follows:

  $$2H_2O_2 + \text{catalase} = 2H_2O + O_2$$

  Mastitic milk is rich in this enzyme and the release of O_2 from H_2O_2 is used as a diagnostic tool for mastitic milk.

- **Phosphatase:**
  The phosphatase enzyme in milk is used in the phosphatase test to determine whether milk has been properly pasteurised. The enzyme is inactivated by heat treatments that are sufficient to destroy pathogenic bacteria such as *Mycobacterium tuberculosis* but that is insufficient to damage the creaming ability of milk, e.g. 72°C for 15 seconds, generally pasteurisation. Any residual activity remaining after pasteurisation and as indicated by the phosphatase test, indicates inadequate pasteurisation.

- **Lipase:**
  Lipase plays an important role in milk in that it hydrolyses the triglycerides to set the fatty acids free which result in a rancid taste in milk.

In closing

Milk has some distinctive features containing food sources such as fat, protein, lactose, minerals and water. These components vary according to breed. The total solid content of milk is about 13% while the solids-no-fat may be about 9%. The production of milk is a biological process and a considerable number of factors affect the composition of milk. This may result in the composition of milk varying from day to day. The fat in milk consists of a number of fatty acids which have different effects on human health, Because milk has a natural creaming effect, e.g. fat molecules moving upwards in the milk and forming a layer on top of the milk, the way in which milk is sampled for the analysis of its fat, protein and lactose content may affect milk prices. Milk has to be stirred for at least five minutes before milk sampling can be done.

CHAPTER 50

FACTORS AFFECTING THE COMPOSITION OF MILK

A cow is a peculiar animal, sometimes she reacts, sometimes not and other times even less

Introduction

Milk does not have the same composition at all times because it is a biological product resulting from a number of chemical processes in the udder. The chemical composition of milk also varies because of environmental and physiological factors. In the case of a single cow, the composition of her milk may differ considerably over short periods, e.g. from one milking to another. The extent of the variation of a bulk milk sample would be less when a large number of cows contribute to the sample. Even in large herds the chemical composition of bulk-milk may vary significantly from day to day. The most important factors affecting milk composition are as follows:

1. Breeds and breeding

Milk yield and milk composition are hereditary characteristics and are influenced markedly by breed (Table 50.1).

Table 50.1. The average lactation milk yield and milk composition of all grade and registered dairy cows in milk recording in South Africa for the period 1 March 2006 to 28 February 2007 (4% FCM = fat corrected milk: (0.4 x kg milk) + (15 x kg fat)

Breeds	Number of lactations	Milk (kg)	4% FCM (kg)	Fat (%)	Fat (kg)	Protein (%)	Protein (kg)	Protein:Fat ratio
Holstein	60429	8260	7133	3.80	255	3.23	217	0.85
Jersey	49601	5596	5823	4.68	239	3.75	191	0.80
Ayrshire	6773	6200	5918	3.95	229	3.33	193	0.84
Guernsey	1099	5978	5778	4.28	226	3.46	183	0.81

From the data in Table 50.1, it seems that for dairy cow breeds, an increase in milk yield is accompanied by a decrease in fat and protein percentages in milk. Breeds producing less milk have higher fat and protein percentages. Although this increases fat and protein yields, breeds producing a higher volume of milk have higher lactation fat and protein yields.

The fat to protein ratio in the milk of different breeds differ considerably, being 1 : 0.90, 1 : 0.91, 1 : 0.81 and 1 : 0.83 for Friesians, Ayrshires, Guernseys and Jerseys, respectively.

The fat to protein ratio is important with respect to the following:

- It determines the composition of dairy products.
- It is a major factor in determining the producer's milk price. When the unit price between these two components differs significantly, it may affect breeding strategies.
- In the milk of a single herd, this may indicate diet deficiencies with regards to roughage and energy contents.

Both milk yield and milk composition are hereditary and can thus be affected by breeding and selection programmes. As the heredity of milk characteristics is correlated, a change in the breeding programme may affect all milk traits (Table 50.2).

Table 50.2. The genetic correlations between milk traits

Traits	Milk (kg)	Fat (kg)	Protein (kg)	Fat (%)
Fat (kg)	0.88	-	-	-
Protein (kg)	0.95	0.93	-	-
Fat (%)	- 0.20	0.24	- 0.01	-
Protein (%)	- 0.19	0.04	0.06	0.49

From Table 50.2 it seems that the genetic correlation between milk yield and fat and protein yields are highly positive (more than 88%), while on the other hand the correlation between milk yield and fat and protein percentages is negative (about -20%). Therefore, breeding for more milk would increase fat and protein yields, though reducing the fat and protein percentages of milk.

In Table 50.3 the effect of selecting for specific characteristics over a period of 20 years is shown.

Table 50.3. The milk yield and milk composition as affected by breeding for specific traits over a 20 year period (*Income per lactation based on fat = R7.93/kg and protein = R11.87/kg)

Traits	Milk (kg)	Fat (%)	Protein (%)	Income* (R)
Milk (kg)	5168	4.3	3.6	3971
Fat (kg)	4622	4.9	3.8	3881
Protein (kg)	5126	4.5	3.8	4141
Fat (%)	3677	5.8	4.0	3437
Protein (%)	4300	5.4	4.1	3934
Maximum difference (%)	43	45	14	20

The lactose and ash content of milk are also affected by breed, although to a lesser degree, lactose being 4.87, 4.81, 4.96 and 5.00%, respectively, for Holstein, Ayrshire, Guernsey and Jersey milk. The ash content for these breeds was 0.68, 0.68, 0.74 and 0.70%, respectively.

2. Stage of lactation

The stage of lactation has a marked and recognisable effect on both milk yield and milk composition. Milk produced during the first 4 to 5 days after calving is called colostrum, which differs markedly from normal milk. Colostrum contains high levels of most of the milk components except for lactose and potassium. The fat percentage is usually higher, although it may vary considerably. The protein content of milk, especially the albumin and globulin contents, is initially very high, decreasing within a few days back to normal levels (Table 50.4).

Table 50.4. The progressive change of colostrum into milk

Time after calving	Total solids (%)	Protein (%)	Albumin + globulin (%)	Lactose (%)	Chlorides (%)	Fat (%)
0 h	27.0	17.6	11.3	2.2	0.15	5.1
6 h	20.5	10.0	6.3	2.7	0.16	6.8
36 h	12.2	4.0	1.0	4.0	0.16	3.6
4 days	11.9	3.8	0.8	4.7	0.13	2.8
7 days	12.1	3.3	0.7	5.0	0.11	3.5

2.1 Milk yield

Following the colostrum period, daily milk yield usually increases sharply to reach peak production at about 4 to 10 weeks after calving. During this period, both the fat and protein percentages of milk decrease reaching minimum levels at about the same time as when maximum daily milk yield is reached. At this stage, the fat percentage of milk may be 0.2 to 0.6 percentage points lower than the fat percentage at the start of the lactation. The decline in protein percentage is usually less than that of fat, also reaching minimum levels at about the same time as maximum milk yield (Figure 50.1).

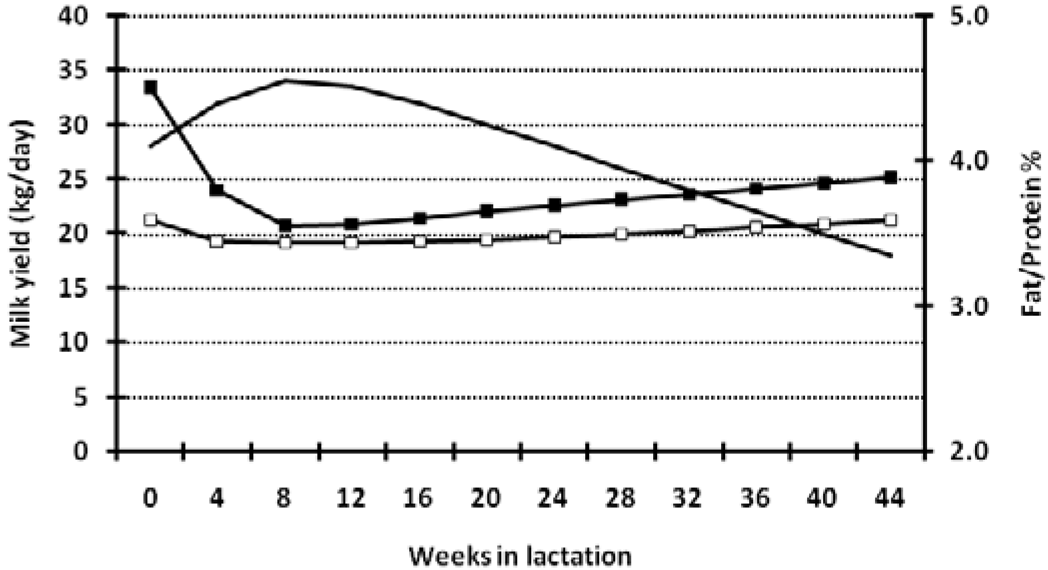


Figure 50.1. The effect of lactation stage on the milk yield (—), fat (■) and protein (□) percentage of dairy cow milk

Peak milk yield is, among other factors, dependent on the genetic merit for milk yield in dairy cows. It is also affected by body condition at calving, feeding strategy in terms of the late dry and early lactation stages, as well as udder health.

Maximum milk yield usually continues for a few weeks after reaching peak milk yields after which the daily milk yield of cows gradually declines. This decline in milk yield continues until the end of the lactation period and accelerates until after the 30th week of the lactation. A useful approximation is that from peak milk yield, the rate of milk yield decline should not exceed 2 to 2.5% per week.

2.2 Fat percentage

After reaching a minimum level at around peak milk yield, the fat percentage of milk stays relatively constant for a few weeks before gradually starting to increase. This increase continues until the end of the lactation period, when the fat percentage of milk is usually higher than at the start of the lactation period. Cows being milked until very close to calving often show a decline in fat percentage.

The difference between maximum and minimum fat percentages in milk over the lactation period may be about 0.6 percentage points and is often higher in breeds producing milk containing high fat levels. During first lactation, the fat percentage of milk is relatively low at the beginning of the lactation period, while reaching higher levels at the end of the first lactation than in subsequent lactations.

2.3 Protein percentage

The protein percentage of milk is affected by stage of lactation following a similar lactation trend as for milk fat percentage. The variation in protein percentage in milk is, however, less, usually about 0.3%. After the decline in early lactation, a minimum level is reached at the time of peak milk yield or shortly thereafter. Protein percentage then remains fairly constant up to 2 to 5 months after the cow has been inseminated after which protein percentage continues to increase. This increase in protein percentage during late lactation is often not noticeable in non-pregnant cows.

2.4 Lactose percentage

The lactose percentage of milk tends to follow the trend for milk yield. Lactose percentage reaches a maximum level at about the 7th week after calving. After peak, the lactose percentage slowly decreases until mid-lactation, after which the decline becomes more pronounced. The difference between maximum and minimum lactose percentages may be about 0.4% percentage points.

2.5 Minerals

The mineral content of milk varies during the lactation period in a similar way as the protein percentage in milk. The calcium and phosphorus contents decrease during the first month of the lactation period, after which it remains relatively constant while increasing during the last three months of the lactation period. During late lactation, the sodium and chloride contents of milk may increase sharply.

3. Age of the cow

Cows produce more milk as they get older. The milk yield of mature cows in 4th lactation is about 25% higher than that in first lactation cows. However, with consecutive lactation periods, fat, protein and lactose percentages of cows decrease by about 0.03, 0.01 and 0.04 percentage points, respectively. After 5th lactation, these decreases level off considerably. Due to the higher milk yield in later lactations, the fat and protein yield of older cows also increase (Table 50.5).

The higher milk, fat and protein yields of cows in later lactation are related to an increase in body size (for a higher feed intake) and udder capacity.

Table 50.5. The average production of registered Holstein-Friesian cows in the 1985/86 milk recording year

Lactation number	Milk	Fat		Protein	
	(kg)	%	kg	%	kg
1	4746	3.61	171	3.24	154
2	5336	3.56	190	3.24	173
3+	5802	3.54	205	3.20	186

4. Interval between milkings

When the interval between milking sessions is unequal, the milk yield of cows is less after the shorter interval. It is for this reason that the milk yield at the morning milking is higher than the milk yield in the afternoon. The fat percentage in the milk is, however, higher in milk following the shorter interval (Table 50.6).

Table 50.6. The milk yield and milk composition of Jersey cows as affected by milking interval

Parameters	Preceding milking interval (hours)		
	5	7	12
Milk (kg)	15.0	17.0	29.0
Fat (%)	6.63	6.53	3.93
Fat (kg)	1.10	1.10	0.99
Solids not fat (kg)	9.43	9.48	9.59

On a fat-free basis, milking interval has little effect on the protein percentage in milk. When cows are milked twice a day at equal intervals, say at 06:00 and 18:00, the milk yield is usually higher at the morning milking, although at a lower fat percentage.

5. Water intake

Lactating cows require 3 to 5 litres of water for each kg of milk produced. Therefore, restricting the amount and quality of water for dairy cows result in a lower milk yield, as well as fat percentage. Cows having free access to fresh water produce about 7% more milk and 6% more fat than cows having access to water only two to three times per day.

6. Mastitis

Udder infection, or mastitis, has a marked and characteristic effect on the milk yield and milk composition of dairy cows (Table 50.7).

Udder infection affects all the major milk components which tend to decrease in concentration, although whey protein, sodium (Na) and Chloride (Cl) show an increase (Table 50.8).

Table 50.7. The effect of somatic cell count (SCC) on the milk yield of dairy cows

SCC x 1000/mℓ	Degree of mastitis	Milk loss (%)
Below 200	Slight	2.7
201 - 500	Middling	4.1
501 - 1000	Bad	6.4
More than 1001	Severe	8.8

Table 50.8. The milk composition of cows as affected by mastitis

Milk component	Effect	Composition (%)	
		Normal milk	Mastitic milk
Fat (%)	Decrease	3.8	3.6
Protein (%)	Slight decrease	3.6	3.5
Casein (%)	Decrease	2.8	2.3
Whey protein (%)	Increase	0.8	1.2
Lactose (%)	Decrease	4.9	4.4
Sodium (Na^+)	Increase	0.05	0.08
Chloride (Cl^-)	Increase	0.10	0.18
Calcium (Ca^{++})	Decrease	0.13	0.09

- The loss in fat yield may be as high as 6 kg/cow/year for each increase of 250 000 cells in somatic cell count above 200 000 cells/mℓ of milk.
- The lactose content decreased markedly. A lactose content of less than 4.6% in the milk of an individual cow is an indication of mastitis. To maintain the osmotic pressure of milk, the decrease in lactose concentration is countered by an increase in sodium chloride content.
- The total protein content remains relatively constant because the decrease in casein is countered by an increase in the albumin and globulin percentages.
- Mainly due to the decrease in the fat and lactose percentages, the total solids and solids-not-fat content decrease in mastitic milk. A study showed that the total solids concentration was 0.26% lower in mastitic milk (SCC more than 1 x 10^6/mℓ of milk) than in normal milk (SCC below 500 000/mℓ of milk)
- Mastitic milk shows a greater enzyme activity. The catalase activity may be double that of normal milk.

7. Variation in milk composition during a single milking

It is well known that the fat content of milk increases continuously during the milking process, i.e. the fore milk has a very low fat content while stripped milk at the end of the milking process has the highest fat content (Table 50.9). The fat content of the final 5% of milk may be as high as 10%.

Table 50.9. The effect of the stage of the milking process on the fat percentage of milk

Milk portion	Proportion of total yield (%)	Fat (%)
First	15	1.9
Middle	58	2.3
Last	27	6.8
Composite	100	3.1

The magnitude of this effect differs greatly among cows, i.e. being more pronounced in high producing cows. From this, it follows that incomplete milking would result in the production of milk containing less fat. When the udder is subsequently milked normally, the fat content of the milk should be higher. When milking is incomplete for several successive days, the fat percentage is markedly less only on the first day of incomplete milking.

The solids-not-fat content, estimated as a proportion of the fat-free milk, does not change during the milking process. Milk yield lost due to incomplete milking, especially in high-producing cows, are normally not fully recovered.

8. Exercise

Excessive exercise has a marked decreasing effect on milk yield. As a result of the lower milk volume, fat percentage increases. The nett result is a slight reduction in fat yield.

Exercise aids in the digestion of feed and coupled with an increased feed intake, milk yield may be maintained, even while the fat percentage increases.

9. Climate

9.1 Season

The seasonal influence on the milk of a single herd is dependent on factors, such as seasonal calving, environmental temperature, and seasonal related feeding strategies.

In South Africa as a whole, milk production is high from September to February and low during the winter months. Fat and protein percentages follow a reverse pattern and are low during the months of high milk production (Figure 50.2).

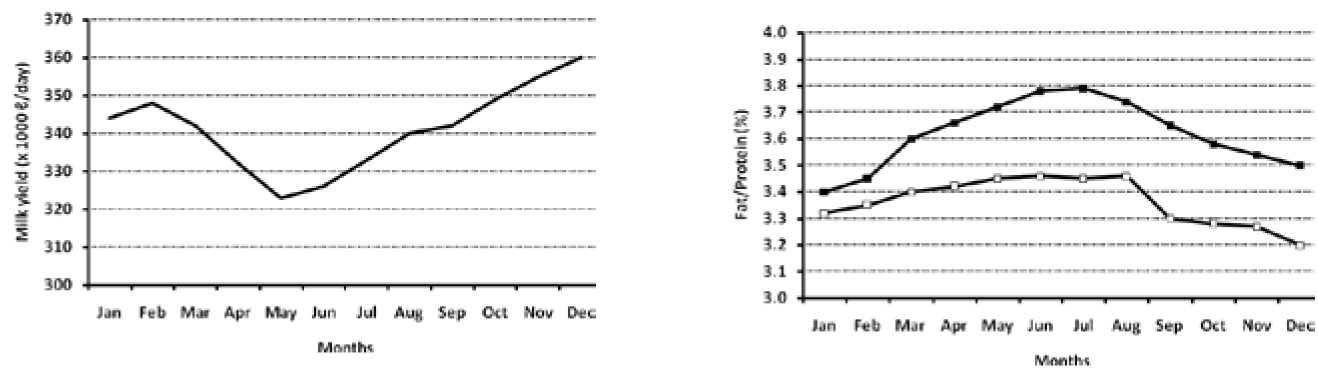


Figure 50.2. The (a) average daily milk yield (litres x 1 000) and (b) fat (■) and protein (□) percentage of milk as affected by month of the year

9.2 Ambient temperature

Ambient temperature is usually the most important single climatic factor affecting the milk yield of dairy cows. The magnitude of the effect of temperature is dependent on factors, such as breed, air movement, air relative humidity, period of exposure, and individual cows.

The adverse effect of high temperatures is enhanced by long periods of exposure, the absence of air movement, and high humidity.

Milk breeds, which originated in the cold to temperate climate of Europe, are better adapted to low than to high temperatures. The approximate lower and upper critical temperatures for Holstein-Friesian and Jersey cows are shown in Table 50.10.

Table 50.10. Critical temperatures for Holstein-Friesian and Jersey cows

Breed	Critical temperatures (°C)	
	Low	High
Holstein-Friesian	- 12	27
Jersey	- 1	30

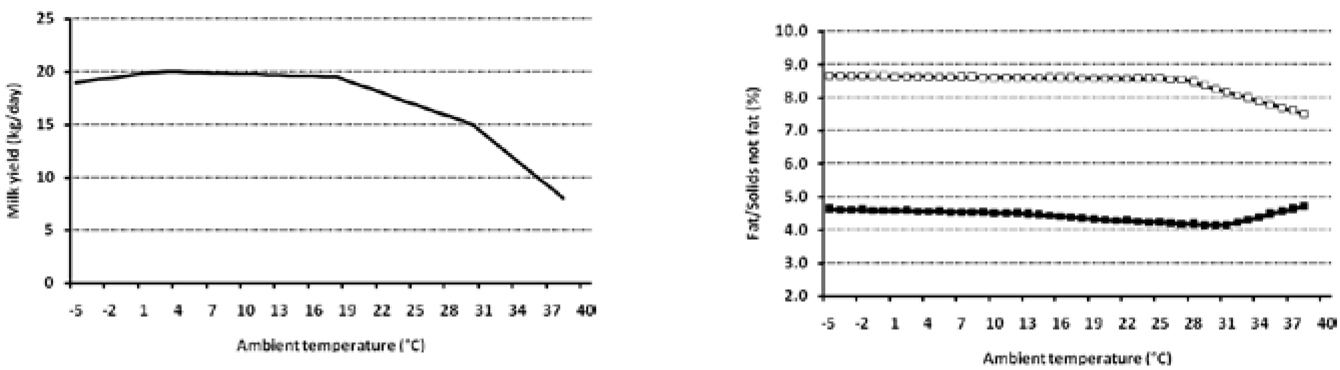
High ambient temperatures (above 27°C) for short periods, e.g. for only one day, while night temperatures are low, may only have a slight effect on the production performance of dairy cows. Heat stress has a more marked effect on high producing cows, especially during peak production, than on low producing cows.

The influence of high environmental temperatures on the physiology of the cow is given in Table 50.11.

Table 50.11. The respiration rate, rectal temperature, hay intake and milk yield as affected by increasing ambient temperatures

Ambient temperature (°C)	Respiration rate (breaths/min)	Rectal temperature (°C)	Hay intake (kg/day)	Milk yield (kg/day)
10	17	38.3	13	20
21	42	38.5	12	20
27	56	38.7	11	18
33	88	39.2	7	11

During cold weather, milk yield and protein percentage may decrease slightly. An increase in fat percentage may occur (Figure 50.3).



(a) **(b)**

Figure 50.3: The effect of ambient temperature on (a) milk yield and (b) milk composition of dairy cows

These variations are more noticeable when the ambient temperature approaches the critical levels. Wind and a low-energy diet increase the negative effects of low temperatures.

The optimum ambient temperature for dairy cows ranges between 4 and 21°C. As the temperature increases within this range, the fat percentage usually decreases by 0.1 – 0.2% per 6°C. Between 21 and 27°C, the milk yield slowly starts to decrease and the decrease in fat percentage becomes more noticeable.

When the critical temperature is exceeded, milk yield, protein and lactose percentages drop sharply, while the fat percentage usually increases because of the reduction in milk yield.

The detrimental effect of high environmental temperatures may be partly eliminated by measures such as providing shade (Table 50.12), spray cooling and the cooling of the drinking water.

Table 50.12. The effect of providing shade to dairy cows

Parameters	Shade provided	No shade
Ambient temperature (°C)	28.4	36.7
Milk yield (kg/day)	16.6	15.0
Fat (%)	3.8	3.4
Number of mastitis infections	9	19
Conception rate (%)	79	60

10. Dry period and body condition

The length of the dry period and the body condition of cows at calving are related. Cows must have a dry period of about 60 days to replenish their body supplies and to regenerate secretory tissue in the udder. Cows calving down in a good condition usually produce more milk with higher fat and protein percentages in the following lactation period in comparison to thin (lower body condition score) cows (Table 50.13).

Table 50.13. The effect of the condition score of cows at calving down on the milk yield and milk composition of cows during the first 16 weeks of the lactation period

	Condition score	
Production parameters	2.5	3.5
Total feed intake (kg DM/day)	16.3	15.9
Peak milk yield (kg/day)	27.8	29.8
Mean milk yield (kg/day)	23.6	25.7
Fat (%)	3.86	3.95
Protein (%)	3.19	3.06
Loss in live weight (kg/day)	- 0.04	- 0.10
Milk yield (kg/lactation)	5 096	5 718

In another study, the milk, fat, and protein yield during the first five months of the lactation period increased by 122, 8 and 4 kg, respectively, for each 30 kg increase in live weight during the dry period.

An increase in milk yield is obtained with dry periods of up to approximately 60 days. Increasing the dry periods from 20 to 40 and 40 to 60 days, increases in milk yield of approximately 13 and 3.5%, respectively, can be expected.

11. Season of calving

Particularly in regions where cows are fed a dry ration during winter and go onto green grazing during spring, the season of calving will influence their milk yield per lactation. In the UK, the effect of the so-called spring flush (with regards to the change to pasture feeding), increases the milk yield of cows by 10 to 15%, regardless at which stage of the lactation curve pasture feeding starts. For the spring calving cows, peak production increases followed by a subsequent rapid decline in milk yield. The effect on winter calving cows is most beneficial, because the increase in milk yield then occurs slightly after peak production, which increases and maintains persistency. Cows calving down in autumn experience the spring flush too late in the lactation period to affect milk yield to any extent.

12. Feeding

The effect of feeding on milk production and composition is complicated. A few basic principles apply:

12.1 Composition of ration

A cow, to produce at an optimum level within her genetic potential, needs various nutrients. An ideal ration should contain:

- 16% CP (crude protein),
- 10 – 11 Megajoules (MJ) digestible energy per kg DM,
- 0.6% Ca (calcium),
- 0.4% P (phosphorus), and
- At least 15% CF (crude fibre).

Over and above these guidelines, factors such as protein and fibre quality, mineral and vitamin status should also be taken into account.

12.2 Energy intake

A high energy intake usually results in a higher milk yield and higher protein percentage, but, due to the higher milk yield, fat percentage may decrease.

12.3 Protein intake

Underfeeding protein affects milk yield negatively and may also depress protein percentage during early lactation. By increasing protein intake while maintaining energy levels, the protein percentage in the milk may increase. The response is, however, dependent on the rumen degradability of the protein in the ration. To ensure a high protein percentage in milk, it is advisable that the ration should contain at least 4% non-degradable protein, such as fish meal or oil cake.

12.4 Fat supplements

Including rumen-protected fats in rations usually increases the fat percentage of milk.

The addition of most types of fats and oils to a fat-free or low-fat ration, e.g. to a ration very rich in fibre (1% or less fat), increases the fat percentage of the milk. However, when the level of dietary fat exceeds about 7%, the milk fat percentage, and maybe also the protein content in milk may decrease.

Broadly, it can be accepted that all fats and oils, particularly unsaturated fats such as soya and maize oil, included in rations high in concentrates, decreases butter fat percentage.

12.5 Roughage-to-concentrate ratio

The roughage-to-concentrate ratio in the ration has a distinct effect on the ratio of acetic to propionic acid produced in the rumen.

Acetic acid, the precursor of milk fat, is produced when fibre is digested in the rumen. Propionic acid is derived from the degradation of carbohydrates and promotes the synthesis of lactose, which encourages milk production. Propionic acid serves as an important source of energy during the synthesis of protein by rumen microbes, resulting in higher protein levels in milk. Rations containing high concentrate levels increase the milk yield and protein percentage of cows, while diets high in fibre increases milk fat percentage (Table 50.14).

Table 50.14. The effect of roughage-to-concentrate ratio on the milk yield and fat percentage of milk

Percentage		Milk yield (kg/day)	Fat	
Roughage	Concentrate		(%)	(kg)
45	**55**	24.1	3.51	0.85
60	**40**	23.9	3.58	0.85
75	**25**	22.2	3.71	0.82

12.6 Physical structure and quality of roughage

Finely ground (less than 1.0 - 2.5 cm) and pelleted roughages move through the rumen at a faster rate than long hay. The result of this is that cows ruminate less (chewing the cud) and therefore producing less saliva which normally buffers the rumen resulting in less acetic acid being produced. This may affect the fat percentage in milk negatively. Feeding a small quantity of ungrounded, coarse hay may help to overcome this situation.

Feeding roughages containing high energy levels, such as early-cut silage or hay, increases milk and protein yield, while decreasing fat percentage in milk.

Milk yield, fat and protein percentages may increase when roughage is fed as silage instead of hay. The reason for this is that forage crops are usually harvested earlier for silage than for hay. This increases the energy content of the roughage, while maintaining its fibre content, which is more digestible as it contains less hemi-cellulose and lignin.

12.7 Level of feed intake

The milk yield of cows increases by feeding larger quantities of the same diet, although the fat percentage may decrease. The net result may be a decrease in fat yield.

12.8 Frequency of feeding

When high concentrate rations are fed, the milk fat depression could be overcome by more frequent feeding, i.e. feeding more times per day.

12.9 Feeding of supplements

Milk fat depression as a result of rations low in fibre or in which the roughage is finely ground, may be reduced by feeding pH buffers, such as sodium bicarbonate, magnesium oxide, or sodium bentonite. The optimum level of intake is about 150 to 200 g sodium bicarbonate per cow per day or either 1% sodium bicarbonate or 0.5% magnesium oxide in the concentrate.

13. Milk sampling

For milk analysis, the value of the final results is dependent on the representativeness of the milk sample collected of the total volume of the product to be tested. It is therefore very important that a representative sample for testing is collected. This is very important in the case of milk as creaming takes place when milk is not stirred during storage (Table 50.15).

Table 50.15. The effect of creaming on the fat content in the top 25% of unstirred milk

Time (h)	Fat content (%)
0	5.25
½	5.36
1	6.06
3	12.00
5	13.40

The rising fat globules serve as a filter carrying bacteria and somatic cells to the top layers of milk. The latter, upon creaming, will thus also be concentrated in the upper milk layer. Therefore, thorough agitation of milk is required before milk sampling is done to ensure homogeneity. However, agitation of milk should not be excessive to prevent the churning of fat.

When a single sample from several containers is to be compiled, for example, to determine the fat content in the milk of a herd over a 24 h period, a sub-sample of each container should be taken in proportion to the quantity of milk in the specific container. The sub-samples should be combined and, if necessary, mixed and resampled to obtain a suitable sample volume.

Factors such as lipolysis (rancidity), churning, and bacteriological deterioration may affect the accuracy of chemical analysis. As these influences are enhanced by temperature, it is advisable to store milk samples prior to analysis at a temperature of below 10°C. To facilitate thorough mixing of a sample before analysis, it is advisable that the bottles should be of a convenient size and not be filled to more than 75% of their capacity.

14. Diagnosing problems with regards to low milk solids content

In Figures 50.4 to 50.6 flow diagrammes are presented to identify possible problems with regards to low fat, protein and lactose percentages in milk. These diagrammes can be used to identify problems quickly.

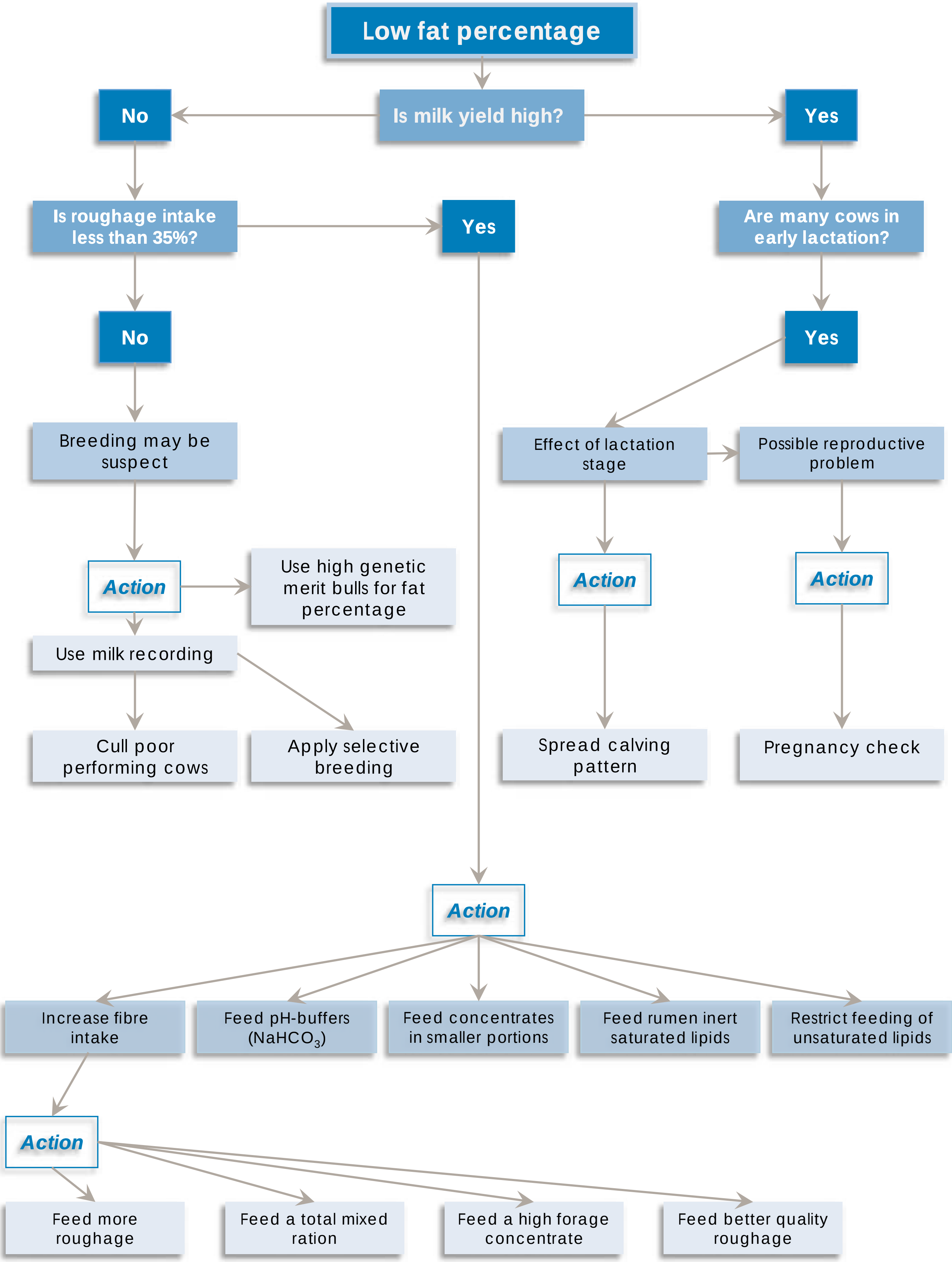


Figure 50.4. A flow diagramme to determine problems with regards to a low fat percentage in milk

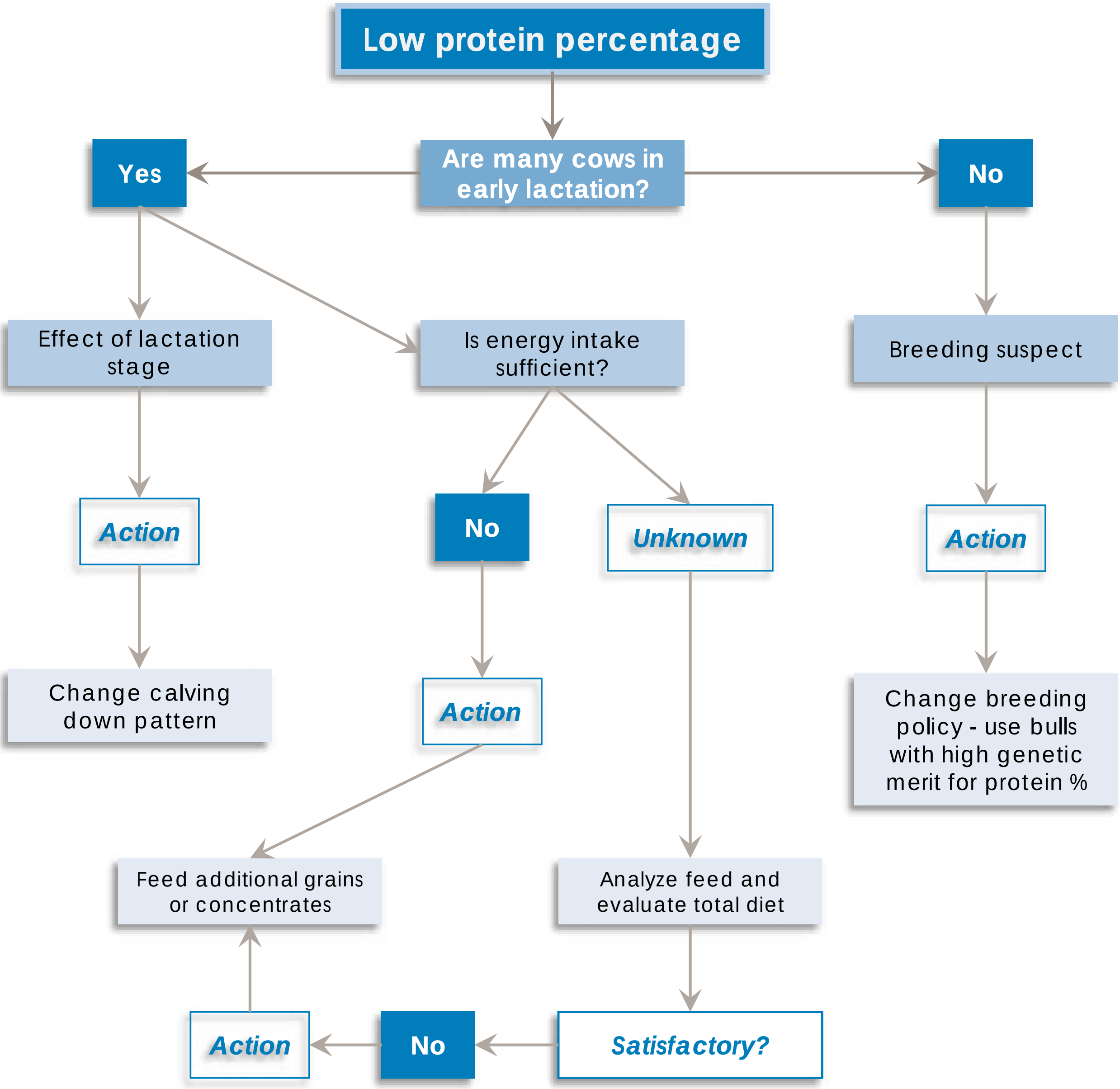


Figure 50.5. A flow diagramme to determine problems with regards to a low protein percentage in milk

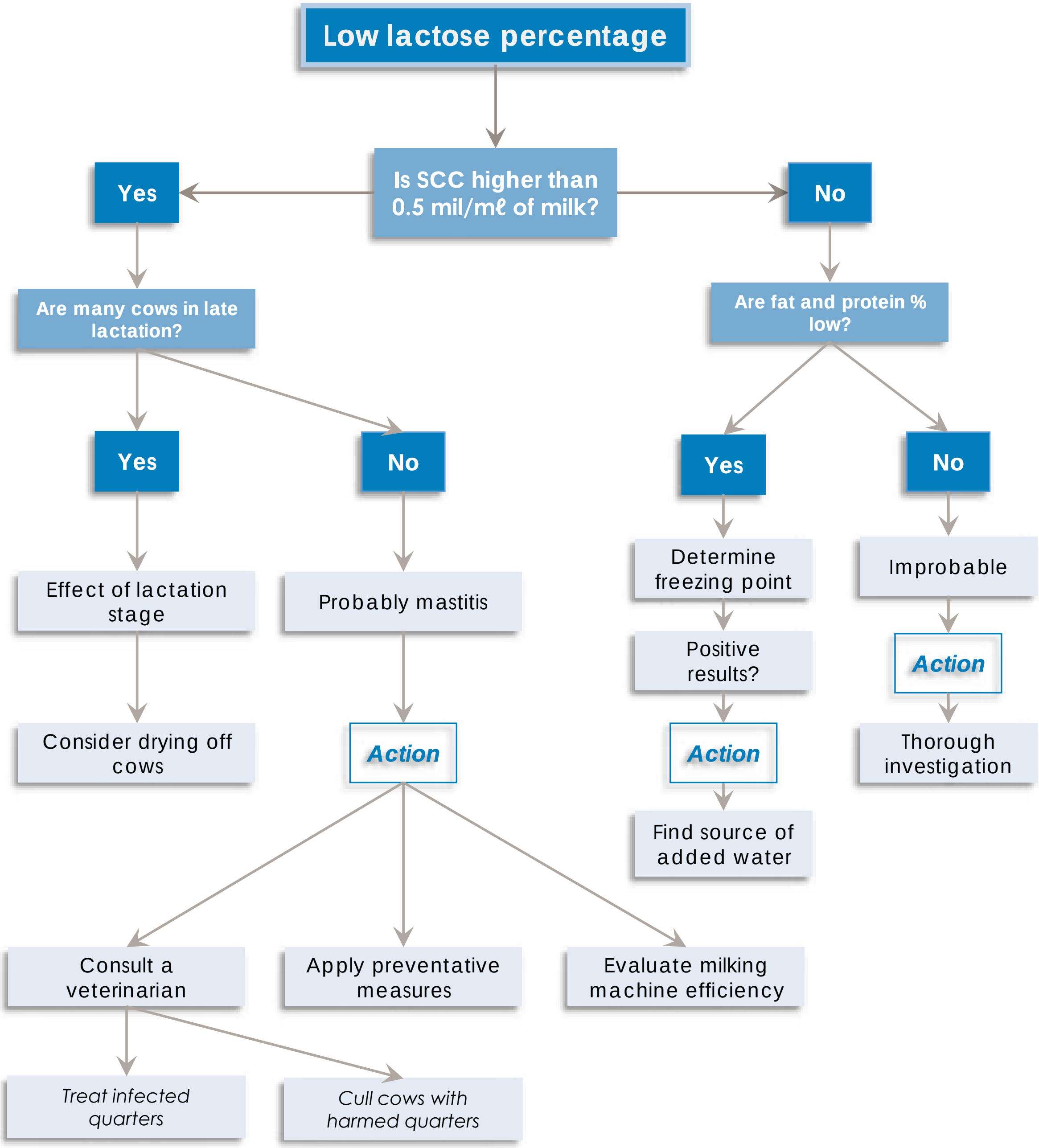


Figure 50.6. A flow diagramme to determine problems with regards to a low lactose percentage in milk (SCC = somatic cell count)

CHAPTER 51

MILKING PARLOUR HYGIENE

Hygiene is a way of life

Introduction

Milk, in addition to being a nutritious food source, presents a favourable physical environment for the growth and increase in the number of micro-organisms. Being a metabolic product, it is subjected to widely different production conditions and is normally contaminated by a broad spectrum of micro-organisms. Although bacteria dominate in fresh milk, molds, yeasts, and viruses may also occur.

1. Micro-organisms associated with milk

From the viewpoint of the dairy producer and dairy technologist, it would be sensible to group different bacteria according to the specific changes they bring about in milk and dairy products, or according to their temperature-related characteristics. Important groups, based on these characteristics, are the following:

1.1 Acid-producing bacteria

Acid-producing bacteria ferment lactose mainly into lactic acid. As a result of the acid production, the pH of fresh milk drops from about 6.66 to as low as 4.6. At a pH of about 5.2 and lower, casein in milk coagulates and milk thickens. These bacteria are usually mesophilic, i.e. growing best at moderate temperatures, neither too hot nor too cold, typically between 20 and 45°C. They are the dominant population in milk that has been inadequately cooled. Examples of such bacteria are *Streptococcus lactis* and *Lactobacillus bulgaricus.*

1.2 Gas-forming bacteria

These bacteria ferment lactose to produce gas (CO_2 and H_2) in milk and dairy products. Well-known examples include:

- coliform bacteria, e.g. *Escherichia coli (E. coli)* causing early blowing of cheese, and
- *Clostridium butyricum*, which is an anaerobic spore-forming bacteria causing late blowing of cheese.

1.3 Sweet curdling and ropiness

Bacteria responsible for these defects in milk are capable of increasing the viscosity of the milk without significant acid production. The responsible bacteria are often contaminants from stagnant water. Examples include the following bacteria:

- *Alcaligenes viscosus* from stagnant water, and
- *Bacillus subtilis* from hay and dust.

1.4 Proteolytic bacteria

Proteolytic bacteria decompose the casein in milk, causing faecal odours and bitter flavours. Because of the proteolysis of proteins in milk, it appears to be watery.
Example: *Clostridium butyricum.*

1.5 Psychrotrophic bacteria

Psychrotrophic bacteria are capable of multiplying at temperatures between 2 and 10°C and therefore often become the dominant population in milk that is stored at below 10°C for 2 days or longer. During the first 24 hours' cold storage, the percentage psychrotrophic bacteria in milk may, for example, increase from 15 to 80% of the total population.

Pseudomonas spp., mainly *P. fluroescens*, usually account for about 50% of the psychrotrophic bacteria in milk and are capable of producing heat resistant enzymes which easily survive pasteurisation.

Due to the proteolytic activity of these enzymes, they are often responsible for the bitter flavours that may develop in pasteurised and sterilised milk.

Off-flavours which may develop in UHT (long-life) milk are often caused by these enzymes.

1.6 Mesophilic bacteria

Mesophilic bacteria can grow at temperatures ranging from 5 to 45°C with an optimum growth temperature of about 25 to 37°C. The majority of bacteria occurring in nature, and thus also in milk, falls within this group.

Example:
- *Streptococci,* e.g. *S. lactis* – lactic acid fermenter,
- *Micrococci,* e.g. *M. pyogenes* – mastitis, and
- *Staphylococcus areus* – mastitis.

1.7 Thermoduric bacteria

Thermoduric bacteria can survive, but do not grow, at pasteurisation temperatures. Examples of temperature-time combinations for the pasteurisation process are:

- 75°C for 15 seconds, or
- 62.8°C for 30 minutes.

1.8 Spore forming bacteria

Spore forming bacteria are capable of producing endospores (internal) which can survive a heat treatment of 80°C for 10 minutes.

Typical examples are:
- *Bacillus cereus* which causes bitty cream,
- *B. subtilis* which causes ropiness, and
- *Clostridium butyricum* which is responsibile for late (butyric) blowing of cheese.

1.9 Coliform organisms

Coliform bacteria have the capacity to produce both gas and acid from lactose at 30°C. The incidence of coliforms in raw milk has received considerable attention due to the following reasons:

- their association with contamination of faecal origin *(Escherichia coli)*,
- the off-flavours that they produce in milk, and
- the ease at which their presence can be indicated.

Coliforms readily multiply on moist dairy utensils, especially in the presence of milk residues. Poorly cleansed utensils are often the main source of contamination. *Escherichia coli (E. coli)* may be distinguished from the rest of the group due to their ability to produce grass in brilliant green broth at 44°C and indole in tryptone water (Eijkman test). The presence of *E.coli* in water usually indicates recent faecal contamination.

1.10 Total viable count

The total viable or standard plate count indicates the total number of viable micro-organisms present in 1 mℓ of milk as determined by the colony plate count method. The total viable count is often confused with the total count, which is determined microscopically and includes both viable and dead microbial cells. Raw milk sold in South Africa for further processing, is usually classified according to bacterial quality as follows:

- Class A = less than 50 000 bacteria/mℓ of milk,
- Class B = 50 000 to 200 000/mℓ of milk, and
- Class C = more than 200 000/mℓ of milk.

2. The bacterial content of freshly drawn milk

Milk drawn aseptically from a healthy udder usually contains less than 1 000 bacteria/mℓ of milk. There is a considerable variation in the numbers of organisms found in milk at different stages of the milking process. The foremilk contains the highest number of bacteria, for example, from 1 000 to 10 000/mℓ. After the first few streams of milk, the count in bacteria decreases sharply and thereafter more gradually until a minimum of 100 to 200/mℓ is reached in stripped (last) milk. Bacteria present inside a healthy udder are mostly micro-cocci, which are inactive and do not have a significant influence on the hygienic quality or keeping quality of milk.

Mastitic infected quarters may excrete fluctuating numbers of organisms in their milk. The counts may vary, for example, from a few thousand per mℓ in milk from sub-clinical cases to more than 10 million/mℓ in milk from clinically infected quarters. Where bulk milk has a total bacterial count of more than 50 000 bacteria/mℓ, mastitis is often the reason for the high count.

Milk secreted by infected cows/udders may convey the following pathogens (disease causing) bacteria to the consumer:

- Tuberculoses–*Mucobacterium tubercolusis,*
- Contagious abortion Brucelloses – *Brucella abortus,*
- Anthrax – *Bacillus anthrax,*
- Food poisoning – *Staphylococcus aureus* (mastitis), and
- Sore throat – *Streptococcus pyogenes* (mastitis).

3. Sources of contamination

During milk harvesting, bacteria from the external part of the udder, environment, and milking utensils gain entry into the milk. The result is that at the end of the milking process, milk may contain from 10 000 to several hundred thousand bacteria per mℓ of milk.

3.1 Contamination from the exterior udder and teats

Between milking sessions, udders and teats of cows may become soiled in different ways, e.g. dung, mud, and bedding material. Such dirt may contain many millions of bacteria per gram. If not removed beforehand, the dirt on the teats, together with the large number of bacteria associated with it, may be washed into the milk during milking, resulting in an increase in the bacterial count of the milk accordingly (Table 51.1).

Table 51.1. The effect of housing and teat washing on the bacterial content of bulk tank milk

Housing	Teats	Bacteria per mℓ of milk
Bedded on sand	Unwashed	31 700
	Washed	15 500
On pasture	Unwashed	4 250
	Washed	3 530

To minimise contamination from external sources, it is essential to wash the teats thoroughly before milking starts. It is also important to dry teats using a disposable paper towel before attaching the milking clusters.

3.2 Aerial contamination

The number of organisms contaminating milk from the air is normally not high. Bacterial counts on air in milking-sheds should not exceed 200 bacteria per litre. Under normal conditions the levels of contamination from this source are negligible in comparison to that derived from teats, utensils, and surfaces.

Because of the severe conditions existing in the atmosphere, most of the organisms coming from this source are comparatively resistant. They are often responsible for specific defects in milk and dairy products. For this reason, and because the number of micro-organisms in the air is largely dependent on the dust load, pollution of the air with dust, especially immediately before milking, should be kept to a minimum.

Examples:
- *Bacillus cereus* – bitty cream, and
- *Bacillus subtilis* – sweet curdling.

3.3 Water supplies

Water used in the process of milk production should be of bacteriologically potable quality. Using water with a high bacterial load for washing would increase the bacterial count of milk through contamination. Water from storage tanks, boreholes, wells and dams, inadequately protected from rodents, birds and dust, may be contaminated with bacteria from faecal origin. This type of contamination may not only increase the total bacterial count of the milk, but may also be harmful and even pathogenic. Examples of such pathogens include the following:

- *Eschericia coli,*
- *Pseudomonas,*
- *Faecal streptococci,* and
- *Bacillus* spores.

When water quality is under suspicion, it would be a good practice to delay chemical disinfection of milking equipment until just before the next milking and to merely drain the disinfectant solution from the equipment before milking.

Chlorination, by dosing with hypochlorite, is a common practice to improve the bacteriological quality of water. Chlorinated rinsing water should contain between 1 to 3 parts of active chlorine per million parts of water.

3.4 Milking equipment as a source of bacterial contamination

Inadequately cleansed and disinfected milk contact surfaces are major sources of bacterial contamination of milk. During the usual cleaning process, it is impossible to eliminate all the bacteria on these surfaces. A survey of 350 milking machines showed that in 91% of cases, the total bacterial count on milk contact surfaces was higher than 100 bacteria per cm^2. For smooth surfaces, such as glass and stainless steel, which are relatively easy to clean, bacterial counts less than 5 bacteria per cm^2 would be satisfactory. On more porous or coarser surfaces, such as rubber, equipment in poor physical condition, or where milkstone layers occur, the bacterial count may run into many thousands per cm^2.

The number of bacteria occurring on milk contact surfaces depends, amongst others, on the following factors:

- **The effectiveness of the washing process:** When milk residues, such as fat, protein and minerals, are not completely removed during the washing process, the following may result:

  - large numbers of bacteria surviving in the residues, and
  - protein residues, especially, reacting with sanitising agents, such as chlorine, decreasing the effectiveness of the latter.

  Milking equipment should be washed shortly after being used. When milk residues are allowed to dry on contact surfaces, a film, i.e. milkstone, forms. Milkstone consists of protein and milk salts. It is a hard film and difficult to wash off. Milkstone may also form when milk is rinsed from utensils by very hot water.

- **The condition of utensils used:** Corroded or roughened surfaces, milkstone deposits, open seams, etc. not only increase the surface on which bacteria can settle, but also impede effective washing of utensils. Rubber, having an absorbent surface that may become very porous due to maltreatment and corrosion, may, for this reason, be a major source of bacterial contamination. In a study on farms producing milk of unsatisfactory bacteriological quality, it was found that the rubber-ware of the milking machines added 10 to 120 times the number of contaminants normally contributed by the metal and glass parts.

- **Time and conditions under which utensils are stored:** Bacterial growth is largely dependent on temperature and moisture. When utensils are stored under humid conditions, or not properly drained after cleaning, the bacteria that survived the cleaning process may multiply rapidly to large numbers in the interval between milking sessions.

- **Sanitation of utensils immediately prior to use:** The bacteria that survive the initial cleaning process may multiply considerably in the interval between milking sessions. To limit contamination from this source, it is advisable to rinse, immediately prior to use, all milk contact surfaces with a sanitiser. Such sanitisers may be a chlorine solution containing 100 to 150 ppm available chlorine.

  Even by rinsing utensils with clean water, depending on the vigorousness of the rinse, 50% and more of the bacteria may be removed from the utensils.

- **Construction of utensils** Milking equipment is seldom uniformly contaminated. Bacteria and residues accumulate in difficult-to-clean areas and in parts of badly designed components. In any specific milking installation, these problem areas should be identified, regularly inspected, and, if necessary, routinely cleaned by hand. A few examples of trouble areas include the following:

- all rubber to metal connections,
- sample cocks at measuring jar outlets,
- dead-ends in pipes,
- vacuum to milk line connections,
- bulk tank outlet taps, and
- rubber seals such as between lids of containers such as on some measuring jars and milking machine buckets.

3.5 The vacuum line as a source of contamination

In some milking systems, vacuum lines, which are not cleaned during the normal circulation of detergents, open together with milk lines into the same receptacle, for example:

- where the vacuum line, as such or through a pulsator, enters the bucket of a milking system, and
- in most releasers.

Milk residues may enter the vacuum lines through overfilling of containers, cracked inflations, or due to evaporation of warm milk under vacuum and condensation of the moisture in the vacuum system. Bacteria multiplying in these residues may constitute a major source of contamination and for this reason, the vacuum system should be cleaned on a routine basis or whenever milk was sucked into the system.

Table 51.2. The relative importance of the different sources of contamination

Source of contamination	Contribution to bacterial count/mℓ of bulk milk
Internal healthy udder	300 to 4 000
Mastitic udder	Up to 25 000 and more
External udder	500 to 15 000
Air (hand-milking)	100 to 1 500
Milking equipment	Up to 500 000

4. The washing and cleaning of milk utensils

4.1 Types of cleaning agents available

Different types of compounds are formulated to serve a specific purpose in the cleaning process. The best known cleaners available to the dairy industry are:

4.1.1 Detergents

Detergents are formulated to remove organic residues, such as milk fat, protein and mineral deposits. These compounds as such usually have very little, if any, bacterial influence.

Two main types of detergents are available.

4.1.1.1 Alkaline detergents

Alkaline detergents are the oldest and most commonly used dairy cleaner. Normally, they are mixtures of inorganic alkalines, such as:

Sodium carbonate	- Na_2CO_3
Sodium bicarbonate	- $NaHCO_3$
Sodium phosphate	- $Na_3PO_4.12H_20$
Sodium hydroxide	- NaOH

Formulations to improve detergency may include additives, such as wetting agents, water softeners and chlorine. Chlorine is included at a concentration of about 100 ppm available chlorine to assist in the removal of proteins. Due to the low concentration of chlorine, the presence of milk solids, and the high pH of the solution, the bactericidal effect of chlorine may be questionable.

Advantages:
- Dissolves both fat and protein.
- Relatively low corrosiveness.

Disadvantages:
- The continual use of alkaline detergents, especially when used together with hard water, tends to cause a build-up of mineral layers (milkstone). To prevent this, it is advisable to alternatively use an acid detergent once a week.
- Corrosive on aluminum.

4.1.1.2 Acid detergents

Acid detergents usually contain nitric, phosphoric, or sulphamic acid. Their principal function, in a balanced cleaning programme, is to prevent the accumulation of mineral deposits (milkstone).

Advantages:
- Remove or prevent the formation of organic layers.

Disadvantages:
- Acid detergents have little effect on fat and protein containing organic residues.
- Normally more corrosive than alkaline detergents.

4.1.2 Sanitisers

The purpose of sanitisers is to destroy micro-organisms. The best sanitisers used in the dairy industry include the following:

4.1.2.1 Chlorine

Active chlorine, especially in a slightly acid medium, is an effective sanitiser. A disadvantage is that it is readily inactivated by organic material, such as fat and protein, and is usually unstable above about 50°C.

When sodium hypochlorite as such is to be used as a sanitiser, it is recommended that the solution temperature should not exceed 50°C and that the concentration should be between 150 to 200 ppm, with the contact time being about 5 to 10 minutes.

4.1.2.2 Iodine

Active iodine solutions are excellent sanitisers, relatively stable in storage and in the presence of organic material. The brown colour serves as an indication of solution strength and the low pH prevents the formation of inorganic layers.

Due to its volatility, the temperature of working solutions should not exceed 50°C.

4.1.2.3 Quaternary ammonium compounds (QAC's)

These agents are very stable during storage at high temperatures. They are also effective against many types of organisms, non-odorous and non-colouring. Their rinse ability is usually relatively low, which is a decisive disadvantage.

4.1.2.4 Hydrogen peroxide acetic acid

This type of sanitiser has been available since the 1980's. Bacterial activity is dependent on the presence of peroxi acetic acid and hydrogen peroxide. Characteristics are:

- effective at room (low) temperature (high temperatures will result in the breaking up of the active chemicals and should be avoided),
- kills a broad spectrum of microbes,
- has a fast action,
- effective at a low concentration (0.25 to 0.40%),
- residues, viz. water, oxygen and acetic acid, are non-toxic and do not cause off-flavours in milk,
- long acting, for example, up to 8 hours, and
- at recommended concentrations, it is not corrosive on stainless steel, tin-coated surfaces or aluminium, but may corrode rubber.

4.1.3 Detergent-sanitisers

Detergent-sanitisers are compounds containing both detergents and sanitisers. The advantage of such a compound is that the cleaning operation is simplified. The disadvantage is that the effectiveness of the sanitiser being applied in the presence of milk residues is usually impaired.

Examples of this type of compound are:
- Chlorine containing alkaline detergents. In this case the chlorine content of the working solution is about 200 ppm.
- Iodofors. Iodine together with a wetting agent. Iodofors usually contain phosphoric acid.
- Quaternary ammonium compounds are in themselves good wetting agents and therefore have a built-in detergency.

Cleansing agents, especially alkaline detergents, are available in powdered, as well as in liquid form. Foaming and non-foaming formulations are also available for manual and circulation cleaning respectively.

5. Cleaning procedures

The cleaning process has as purpose:
- to remove organic and inorganic residues, and
- to destroy as many of the remaining bacteria as practically as possible.

5.1 Five-stage system

The traditional procedure for the cleaning of the dairy utensils, both in manual or circulation-in-place (CIP) systems, consists of the following five stages:

- **Pre-rinse**
  The function of the pre-rinse, which is done with water at a temperature not exceeding 45°C, is to remove as much of the milk residues as possible. In CIP systems, rinsing water is not circulated but run to waste until free of milkiness.

To prevent the formation of a film of milk solids which, at a later stage, will be difficult to remove, pre-rinsing should be done as soon as possible after utensils have been used. Hot water is not recommended for pre-rinsing as it encourages the formation of milkstone.

- **Wash**
  The purpose of the washing process is to remove all remaining residues. Wash with a hot (60 to 80°C) alkaline detergent solution. Solution strength is usually about 0.5% and the minimum circulation time in CIP systems, about 10 minutes. For manual washing, the temperature should be above 40°C. To prevent the build-up of milkstone, the alkaline detergent has to be alternated, say once a week, with an acid detergent.

- **Intermediate rinse**
  Clean water is used to remove the soiled detergent wash. The rinsing allows the sanitiser to act on surfaces free of organic residues.

- **Sanitising**
  Circulate a sanitiser solution containing, for example 150 to 200 ppm active chlorine, for at least 5 minutes.

  By separating the cleaning and sanitising processes, the sanitiser can be used at its optimum pH for a minimum contact time and at a lower concentration. This reduces the risk of corrosion, as well as costs.

- **Final rinse**
  The last step in the cleaning process is to get rid of the residues of cleaning compounds, which may tint the milk or corrode the utensils. Water of good bacteriological quality, such as chlorinated water containting 1 to 3 ppm chlorine, is used for the final rinsing.

Alternative
Instead of sanitising immediately after washing, the sanitiser may also be applied just before the utensils are used. This assures a low number of bacteria on the equipment and prevents the corrosion of stainless steel, which can occur if certain sanitisers are in contact with the metal for a long period of time.

5.2 Three-stage system

By developing detergent-sanitisers, it became possible to combine the cleaning and sterilising processes. This has led to the well-known three stage method, which consists of the following stages:

- pre-rinse,
- circulate hot detergent-sanitiser solution, and
- final rinse.

In both the 3- and 5-stage cleaning procedures, an acid detergent, at about one tenth of the normal concentration, can be used to acidify the final rinsing water. By reducing the pH of the rinsing water to less than 4.5, the build-up of milkstone and the multiplication of bacteria is largely prevented.

5.3 Acidified boiling water (ABW) system

This system was developed for the cleaning of pipeline milking machines and consists of only two stages:

- pre-rinse to remove milk residues, and
- the flushing of the pipelines with water, at a temperature of 90°C or higher, which contains about 0.5% sulphamic or nitric acid.

This method of cleaning can be very effective, but requires considerable supervision. All inner plant surfaces must come in contact with the diluted acid and a temperature of at least 77°C must be maintained within the cleaning circuit for at least 2 minutes. Examples of cleaning programmes for milking machines are presented in Table 51.3.

Table 51.3. Examples of cleaning programmes for milking machines

Actions	Programmes			
	1	2	3	4
1. Pre-rinse with water at ≤ 40 °C	Yes	Yes	Yes	Yes
2. Wash with ± 0.5% warm (60 - 80 °C) alkaline detergent	Yes	Yes	Yes	-
3. Rinse with water	Yes	Yes	Yes	-
4. Sanitize with 150 ppm chlorine, 25 ppm iodine or 0.25% H_2O_2/Hac, preferably before being used	Yes	-	Yes	-
5. Rinse with clean water	Yes	-	-	-
6. Rinse with ± 0.15% acidified water with a pH of < 4.5		Yes	-	-
7. Periodically remove milkstone with 0.3 to 1% acid detergent	Yes	-	-	-
8. Wash without circulation using 0.55% acidified water at ≥ 90 °C	-	-		Yes

5.4 Cleaning of bulk tank

When the bulk tank is not cleaned by means of a CIP system, the following procedure is recommended:

- Rinse with tap water.
- Prepare, in a plastic bucket, a chlorinated, foaming alkaline detergent at 7 - 10 times the normal strength. Close tank outlet, place bucket containing the detergent inside the tank and thoroughly brush all inside surfaces from the bucket. Let detergent flow from the tank to the bucket. Dismantle outlet tap and wash brush in the bucket. Use detergent from bucket to wash the outside of the tank.
- Rinse inside and outside with tap water.
- Rinse inside with acidified water (acid detergent) at about 10% normal concentration.
- Sanitise before use.

5.5 Cleaning the vacuum line

- Draw hot alkaline detergent through each stall cock into the vacuum line. Start at the cock nearest the vacuum pump. Do not draw more solution into the system than the moisture trap can hold.
- Drain detergent from moisture trap.
- Repeat with hot acid detergent, starting at the cock farthest from the pump. Drain trap.
- Rinse with clean water, starting at the cock farthest from the pump. Drain trap.
- Open all stall cocks and run the pump to dry the vacuum line.

6. Factors affecting the success of a cleaning programme

The following factors have a decisive effect on the effectiveness of a cleaning programme.

6.1 Quality of the water

The most important characteristics that determine the quality of the water are the hardness, the bacteriological quality, and the iron and manganese content.

Water hardness is measured by the content of calcium carbonate equivalent in mg/litre (Table 51.4).

Table 51.4. Classification of water hardness

Hardness	$CaCO_3$ equivalent mg/ℓ of water
Soft	0 to 60
Moderate	60 to 120
Hard	120 to 180
Very hard	Over 180

The water softening ability of well-formulated detergents is usually sufficient for moderately hard water. If the hardness is more than 150 mg/ℓ, it is recommended that the detergent concentration should be increased by 10% for each increase of about 50 mg $CaCO_3$/ℓ. For very hard water, special formulations may be required.

Iron and manganese present in concentrations of 0.1 ppm or higher, may, especially in the presence of alkaline detergents, be responsible for a build-up of brown-red or black layers. To prevent this build-up, acid detergents should be used more often in the cleaning programme.

When the water used for the washing of udders or the rinsing of the milking utensils contains large numbers of bacteria, it will have a detrimental effect on the quality of the milk. Water of good bacteriological quality should comply with the standards indicated in Table 51.5.

Table 51.5. The bacteriological standards for water used for washing of udders and rinsing of milking utensils

Criterium	Standard
Total viable count 21 °C/72 h	< 500/mℓ
Total viable count 37 °C/72 h	< 50/mℓ
Coliforms	< 50/100mℓ
E.coli	Negative/100mℓ

6.2 Choice of cleaning compounds and procedure

Cleaning compounds are formulated for a specific purpose (see 4.1) and should be applied accordingly in an effective programme (see 5).

6.3 Concentration of the cleaning compound

Both economy and the effectiveness of the compound are influenced by its concentration. The recommended concentration is usually the optimum and should be adhered to. Cleaning agents, especially those containing chlorine, may lose strength during the storage; therefore, it is important to limit the storage time while keeping containers well closed and in a dry area.

When the water is very hard or the temperature is low, then the concentration of the detergent should be increased.

6.4 Temperature of detergents

The effectiveness (detergency) of any detergent is largely dependent on the temperature of the washing water. Usually, the detergency of washing water is better when the temperature of the water is higher. For circulation cleaning of milking machines, the initial temperature of the detergent should be about 75 to 80°C (Table 51.6). At the end of the circulation time, it should preferably not be below 45°C.

Table 51.6. The total viable count on milking machine rinsings

Initial temperature of detergent (°C)	Distribution of bacteria/0.1m² (%)	
	Less than 10 000	More than 50 000
82	50.2	23.7
45 to 60	20.0	67.8
45	14.3	73.9

6.5 Volume of detergent and circulation speed

The volume must be sufficient to wet all milk contact surfaces. For milking machines with weighing bottles, approximately 8 to 14 litres of solution is required per milking point.

For the thorough removal of residues, a flow speed of not less than 3.5 litres/minute/milk point must be maintained.

6.6 Circulation time

Due to the decrease in solution temperature, an extended circulation time may be counter-productive. Circulation for 10 to 15 minutes should be sufficient. The temperature at the end of the washing cycle should preferably not be less than 45°C.

6.7 Supervision

An important reason why cleaning programmes fail is because of the lack of supervision. If the operator adheres to the abovementioned details, success, even using a simple procedure, is obtainable.

7. Cooling and milk quality

The bacteria present in milk at the end of the milking process multiply quickly during storage at room temperature. As the generation time of bacteria is strongly affected by temperature, prompt cooling to a low temperature delays the increase in the number of bacteria in milk. The effect of cooling is, however, dependent on:

- storage temperature,
- rate of cooling,
- storage time, and
- initial bacterial count.

7.1 Storage temperature and time

The generation time, i.e. the time necessary for a single bacterium to divide into two cells, is largely dependent on temperature. A generation time of 30 minutes at 35°C may for example increase to 11 hours at 5°C. The effect of storage temperature and time on bacterial counts on the bacterial count in milk is presented in Table 51.7.

Table 51.7. The increase of bacterial counts as affected by storage temperature and time

Storage temperature (°C)	Bacterial count after storage for days		
	0	2	3
5	160 000	430 000	3.1×10^5
7	160 000	3 400 000	19×10^6
10	160 000	69 000 000	230×10^6

7.2 Initial count

The generation time at a specific temperature is significantly affected by the initial bacterial count (Table 51.8). At a storage temperature of 5°C, the bacterial count of fresh milk may increase by 25% after 24h, however, when the bacterial count in fresh milk is higher, the increase in bacterial count is much higher, e.g. 180%. At a higher storage temperature, the increase in bacterial count is even higher, e.g. 250 and 780%. These increases in bacterial count in milk would have a major effect on the quality of milk following its initial bacterial count and storage temperature.

Table 51.8. The rate of bacterial growth during storage as affected by initial count

Storage temperature (°C)	Bacterial count		Increase %
	Fresh	After 24 h	
5	4 000	5 000	25
	136 000	381 000	180
10	4 000	14 000	250
	136 000	1.2×10^6	780

In closing

Milk, being a food source, is a ideal medium for the growth of micro-organisms. It naturally contains a broad spectrum of such organisms which multiply under specific environmental conditions. Milk contains acid-producing bacteria which naturally ferments lactose in milk to lactic acid increasing the acidity levels in milk as indicated by a decrease in the pH level of milk. At a pH below 5.2, the casein component in milk coagulates and milk thickens. Mastitis is a major problem in dairy cows as mastitic milk contains large numbers of different bacteria which reduces the feeding value of milk. During milking, or milk harvesting, bacteria from the external part of the udder, environment, and milking utensils gain entry into the milk. Therefore, the milking process, the operation and maintenance of the milking machine as well as the environment cows are housed, have a major effect on the occurrence of mastitis in cows and the quality of milk.

CHAPTER 52

MASTITIS AND MILK QUALITY

Introduction

The quality of milk is described by the solids content consisting of fat, protein and lactose percentages, as well as the somatic cell count (SCC) in milk. The SCC of milk refers to the number of white blood cells and the number of epithelial cells in milk, usually per mℓ of milk. The SCC is used as an indication of the level of infection in the udder and is regarded as an indirect way of describing the level of mastitis in milk. When an infection occurs in the udder, the body produces a large number of white blood cells to resist the infection. Because of the increasing number of white blood cells, especially neutrophils, the SCC count in milk increases above the standard level in milk. Udder infection or mastitis is the single most important reason for an increasing number of white blood cells. For this reason, an increase in the SCC of milk is the most reliable and practical way to identify sub-clinical mastitis in the udder of dairy cows.

The SCC in milk from a healthy udder is usually below 200 000 per mℓ of milk. A positive indication of udder infection (mastitis) is usually when the SCC in milk has increased to about 400 000 per mℓ of milk. As mastitis may occur in only one of the four quarters, the SCC of a single milk sample from all quarters must be evaluated carefully, especially when setting threshold values for SCC (Table 52.1).

Table 52.1. The percentage correct and incorrect mastitis classifications when using different mathematical estimations of threshold values for somatic cell count (SCC) for individual cows

Threshold value (SCC/mℓ of milk)	Classification (%)		
	Correct	False negative	False positive
100 000	44	0.3	55.9
200 000	69	2.0	29.1
300 000	78	5.1	16.9
400 000	84	9.1	6.8

In dairy herds already applying the correct mastitis control measures, individual cow SCC may be used as an additional source of information with regards to the mastitis status of the herd. Possible advantages emanating from regular testing for mastitis may be as follows:

- An indication of the number of cows to be culled because of chronic infections not responding to the treatment of mastitis.
- An indication of early drying-off cows with the aim of treating an infected quarter while the cow is dry.
- An early indication of infections which may then be treated or to conduct bacteriological culturing towards identifying specific bacteria that may respond differently to treatment.
- By grouping records according to lactation stage, age of cows, etc. valuable deductions could be made regarding the following:
  1. The number of mastitis cases in the herd,
  2. The number of mastitis cases among first lactation cows,
  3. The lactation stage when udder infections occur, and
  4. The effect of herd management on the incidence of mastitis.

When individual SCC numbers are being used to determine when and which cows to cull, dry off, and to treat cows, this may result in preventive measures being disregarded. This may result in an increase in the number of mastitis cases in the herd. The axiom ‘prevention is better than cure’ applies especially with regards to mastitis management.

Herd somatic cell count (HSCC)

Herd SCC is generally used as a suitable indicator of the udder health in a dairy herd (Table 52.2).

Table 52.2. The relationship between herd somatic cell count and level of mastitis

Herd somatic cell count	Level of mastitis	Mastitis infected quarters in the herd (%)
Less than 250 000	Good	None
250 001 - 500 000	Acceptable	<20
500 001- 750 000	Dangerous	21 - 40
More than 750 001	Herd problems	40 +

It must be kept in mind that a high HSCC may be the result of high proportion of subclinical mastitis cases (infected quarters) or a smaller proportion of clinical cases of mastitis. With regards to clinical cases, the SCC in individual quarters may be higher than 10 million per mℓ of milk. In a small herd, a single or a few cases of clinical mastitis may affect the herd SCC very strongly.

The HSCC of milk samples collected monthly from about 1650 dairy farmers in the Western Cape during a 12-month period is presented in Table 52.3.

Table 52.3. The distribution of herd somatic cell counts (HSCC) for dairy farmers in the Western Cape over a 12-month period

HSCC (x 1000/mℓ milk)	Proportion of milk samples (%)
< 99	2.2
100 – 199	12.7
200 – 299	20.1
300 – 399	18.2
400 – 499	13.8
500 – 699	16.5
700 – 999	10.4
> 1000	6.1

Economic implications of a high herd somatic cell counts

It is well-known that mastitis not only affects the appearance and composition of milk, it also results in a reduction in milk yield. Although the reduction in milk yield may not always be noticeable, it may be responsible for up to 80% of the total cost of mastitis. The relationship between HSCC and a reduction in milk yield varies among studies. A realistic relationship between HSCC, the percentage milk yield loss, the amount of milk and potential income lost annually is presented in Table 52.4.

Table 52.4. Milk and financial losses because of mastitis as reflected by herd somatic cell counts (HSCC)

HSCC	Milk yield loss (%)	Monthly loss depending on daily milk yield		
		600 ℓ	**1 000 ℓ**	**2 000 ℓ**
250 000	3	540 ℓ	910 ℓ	1825 ℓ
		R326	R728	R1 460
500 000	6	1 095 ℓ	1 825 ℓ	3 650 ℓ
		R876	R1 460	R2 920
1 000 000	10	1 825 ℓ	3 040 ℓ	6 080 ℓ
		R1 460	R2 433	R4 866

Based on another study, the following equation was developed to estimate the reduction in milk yield because of mastitis:

Milk yield loss (%) = 2.39 + 0.01(HSCC/1000)

This means that for herd somatic cell counts of 250 000, 500 000 and 1 000 000, milk yield losses are estimated to be 4.9, 7.4 and 12.4%, respectively.

Mastitis in dairy cows also affects milking parlour management. Infected cows have to be milked separately, while the milk from cows under treatment has to be discarded so as to not contaminate milk to be collected by the dairy processors. Furthermore, mastitis also affects the composition of milk (Table 52.5).

Table 52.5. The effect of mastitis on milk composition

Milk component	Effect	Composition (%)	
		Normal milk	Mastitis milk
Fat percentage	Reduction	3.8	3.6
Protein percentage	Small reduction	3.6	3.5
Casein percentage	Reduction	2.8	2.3
Whey protein percentage	Increase	0.8	1.2
Lactose percentage	Reduction	4.9	4.4
Na^+	Increase	0.05	0.08
Cl^{--}	Increase	0.10	0.18
Ca^{++}	Reduction	0.13	0.09

Some of the changes in the chemical composition of milk, as indicated in Table 52.5, reduce the quality of dairy products that are produced from mastitic milk. Examples include a reduction in the curdling of milk and cheese, milk powder dissolving poorly, and sedimentation occurring in ultra-high temperature (UHT) milk.

Mastitis prevention

A strategy to reduce the incidence of mastitis in a dairy herd should include the following principles:

1. Treating infected quarters; although this is part of the mastitis prevention strategy, it only treats the symptoms, and not the causes, of mastitis.
2. The prevention of mastitis does not rely on some superior medicine and quick fixes, but largely on a continuing evaluation and adaptation of mastitis control measures.
3. A case of mastitis can only occur after a pathogen has entered the udder through the teat opening. The aim of mastitis management should be to reduce the possibility of such an event. For this reason, injuries to the teat opening should be prevented, while the exposure of the teat opening to pathogens should be reduced.
4. Aiming to maintain a realistic standard of mastitis infection in the herd should be part of a mastitis control system. Examples of such a goal should include the following:
   - A mean monthly HSCC of less than 300 000 per mℓ of milk.
   - A maximum of 35 clinical infected quarters per 100 cows per year, (35/(100*4)) = 8.75%.
   - 90% of cows should have SCC less than 400 000 per mℓ of milk.

A mastitis control programme should include the following principles:

1. A correct milking procedure, e.g.:

- Not wetting the udder excessively,
- Drying teats and udder properly,
- Ensuring that a proper milk let-down process occurs,
- Test regularly for mastitis before milking by using the strip cup,
- Keeping record of positive quarters (mastitis can be transferred by milkers by hand between cows),
- Attach milking clusters correctly, not too soon or too long after stimulation,
- Prevent over-milking in cows,
- Rinse milking clusters between successive cows,
- Milk cows with infected quarters at the end of the milking process, which is especially important for *Staphylococcus areus* and *Streptococcus agalactiae* infections, and
- Applying teat dip after milking.

2. A correct milk machine operation, sanitising and maintenance, e.g.:

- Prevent air leakages between teat and milk cluster during the milking process,
- Cut vacuum before attempting to remove the cluster unit from the udder,
- Efficient milking machine functioning involves the following:
  - Regular servicing and testing of the milking machine,
  - Maintaining the correct vacuum levels (50 kPa),
  - Maintaining a stable vacuum level in the cluster which depends on sufficient vacuum reserve levels (100 + 25 x n) where n = <10, sufficient capacity of the cluster, air flow holes in the milking cluster are open, a short milking tube between cluster and milk line (not longer than 1.5 m), and low milk lines.
- A correct pulsation rate (60 ± 5 per min), and
- The correct pulsation ratio (D-value = >15%).

3. Acceptable treatment strategies:

- Establish a strategy with regards to the treatment of mastitis cases during the lactation period and at the end of the lactation period, at drying off. Dry cow treatment should either be for all cows or only for specific cows. The correct treatment of mastitis in lactating cows involves treating cows early using a suitable antibiotic while maintaining the treatment until the infection is cleared up.
- Using a specific antibiotic treatment should be motivated.
- Keep records of treatments and the success rate of treatment.
- Were possible, bacteriological culturing should be done to identify bacteria for a specific treatment.
- Keeping a realistic cull rate of cows suffering from recurring incidences of mastitis.

4. Managing the environment:

Provide a friendly, hygienic and dry environment for cows in the herd. This specifically refers to:

- Calving down areas,
- Holding areas before and after milking,
- Passage ways at feeding troughs and lanes to and from the milking parlour,
- Avoid wet, saturated pastures, provide good drainage,
- Provide correctly designed and built free stalls for cows to lie down in housing systems. This specifically refers to the length, width of free stalls, free stall surfaces areas (avoid using saw dust as bedding), well ventilated buildings and high roofs to reduce heat stress,
- Control flies by removing manure and keeping soil surfaces dry,
- Provide hygienic and a dry area for dry cows, and
- Maintain a correct feeding programme with regards to minerals and vitamins, specifically shortages in selenium and vitamin E may have a negative effect on udder health.

Know the enemy

Knowing the specific pathogen causing mastitis in dairy herd may go a long way in reducing the herd somatic cell count. For this reason, it is important that mastitic milk should be regularly cultured to identify pathogen causing mastitis. A sterile milk sample from an infected quarter should be collected for culturing at a suitable facility for identifying specific bacteria. A summary of the most important mastitis-causing bacteria is presented in Table 52.6.

Table 52.6. The most important mastitis causing bacteria affecting dairy cows

Pathogens	Source of contamination	Control measures
1. Pathogens transferred during milking		
Staphylococcus areus	• Infected quarters • Open wounds on teats • Damaged teat openings • Skin of the teats and the udder	• Maintain a functional milking machine • Prevent injuries to teats and cross contamination • Maintain a high milking parlour hygiene • Apply teat dip after milking • Apply a correct dry cow treatment • Cull chronic cases of *S. areus* infection • Treatment during the lactation period is often unsuccessful (less than 40%)
Streptococcus agalactiae	• Infected quarter	• Maintain a functional milking machine • Prevent cross contamination • Maintain a high milking parlour hygiene • Apply teat dip after milking • Apply a correct dry cow treatment • May be successfully treated during the lactation period (> 75%)
2. Pathogens from the environment		
Streptococcus uberis	Occur on a wide spread basis e.g. • in the housing environment, • on the skin surface of cows, • infected quarters, wet udders and • teat washing cloths	• Maintain a high milking parlour hygiene • Wash and dry teats before milking • Provide a clean and dry housing environment • Consider applying a pre-milking teat dip • Treatment during the lactation period and the dry period is often successful
Different coli-form bacteria such as: ***Escherichia coli*** ***Klebsiella spp.*** ***Enterobacter spp.***	• Manure, • Dirty, wet and muddy soil surfaces • Infected water • Dirty milking equipment • Bedding material such as saw dust	• Provide a clean and dry housing environment • Maintain a high standard of hygiene in free stalls • Keep teats and the udder dry and clean • Apply a dry cow treatment • A post-milking teat dip is not very efficient for these pathogens

It is well known that a wide range of factors, separately and complementary, may contribute to the occurrence of mastitis in a dairy herd. Because of the relative importance of the individual factors that may differ between herds, each factor's contribution is difficult to quantify. The following summary (Table 52.7) provides an indication of the most probable effect of some of the factors causing new cases of mastitis.

Table 52.7. The most probale effect of different factors on mastitis

Factors	Most probable effect on mastitis
Teat dip	50 – 70% less
Milking cluster	About 20% less
Screens in short milking tube	About 15% less
Clusters slipping off	Significantly more
Changes in vacuum during milking	Little to significantly more
High vacuum levels	Mostly more
Rinsing of clusters between cows	Relative little value
Incorrect pulsation	Increases
Incorrect cluster removal	Increases
Over-milking	Uncertain to probably
Incomplete milking	Varying response
Separating infected cows	Result in fewer cases
Pre-milk teat dipping	No to little effect

From this it seems that some factors require more emphasis than others, e.g. teat dipping after milking is more important than pre-milking. Similarly rinsing clusters between cows seem to have relative value as the water quality may be questionable. High vacuum levels mostly increase the probability of mastitis.

In closing

The fat, protein and lactose contents as well as the SCC of milk indicate the quality of milk. The SCC is used as an indication of the number of white blood cells and epithelial cells in milk which is an indirect indication of the mastitis infection in milk. This is because when some infection occurs in the alveoli, the body produces white blood cells to combat the infection. Increasing the number of white blood cells causes the SCC count in milk to increase above the standard level in milk. Udder infection or mastitis is the single most important reason for an increasing number of white blood cells. For this reason, an increase in the SCC of milk is the most reliable and practical way to identify sub-clinical mastitis in the udder of dairy cows. A wide range of factors, separately and complementary, contribute to the amount of mastitis cases in a dairy herd. The relative importance of individual factors differs between herds. Factors affecting mastitis include the following: a correct milking procedure, a correct milking machine operation using correct sanitising and maintenance procedures, correct treatment strategies and providing a clean and hygienic environment for cows.

CHAPTER 53

MILKING PARLOURS FOR MODERN DAIRIES

Introduction

Like most businesses, dairy farming has to be profitable. Part of the financial success is the consumer demand for the dairy farm's products, namely, milk and beef. Dairy farms require a large capital outlay which consists mostly of cows, feeds, heavy equipment like tractors, trucks, feed mixing equipment, and various buildings. This includes the milking machine, bulk tanks, milking parlour and associated structures, such as holding areas, feeding silos, crushes, a scale for weighing cows, etc. Cows are usually milked at least twice a day for every day of the year. As the labour input of milking cows is a major factor, it is of utmost importance that the milking parlour is suitable for the operation. This is mainly determined by the number of cows being milked every day. Milking cows must be an easy operation as this is mostly reliant on people doing the physical work. The labour force milking cows each day has a major effect on the quality of milk recovered from cows before being processed, as well as the survival or longevity of cows.

This is why it is important that the harvesting of milk, being the most important income on a dairy farm, is done professionally and correctly. This must be done with the greatest care without affecting the welfare of cows, as this may have a large negative effect on their longevity and the eventual financial sustainability of the farm. The genetic level of the herd and the quality of feed being used on a daily basis are important factors affecting the total milk output of the herd. However, the milking process is a major factor in extracting the milk from cows, as this is the major product that is produced on a dairy farm.

A milking parlour on a dairy farm is a specialised building, or section of a building, designed to milk cows and handle milk. The milking parlour must be designed, constructed and managed with the goal of providing a safe and enabling environment for cows and workers. The milking system and its operation must ensure a continuous daily collection and storage of high quality milk. A well-designed milking centre should allow cows, milk, and waste water to be handled effectively and efficiently. Decisions concerning the milking centre are some of the most complicated decisions a dairy farmer has to make. Milking procedures, herd size, expansion plans, milking interval, and the equity position of a producer influence these decisions. One specific milking parlour would not meet the requirements of all dairy farmers.

Past milking systems

Looking at the world production and herd size figures, one can see that average herd size has increased dramatically, with the number of dairy farms decreasing in proportion. In South Africa, the average herd size, in the late 1990s, was 90 lactating cows. Currently, this figure is estimated to be about 130 to 200 lactating cows with the number of large herds (in excess of 500 cows) increasing. This means that the management on dairy farms is getting more and more important, and many crucial decisions have to be made every day on the farm.

Which milking system to use?

Dairy farmers wishing to upgrade existing milking parlours should consider the following factors before selecting a specific system. These factors also apply to new farmers wanting to start up a dairy. Factors to take in account include the following:

1. How many cows are to be milked daily in the milking parlour?
2. Which milking procedure will be used (minimal or full)?
3. If a full milking routine is to be used, how much contact time is required (strips per teat)?
4. Which milking routine is to be used (sequential, grouping or territorial)?
5. Would the milking parlour accommodate expansion in the future?
6. Are there major structural changes to be made to the existing parlour, or is a completely new building the preferred option?
7. Which feeding system is being used, e.g.

pasture-based, total mixed ration (TMR) or mixed system.
8. Are the facilities around the parlour, like holding yards, races, and pens, adequate for the changes, especially when an expansion of the herd is envisaged?
9. Is in-parlour concentrate feeding being considered?
10. What level of automation is required in (and outside) the parlour?
11. Is milk recording to be conducted, i.e. using approved milk meters?
12. What is the maximum milking time per day available?

Options for milking procedures and routines in parallel and herringbone parlours

It is essential that dairy producers develop accurate time budgets for the milking procedures and routines they select. Before the options for milking procedures and routines can be discussed, the following terms must be defined:

- Prep time - time taken to manually clean (wash using running water) and dry teats and udder.
- Contact time - the actual time spent washing and drying teats also stimulating for the release of oxytocin to enable milk let-down.
- Prep-lag time – the time between the start of teat preparation to the application of the milking clusters.
- Milking procedures - the individual events (i.e. strip, pre-dip, wipe, attach) required to milk a single cow.
- Milking routines - defines how an individual milker or a group of milkers carry out a given milking procedure (minimal or full) over multiple cows.

The actual time required for individual events during the milking process is shown in Table 53.1.

Table 53.1. Time (seconds) required for individual events of the milking procedure

	Procedure		
Event	**Minimal***	**Full**	**Full with 10 sec contact time**
Strip (seconds)	4 - 6	4 - 6	10
Pre-dip (seconds)	-	6 - 8	6 - 8
Wipe (seconds)	6 - 8	6 - 8	6 - 8
Attach (seconds)	8 - 10	8 - 10	8 - 10
Total (seconds)	**12 - 18**	**24 - 32**	**30 - 36**

*Strip or wipe and attach

Some of the advantages and disadvantages of minimal and full milking procedures are listed below.

1. Advantages and disadvantages of a minimal milking routine

» Compromises teat skin sanitation.
» Successful when cows enter the milking parlour clean and dry.
» "Machine on-time" may be prolonged.
» Steady unit throughput is increased.
» Time required to milk the herd may be decreased (total milking time).
» May require milkers to decide when extra cleaning of dirty teats is required.
» Can cause lower milk quality and higher mastitis when compared to "full hygiene".

2. Advantages and disadvantages of a full milking procedure

» Maximises teat sanitation and milk let-down.
» Uses 4 separate procedures or can combine into two or three procedures.
» Use when maximum milk quality results are the goal.
» Minimises "machine on-time".
» Results in lower cow throughput or higher labour cost compared to "minimal" or "none".
» Requires milker training to maximise results.

Milking routines

Correct and proper managed routines in the parlour are of crucial importance. A proper routine is required to milk out cows completely. Anything outside the normal routine practice in the parlour adds to higher stress levels in cows, usually resulting in under-milking (not completely milked out) of cows. There are many negative factors that can disturb the daily routine, e.g.:

- Faulty settings of the milking machine, like the teat-end vacuum, or problems related to pulsation and vacuum levels,
- Abnormal noises,
- Change of milking times,
- Change in the handling of the cows prior to entering the parlour,
- Stray voltage (a cow reacts negatively to any stray voltage higher than 2 - 5 Volts), and
- Non-regular visitors in the parlour.

When a proper routine is followed and the stimulation of the cow's milk let-down hormone is done efficiently, it is expected to milk-out cows completely.

In parallel and herringbone parlours, there are three milking routines, namely, grouping, sequential, and territorial.

1. **Grouping milking routine -** In a grouping routine, the milker performs all the individual tasks of the milking procedure on 4 to 5 cows. Once these tasks have been completed for a group of cows, the milker then moves on to the next group of available cows.

2. **Sequential milking routine –** Milkers using a sequential routine split up the individual tasks of the milking procedure between milkers and work as a team. Milkers work as a team following each other, performing their individual tasks.

3. **Territorial milking routine -** Milkers are assigned a number of milking units (clusters) on both sides of the parlour and only operate the units assigned to them. When a territorial routine is used, milkers are not dependent on other milkers to perform specific tasks.

The standard milking procedures for the minimal system include stripping milk, wiping teats, and attaching clusters, while the full system include pre-dipping, stripping milk, wiping teats, and attaching clusters. Full milking procedures affect the number of cows per stall per hour in parallel, herringbone, and rotary parlours. In large parallel and herringbone parlours cows per stall per hour are 5.2 - 6.5 cows per unit per hour when minimal milking procedures are used and 4.4 - 6.0 cows per unit per hour when full milking procedures are used. These figures will, of course, be affected by the level of training and other management procedures to be followed by milkers. In rotary parlours, cows per stall per hour would mainly be determined by the rotation speed of the milking platform and the routine to be followed.

In large parallel and herringbone milking parlours, milking procedures have a large effect on the number of milking units one milker is able to handle. When a full milking procedure is used, a milker should be able to operate 10 units on one side and 17 units on another side when using minimal milking procedures. These recommendations are based on allowing 4 - 6 seconds to strip a cow and attaching all the units on one side of the parlour in 4 minutes. In recent years, several milking management specialists have been recommending stripping 2 - 3 squirts per teat (in 8 - 10 seconds) when stripping cows to increase stimulation and improve milk let-down.

The reason for this is that unit-on-time is reduced by increasing udder stimulation. The sequencing of the individual events of the milking procedure is critical. Research has shown that an ideal prep-lag time is 1 minute and 18 seconds. Prep-lag times of 1-1.5 minutes seem to be accepted as optimal for all stages of lactation. Producers will have to decide which milking procedure they will use and the amount of stimulation that is required.

Selecting parlour type

Dairy farmers usually have a personal preference for a certain parlour type. Often this personal preference conflicts with the number of cows to be milked, length of the milking shift, anticipated milk quality, udder health results, and financial resources. The selection of a milking parlour is affected by the initial herd size, expansion plans, economic impact on the dairy, and the ability to train and manage employees. Dairy producers should visit as many types of milking parlours as possible and make a final decision after having an opportunity to review all types, which may not necessarily be the fastest or latest milking machine and design.

Total hours of use

A milking parlour sized to be used for only 4 to 6 hours a day, will be more expensive to build and operate per cow than when the parlour operates 20 to 21 hours per day. For example, a 250 - cow dairy, milking twice a day could be milked in a double-4 herringbone parlour in a 6-hour shift, or milked in a double-10 herringbone in a 3-hour shift. Fewer hours of use may be desirable if farm personnel also have other duties, such as crop production, feeding, animal health, and raising replacements. However, a larger return on investment will be realised when the milking parlour can be used 20 to 21 hours a day to milk cows. Dairy farmers often have to make a choice between the number of cows that can be milked and which milking procedure they can use under these conditions. If not careful, milk quality and udder health may suffer with negative effects on milk yield.

Number of milkers

The number of milkers may be affected by the availability of personnel, milking procedure, or herd size. Most small herringbone and parallel milking parlours (double-4 to double-12) could be operated by 2 to 3 milkers for the bigger of the two milking parlours. One-person parlours are more efficient in the number of cows per labour hour. Two-or-more-operator parallel or herringbone parlours have the advantage of continuous operation, even during group change, when one operator is late for the milking shift, or when a short emergency requires one operator to leave the parlour. The disadvantage is that it is more difficult for the owner to assess operator performance or quality standards, and the number of cows per labour hour will be less. However, many producers are able to achieve the same labour efficiency in multiple operator parlours as single operator parlours with training and monitoring programmes.

Initial herd size and expansion plans

Dairy farmers should consider their current herd size along with plans to increase the herd size in the future. When a producer wants to grow the herd size in steps, parallel or herringbone parlours should be constructed to allow for expansion as the herd size increases. Parallel and herringbone parlours have an advantage over rotary parlours which cannot be expanded in steps.

One vs. two milking parlours (double pit parlours)

Some research has indicated that two smaller milking parlours are more efficient than one larger milking parlour. Building two separate parlours also allows producers to construct the dairy in phases, while increasing the number of groups of lactating cows.

Training and monitoring milkers

Providing training and monitoring milkers are constant challenges for dairy producers. In parallel and herringbone parlours with multiple milkers, to improve parlour performance, it becomes very important to train teams of milkers to work together. In parallel and herringbone parlours, operators are mobile and able to perform multiple tasks (e.g. stripping, pre-dipping, wiping teats, and attaching clusters) as compared to rotary parlours where operators are fixed in one location and can only perform one or two tasks at this location. To maximise the performance of multiple operator parallel and herringbone parlours, milkers have to work together to perform the milking procedures over multiple cows using a grouping or sequential milking routine. After milker training has been completed, the dairy farmer will have to monitor the performance of individual milkers and parlour performance.

Evaluating parlour performance

Milking parlour performance has been evaluated by time and motion studies to measure steady-state throughput (cows per hour). Steady-state throughput does not include time for cleaning the milking system, maintenance of equipment, effects of group changing, and milking the hospital strings. These studies also allow for the opportunity to determine the effect of different management variables on milking parlour performance. Historically, this information has been used to size milking parlours towards meeting the requirements for dairy farmers.

Sizing milking parlours

As dairy herds increase in sizes, the sizing of milking parlours becomes more complicated. Many dairy farmers choose to use a so-called hospital parlour (for cows under treatment for mastitis, etc.), thereby reducing the pressure of cow through-put in the main parlour. Some dairy farmers are also milking healthy cows in these hospital parlours to increase the number of cows to be milked. Some dairies are increasing the number of daily milkings from three to even five times a day, especially during the first 21 - 42 days of the lactation period, after which the number of daily milkings is reduced to two or three times per day. Such factors have a dramatic impact on how the milking parlour is sized.

Typically, milking parlours are sized so that the herd can be milked once in 10 hours when milking twice a day, 6.5 hours when milking three times a day, and 5 hours when milking four times a day. Using these criteria, the milking parlour will be sized to accommodate the cleaning and maintenance of the parlour. The facilities or cow groups are determined based on milking one group in 60 minutes when milking twice a day, 40 minutes when milking three times a day, and 30 minutes when milking four times a day. Group sizes of cows are adjusted to be divisible by the number of stalls on one side of the milking parlour. Having as many occupied stalls as possible per cycle maximises parlour efficiency.

The number of cows that will be milked per hour can be calculated using the following formulae:

Total number of stalls x turns per stall per hour = cows milked per hour (CPH) and

Number of milking cows = CPH x milking shift length (hours)

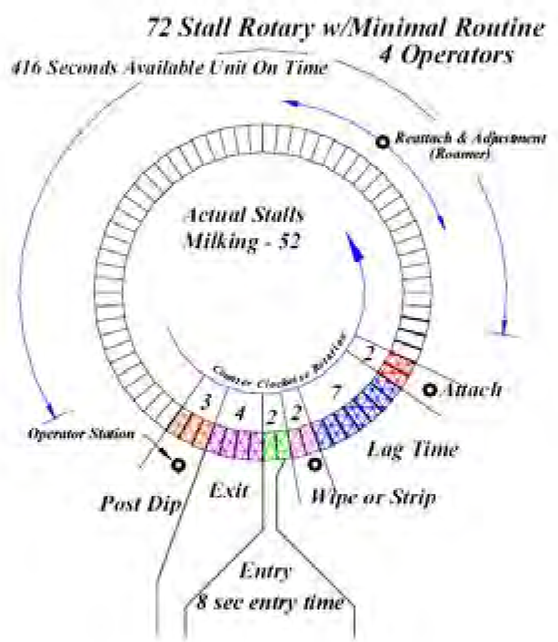


Figure 53.1. An example of utilisation of labour with minimum routine, 4 operators, 72 unit rotary parlour

Sizing rotary parlours

Entry time (seconds/stall), number of empty stalls, number of cows which go around a second time, entry and exit stops, and the size of the parlour (number of stalls) influence the performance of rotary parlours. The entry time will determine the maximum number of cows that can be milked per hour. For example, if the entry time is 10 seconds, the maximum throughput will be 360 cows per hour (3600 seconds per hour / 10 seconds per stall = 360 cows per hour). This is referred to as theoretical throughput.

Theoretical throughput assumes that the parlour never stops, cows are milked out in 1 rotation and a new cow occupies every stall at entry. In reality, there are empty stalls (about 4 at any time, between getting on the table and getting off the table), cows that go around a second time, and times when the rotary table is stopped.

In Table 53.2, rotary parlour performance at different percentages of theoretical throughput is shown. As the number of empty stalls, cows making a second trip around, and number of stops increases, the percent of theoretical throughput is reduced.

Table 53.2. The number of cows per hour in a rotary parlour

Time (sec/stall)	Percentage of theoretical number of cows per hour (%)				
	100	90	80	70	60
8	450	405	360	315	270
9	400	360	320	280	240
10	360	324	288	252	216
11	327	295	262	229	196
12	300	270	240	210	180
13	277	249	222	194	166
14	257	231	206	180	154
15	240	216	192	168	144
16	225	203	180	158	135

The number of stalls or size of the rotary parlour affects the available unit-on-time. In Table 53.3, available unit-on-time for different sizes of rotary parlours at different rotation times is shown. A rotary parlour must be large enough to allow approximately 90 percent of the cows to be milked out in one trip around the parlour.

Table 53.3. Available unit-on-time estimated for rotary parlours at different rotation times*

Number of stalls	Entry time (sec/stall)	Revolution time		Available unit on time	
		Seconds per revolution	Minutes per revolution	Seconds per revolution	Minutes per revolution
40	**8**	320	5:20	240	4:00
40	**10**	400	6:40	300	5:00
40	**12**	480	8:00	360	6:00
40	**15**	600	10:00	780	7:30
60	**8**	480	8:00	400	6:40
60	**10**	600	10:00	500	8:20
60	**12**	720	12:00	600	10:00
60	**15**	900	15:00	750	12:30
72	**8**	576	9:22	496	8:16
72	**10**	720	12:00	620	10:20
72	**12**	864	14:24	744	12:24
72	**15**	1080	18:00	930	15:30
80	**8**	640	10:40	560	9:20
80	**10**	800	13:20	700	11:40
80	**12**	960	16:00	840	14:00
80	**15**	1500	20:00	1050	17:30

*Assumes 5 stalls for entry and exit, 3 stalls for pre-milking hygiene, and 2 stalls to detach

In reviewing the data available today, rotary parlours should be sized at an 11-12 seconds per stall rotation and 81% of theoretical throughput. The parlour should be large enough to allow nine minutes of available unit-on-time. When sizing rotary parlours on a steady state throughput basis, approximately 5 and 5.8 cows are milked per stall per hour for milking parlours with less than 54 and 60 stalls, respectively (Table 53.4). Milking parlours with 60 stalls or larger are able to increase the number of rotations per hour and still maintain adequate time to milk cows completely out, without some cows going around a second time. It is critical that rotary parlours be sized to accommodate some expansion because they are very difficult to expand.

Table 53.4. Results from a survey conducted in the USA showing the performance of different sized rotary milking parlours using a full milk procedure

Parameters	Number of milking parlour stalls 24 - 40	48 - 54	60 - 80
Number of milking parlours	8	5	7
Average number of stalls	36	51	72
Average number of cows/hour	181	258	420
Average number of milkers	2.6	2.7	5.41
Average number cows labour/hour	82	98	77
Average milk yield (kg/day)	32	34	33
Average rotation/stall/hour	5.42	5.42	6.16
Average cows/stall/hour	5.01	5.06	5.82

Research showed that when automatic cluster remover settings were increased, average milking duration was reduced by 10.2 to 15.6 seconds per cow. Higher automatic cluster remover settings did not have a negative impact on the milk yield of cows. The average milk flow per minute also increased. The conclusion was that increasing automatic cluster remover settings represents an opportunity to increase parlour performance.

Herd size and feeding practice determine the level of automation

In essence, there are four parlour lay-out choices for medium to large scale dairy farming:

- Rotary parlours (internal or external configuration)
- Big Bore or swing-over herringbone parlours
- Double sided herringbone parlours
- Parallel or rapid exit parlours

The choice is very much determined by herd size and the cow throughput that is required, and varies from farm to farm. Management style, personal preference and finance available are some of the most important factors that will decide on the choice made. The number of milking units will be determined by the milking time available, as well as by the herd size and feed practice.

Level of automation required

The level of automation in the milking parlour is largely affected by the management level required for the dairy. Usually this includes equipment like electronic milk meters, automatic cluster removers, and milk flow control devices. Computer programmes that help with daily decisions like calving data, lactation data, milking records, cow performance figures and historical data to name only a few, make management easier for the dairy farmer. One should remember that a management programme is as useful as the data that is put into it. Computerised management systems are becoming a very important tool for many dairy farmers on which to base daily management decisions.

The basic norms for modern milking machines

A large volume of information is available on this topic, and international standards are available to assist the manufacturers of milking equipment to ensure that machines will be fully operational once installed. The international ISO standards are widely used as the correct norm for this purpose, and many aspects are dealt with in these norms. Important aspects covered in the ISO standards that are researched continuously, and that may affect the milk harvesting process negatively, include the following:

- Milk and vacuum line design for different size machines,
- Cleaning capacity design,
- Pulsator characteristic design,
- Vacuum drops between different points in the milking machine that are allowed, and
- The important aspect of teat end vacuum level specification, which is surely the most important measurement to do to secure that damage to the cow's teats is eliminated. It should be between 32 and 40kPa according to ISO norms, and can only be tested with specialised equipment.

Robotic milking – a future option

Hundreds of dairy farmers world-wide are milking their cows by robotic or voluntary milking systems. In such systems, cows decide when they want to be milked (most of the times cows visit the milking parlour 4 to 6 times per day), and during milking, various parameters like teat end condition compared to previous milkings, milk quality evaluation, cleaning and drying of each teat, the milking of each quarter individually, the cleaning of the teat cups after milking and post dipping, are recorded automatically. This information is then included in the herd management programme. In some cases specific information can be sent to a mobile phone. The limitation of the voluntary milking system is the number of cows that can be milked per station. Currently, 60 - 70 cows can be milked with one machine. In the near future, robotic milking machines will be improved, which should make them more affordable. Adaptations to current parlour configurations should also follow towards more automation.

In closing

The choice of milking equipment and the type of parlour depends on the level of automation and information that is required for the daily management of the dairy herd. Together with these choices, the availability of services and spares on an ongoing basis will aid the decision making process. The welfare of cows should be considered when considering different milking parlour options. Milk is produced from fewer, but higher yielding cows. Structural changes have caused a decrease in number of dairy farms, while they have increased in size and use of technology. This high technology has become an ordinary tool for the dairy farmer. It should be kept in mind that milking is not only a procedure where the milk is drained from the teats, it is an event where many physiological mechanisms are activated in the body of the lactating cow, events which influence mechanisms regulating production capacity, milk composition, feed intake and animal behaviour.

SECTION 6

DAIRY CATTLE
HEALTH and BIOSECURITY

CHAPTER 54

METABOLIC DISEASES IN DAIRY COWS

Introduction

Metabolic diseases in dairy cows result in milk production and farm income losses. Metabolic diseases differ from contagious diseases as they are not spread by bacterial or viral pathogens and are usually the result of poor management related to nutritional imbalances. Some of these diseases occur mostly during the dry period and early lactation, i.e. the peri-parturient period. It is important that farmers should know how these diseases develop, as most could be prevented by sound nutritional management.

1. Milk fever

Milk fever (hypocalcaemia) usually occurs at calving or about 3 - 4 days after calving. It is not a true fever condition, as it is caused by a sudden decline in blood calcium (Ca) levels because of the production of colostrum at calving. During the dry period (late gestation, non-lactating), dairy cattle have relatively low calcium requirements, with a need to replace approximately 30 g of calcium per day due to its utilisation for fetal growth and faecal and urinary losses. At parturition, the requirement for calcium is greatly increased due to initiation of lactation, when mammary drainage of calcium may exceed 50 g per day. Colostrum contains 8 to 10 times more Ca than the levels in the blood. Due to this large increase in demand for calcium, most cows will experience some degree of hypocalcaemia for a short period following calving down as the metabolism adjusts to the increased demand. Calcium levels in the blood are maintained by the diet and Ca released from the skeleton. The failure of Ca absorption from the diet and skeleton result in a sudden decrease in blood Ca levels. When the mammary drain of plasma calcium causes hypocalcaemia severe enough to compromise neuromuscular function, the cow is considered to have clinical milk fever. It is also referred to downer cow syndrome, as cows experience muscle failure which causes them to lie down.

While milk fever is principally caused by a sudden demand for Ca in colostrum and milk, other probable causes include excessive bone formation due to elevated levels of gonadal hormones and diet containing excessive dietary levels of cations, especially potassium (K). Other metabolic disorders that can lead to clinical and subclinical hypocalcaemia include rumen stasis, displaced abomasums, retained placenta, prolapsed uterus, metritis, and ketosis.

Milk fever is considered a herd problem when more than 10 to 15% of the cows are affected every year. Milk fever seldom develops in first parity cows, occurring mostly in older, higher producing cows. It is also more common in Jerseys than in other dairy breeds. It is a problem when a high proportion of cows in a sizable group of cows calving down are affected, such as when five out of the last eight cows calving down are diagnosed with milk fever. The main reason for the development of milk fever is the sudden increase in demand for Ca early in the lactation and the inability of the parathyroid gland to stimulate the absorption of Ca from the digestive tract while additional Ca is mobilised from the skeleton. Specific management practices have been developed to stimulate the activity of the parathyroid gland.

Mechanism

In normal Ca regulation, a decrease in plasma Ca levels causes the parathyroid gland to secrete parathyroid hormone (PTH), which regulates the activation of Vitamin D3 in the kidney. These two compounds act to increase blood Ca levels by increasing absorption of dietary Ca from the intestine, increasing renal tubular re-absorption of calcium in the kidney, and increasing resorption of Ca from bones. It has been found that tissue is less responsive to parathyroid hormone pre-partum than postpartum. It is believed that hypocalcaemia causing milk fever is due to a lower level of responsiveness of the cow's tissues to circulating parathyroid hormone.

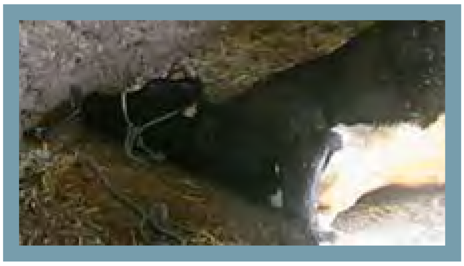
The resultant decreased plasma Ca causes hyper-excitability of the nervous system and weakened muscle contractions, which results in both tetany and paralysis.

The clinical signs of milk fever can be divided into three distinct stages:

1. **Stage I** milk fever often goes unobserved because of its short duration (less than 1 hour). Cows are mobile but show signs of hypersensitivity, loss of appetite, nervousness, weight shifting, and excitability, such as restlessness, tremors, ear twitching, head bobbing, and mild ataxia. Cows lie down with the sternum in contact with the ground.

2. **Stage II** milk fever can last from 1 to 12 hours. The affected cow lies down in a sternal position with its head tucked into its flank. Heart contraction and peripheral pulses are weak. Cows appear dull and listless, with dry muzzles, cold ears, and a lower-than-normal body temperature. Smooth muscle paralysis can cause bloat because of an inactive digestive system developing into constipation. Cows are not able to urinate or defecate. The heart rate is rapid, exceeding 100 beats per minute.

3. **Stage III** At this stage the affected cow lies down in a lateral position, muscles show flaccidity, and unresponsiveness to stimuli. This is followed by a loss of consciousness, progressing to coma. Heart rate can approach 120 beats per minute, with peripheral pulses becoming undetectable. If untreated, progression will continue to death.



Treatment

Treatment generally involves Ca injection by intravenous, intramuscular or subcutaneous routes. Before Ca injection was employed, treatment comprised inflation of the udder using a pneumatic pump. Inflation of the udder worked because the increased pressure created in the udder pushed the Ca in the udder back into the bloodstream of the cow.

Intravenous Ca, though indicated in many cases, is potentially fatal through "heart blockade", or transient high Ca levels stopping the heart, so it should be administered with care.

In unclear cases of downer cows, intravenous calcium injection can lead to diagnosis. The typical reaction will be a generalised tremor of the skeletal muscles and sometimes cardiac arrhythmia, defecation, urination, and eructation are frequent during the treatment, due to the pharmacological effect of calcium on the smooth muscles.

The prognosis is generally good, even in advanced cases. However, some cows can relapse the following day, and even a third time the day after.

Prevention of milk fever

In dairy herds showing a high incidence of milk fever, some preventative measures should be put in place to reduce the risk of milk fever. These measures are mainly aimed at the dry cow feeding. In Table 54.1 conditions associated with milk fever are listed.

Table 54.1. Conditions associated with milk fever in dairy cows

Factors	Situation
Low Ca-intake in dry cows (< 0.40% in total diet DM)	Heavy maize silage feeding, inadequate supplementation of Ca, low grain intake (dry cows), low forage – high grain feeding
Low phosphorus (P) intake (< 0.28% in total diet DM	Inadequate P supplementation, high forage – low grain feeding (cows on pasture)
Excessive Ca (between 0.70% and 1.00% in total diet DM)	High legume intake by dry cows, over supplementation with Ca
Excessive P intake (> 0.40% TRDM)	Over supplementation of P, excessive grain feeding
Excessive vitamin D intake (> 100,000 units per head daily)	Over supplementation can lead to calcification of tissues and result in heart failure
Low magnesium intake (< 0.20% in total diet DM)	Failure to balance low magnesium forages, i.e. corn silage, grasses, and small grains
High potassium (K) intake affecting anion-cation balance (> 1.2% in total diet DM)	Forages high in potassium content - over 1.5% on a DM basis
Reduced mineral absorption; rumen pH over 6.8 to 7.2; higher incidence with increasing age (lack of vitamin D, alimentary tract stasis, lack of motility, constipation)	High legume ration, high pH water (> 8.5), grain intake of less than 1.5 to 2.5 kg, underfeeding forage or effective fibre, excessive intake of protein
Selenium or vitamin E deficiency (< 0.10 ppm) (< 250 units per head daily)	White muscle disease, lack of supplementation

Basic principles for the feeding of cows during the dry period include the following:

i. Limit the intake of Ca to less than 80 - 100 g/day or 0.5 - 0.7% of the diet
ii. Limit the intake of P to less than 45 g/day or 0.30 - 0.35% of the diet
iii. The Ca:P ratio should be less than 2:1, preferably 1:1.

To reduce the Ca content in the diet, legume hays or silages should be replaced by grass or cereal forage crops. A nutritionist should be consulted to evaluate the present ration programme and the feeding management practices towards reducing milk fever in the herd. Provide all pertinent information, including incidence and severity of milk fever cases. Information on the mineral content of forages should be provided. Minerals to test should include Ca, phosphorus, magnesium, potassium, sodium, sulphur, and chloride.

Dietary Cation — Anion Balance

Another method of preventing and controlling milk fever is balancing dry cow rations for anions (negatively charged molecules) and cations (positively charged molecules). Sodium and potassium are the cations and chloride and sulfur are the anions of interest in formulating anionic diets. The dietary cation-anion balance (DCAB) equation most often used to determine milli-equivalents per 100 grams of dry matter is:

mEq/100g = mEq (Na + K) - mEq (Cl + S)

Based on current research, the range that achieves the lowest incidence of milk fever is a DCAB of –10 to –15 mEq/100g dry matter (DM) or –100 to –150 mEq/kilogram.

Achieving a DCAB of –10 to –15 mEq/100g requires adjustments in the major mineral levels that are quite different than what is normally programmed for regular close-up dry cow rations (no anionic salts). DCAB may be calculated from the percent element in diet dry matter.

The equation is as follows:

$$\text{mEq/100g DM} = [\,(\%Na \div 0.0230) + (\%K \div 0.0390)\,] - [\,(\%Cl \div 0.0355) + (\%S \div 0.0160)\,]$$

For example:

DCAB mEq/100g DM = [(0.10 ÷ 0.0230) + (0.80 ÷ 0.0390)] – [(0.70 ÷ 0.0355) + (0.35 ÷ 0.0160)] = 4.35 + 20.5 – 19.7 + 21.9 = 24.9 – 41.6 = –16.7.

In Table 54.2 recommended mineral levels for both regular and anionic rations are presented.

Table 54.2. Guide to mineral composition (dry matter basis) for close-up dry cows

Mineral	Regular	Anionic
Calcium	0.45 to 0.55	1.40 to 1.60
Phosphorus	0.30 to 0.35	0.35 to 0.40
Magnesium	0.22 to 0.24	0.28 to 0.32
Potassium	0.80 to 1.00	0.80 to 1.00
Sulphur	0.17 to 0.19	0.35 to 0.40
Chlorine	0.20 to 0.24	0.70 to 0.80
Sodium	0.10 to 0.12	0.10 to 0.12

Feeding a combination of different anionic salts is necessary for achieving the desired DCAB. The most commonly fed salts are ammonium sulfate, calcium sulfate, magnesium sulfate, ammonium chloride, calcium chloride, and magnesium chloride. Special attention should be paid to the degree of hydration of specific salts in formulating rations, as well as their costs and availability. In Table 54.3 the chemical composition of commonly available anionic salts are presented.

Table 54.3. Chemical composition of commonly available anionic macro-mineral salts

Mineral salt	Chemical formula	N	Ca	Mg	S	Cl	DM (%)
		Percent as-fed					
Ammonium sulphate	$(NH_4)_2SO_4$	21.2	-	-	24.3	-	100.0
Calcium sulphate	$CaSO_4$*$2H_2O$	-	23.3	-	18.6	-	79.1
Magnesium sulphate	$MgSO_4$*$7H_2O$	-	-	9.9	13.0	-	48.8
Ammonium chloride	NH_4Cl	26.2	-	-	-	63.3	100.0
Calcium chloride	$CaCl_2$*H_2O	-	27.3	-	-	48.2	75.5
Magnesium chloride	$MgCl_2$*$6H_2O$	-	-	12.0	-	34.9	46.8

Before incorporating DCAB into a dry cow programme, there are several factors to consider. For instance, some of the anionic salts are very unpalatable which can depress intakes significantly in conventional feeding programmes. In particular, ammonium salts may result in more intake and palatability problems, especially when a silage based ration is not being fed. Reduced dry matter intakes as a result of feeding anionic salts can lead to the development of other metabolic disorders.

Much of the success with anionic salts has been in herds feeding a total mixed ration. The use of an anionic diet is appropriate when high calcium forages are fed at relatively high levels during the close- up dry period. Animals should receive the anionic diet at least three to four weeks prior to the expected calving date.

Forages presumed to be good dry cow forages might actually contain high potassium levels that interfere with DCAB. When the potassium level in the total ration dry matter exceeds 150 grams (or > 1.2%), it is difficult to add the proper amounts of anionic salts to meet the ideal DCAB range. Re-evaluating the ration and forages may be necessary if more than 295 g to 340 g of anionic salts are needed.

If DCAB is to be implemented in a herd, sodium, potassium, chloride, and sulphur must be included in the forage analyses. Buffers must not be used in anionic salt rations, because they will counter the effect of DCAB.

2. Bloat

Bloat causes severe losses because of cow deaths and lower milk production. Bloat is the result of an excessive accumulation of gas in the rumen of cows, which is usually belched away by the cow. Bloat is generally associated with cows grazing high legume pastures such as clover or lucerne in spring and autumn. A clover content of over 50% is considered dangerous. However, problems have occurred at lower clover content levels when abundant new succulent growth is available. Occasionally, pastures containing young grass growth can cause bloat because of a high content of soluble protein. Hungry cows, which gorge themselves when introduced to spring or young pasture, are particularly at risk. Mornings with dew on the grass or overcast, windy days are frequently associated with outbreaks. It has been found that heifers are three times more likely to die of bloat than mature cows. Jerseys are three times more susceptible than Friesians and crossbreds are twice as susceptible to bloat.

Treatment and prevention are costly and it is important to remember that, apart from restricting access to dangerous pastures, there is no single method which will guarantee complete protection from bloat. Many farmers use two or more of the following techniques to reduce the incidence of bloat on their farms:

Signs of bloat

Cattle with bloat may display the following signs:

- no longer grazing,
- a reluctance to move,
- distended left abdomen,
- appear distressed — vocalise, eyes bulging,
- strain to urinate and defecate,
- rapid breathing — mouth may be open with tongue protruding, and
- staggering.

Prevention: Pasture management

Legume pastures should be introduced into the diet gradually over several days. Avoid cows gorging new pastures by feeding them before letting them out to graze. Silage, hay or more mature pasture can be used to reduce the cow's appetite. Initially, cows should only be allowed access to legume pastures for short periods (one hour or so). They should be monitored closely during grazing and immediately after removal from the pasture. Cows become accustomed to suspect pastures over several days by modifying their intake to prevent bloating. It has been suggested that mowing the pasture and allowing it to wilt for 2 - 3 hours should reduce the risk of bloat.

Preventative medication

Three types of medication can be used to control bloat in cows, namely:

- Fermentation modifiers (Anti-bloat capsules),
- Detergents (alcohol ethoxylate), and
- Anti-foaming agents such as Paraffinic oil and tallow.

The systems used to administer these chemicals aim to provide a continuous supply of medication over the whole grazing period.

Movements within the gut ensure that the chemical is thoroughly mixed with the contents of the rumen, preventing the formation of stable gas foam.

Direct medication

Directly drenching cows with a detergent is perhaps the most successful way of controlling bloat and is widely practiced in pasture-based countries. It is usually applied after milking. Cows have to be trained to accept the medication. Molasses can be mixed with the detergent to improve its palatability.

Bloat oils may also be directly drenched; however, larger volumes are required and the duration of action is significantly shorter than for the detergents. Anti-bloat capsules are a longer lasting alternative to aid in the control of bloat in cattle. Administered as a large plastic pellet down the throat (into the rumen), they provide a continuous supply of chemicals for 80 - 100 days. The capsules have been found to reduce bloat deaths by about 80%. Trials have shown that cows with capsules have an increase in milk and protein production. Butterfat test (%) may be depressed, but the total fat yield for the season is unaffected.

Spraying the pasture with oil

Spraying the whole day's grazing with anti-foaming agents, such as paraffinic oil, is a very reliable method of bloat control if carried out properly. It is best suited to 'strip grazing' systems that provide small, fresh areas for intensive grazing at least once per day. Oils only give 2 - 4 hours' protection in the rumen and consequently need to be consumed over the entire grazing period. Spraying the total area of each day's grazing (24 hours) at a rate of 85 ml of oil per cow is recommended. It is important that the grazing area is not over estimated or the oil may be spread too thinly and some cows may not eat enough. Make sure the oil will emulsify with water prior to purchase. Do not spray more than 2 - 3 days' grazing at a time. Respraying may be required after heavy rain. Boom spraying equipment and fencing must be in good condition to avoid failures.

Feeding in the milking parlour

Anti-bloat medications can be mixed with concentrates and fed during the bloat season. Detergents and oils have been added to supplementary feeds (pellets or grain) with good results, providing that the cows eat sufficient amounts twice daily. Feed companies may include anti-bloat detergents. Rumensin (monensin) mixed with supplementary feed may be used for bloat control in dairy cattle.

Flank applications

Between 30 and 70 ml of thick bloat oil can be applied to the flank of each cow with a brush or automated spraying system. Most cows, but not all, will lick this off during grazing. Adding molasses or tallow increases palatability, but encourages some cows to lick it off others. Wet weather and variable consumption reduce the effectiveness of this control method.

Water trough application

Detergent can be added to troughs, if it is the only source of water available to the herd. Detergents are bitter tasting and need to be gradually introduced into the water supply over a week or two, until the herd becomes accustomed to the taste. The fresh water supply must be disconnected, unless a metering device can supply a measured amount of detergent as the water flows in. Troughs must be replenished with the concentrate at regular intervals to maintain protection. Despite this, the daily water consumption of individual cows can fluctuate greatly, leading to variable control within the herd.

Treatment

If the cow is still standing

There are a number of products specifically registered for the treatment of bloat in cattle. If these are not available, bloated cows should be drenched immediately with 60 - 120 ml of bloat (paraffinic) or vegetable oil. Cows should be removed from the pasture as soon as possible to prevent losses.

If the cow is down and in extreme distress

If treatment with oil has not been successful and the cow is likely to die before a veterinarian can attend, the pressure in the rumen should be relieved surgically. Often a wide bore (14G) milk fever needle, or trocar, and cannula are sufficient for this purpose. The site for stabbing is on the left flank, an open hand's width behind the last rib and a similar distance below the ends of the short ribs (spinal vertebrae). If a needle or cannula is not available, or if they become blocked with foam (and the cow is in severe distress), a sharp narrow bladed knife can be used as a last resort. A 2.5 cm stab wound is ample and the knife should be left in the incision and twisted until gas and foam have ceased escaping.

A veterinarian will be required to suture the wound and administer antibiotic therapy if the rumen wall has been punctured during treatment.

3. Ketosis

Ketosis is a common disease in adult cattle. It typically occurs in dairy cows in early lactation and is most consistently characterised by partial anorexia and depression. It rarely occurs in cattle in late gestation, at which time it resembles pregnancy toxemia of ewes. In addition to a poor appetite, signs of nervous dysfunction, including pica, abnormal licking, uncoordinated movement, and abnormal gait, bellowing, and aggression are occasionally seen. The condition is in distribution worldwide, but is most common where dairy cows are bred and managed for high production.

Ethiology and pathogenesis

The pathogenesis of bovine ketosis is incompletely understood, but it requires the combination of intense adipose mobilisation and a high glucose demand. Both of these conditions are present in early lactation, at which time negative energy balance leads to adipose mobilisation, and milk synthesis creates a high glucose demand. Adipose mobilisation is accompanied by high blood serum concentrations of non-esterified fatty acids (NEFAs). During periods of intense gluconeogenesis, a large portion of serum NEFAs is directed to ketone body synthesis in the liver. Thus, the clinicopathologic characterisation of ketosis includes high serum concentrations of NEFAs and ketone bodies and low concentrations of glucose. In contrast to many other species, cattle with hyperketonemia do not have concurrent acidemia. The serum ketone bodies are acetone, acetoacetate, and β-hydroxybutyrate (BHB).

It seems that the pathogenesis of ketosis cases occurring in the immediate postpartum period is slightly different from that of cases occurring closer to the time of peak milk production. Ketosis in the immediate postpartum period is sometimes described as type II ketosis. Such cases of ketosis in very early lactation are usually associated with the fatty liver syndrome. Both fatty liver and ketosis are probably part of a spectrum of conditions associated with intense fat mobilisation in cattle. Ketosis cases occurring closer to peak milk production, which usually occurs at 4 – 6 weeks postpartum, may be more closely associated with underfed cattle experiencing a metabolic shortage of gluco-neogenic precursors than with excessive fat mobilisation. Ketosis at this time is described as type I ketosis.

Epidemiology

All dairy cows in early lactation (first 6 weeks) are at risk of ketosis. The overall prevalence in cattle in the first 60 days of lactation is estimated at 7% – 14%, but prevalence in individual herds varies substantially and may exceed 14%. The peak prevalence of ketosis occurs in the first 2 weeks of lactation. The incidence of ketosis rates vary between herds with some herds showing high levels and others low levels. Ketosis is seen in all parities (although it appears to be less common in primiparous animals) and does not appear to have a genetic predisposition, other than being associated with dairy breeds. Cows with excessive adipose stores (body condition score ≥ 3.75 out of 5) at calving are at a greater risk of ketosis than those with lower body condition scores. Lactating cows with subclinical ketosis are also at a greater risk of developing clinical ketosis and displaced abomasum than cows with lower serum BHB concentrations.

Clinical Findings

In cows maintained in confinement stalls, reduced feed intake is usually the first sign of ketosis. If rations are offered in components, cows with ketosis often refuse grain before forage. In group-fed herds, reduced milk production, lethargy, and an "empty" appearing abdomen are usually the signs of ketosis noticed first. On physical examination, cows may be slightly dehydrated. Rumen motility is variable, being hyperactive in some cases and hypoactive in others. In many cases, there are no other physical abnormalities. Some cows show abnormal licking and chewing, e.g. chewing on pipes and other objects in their surroundings. Muscle incoordination and gait abnormalities are seen occasionally, as well as aggression and bellowing. These signs occur in a clear minority of cases, but because the disease is so common, finding animals with these signs is not unusual.

Diagnosis

The clinical diagnosis of ketosis is based on presence of risk factors (early lactation), clinical signs, and ketone bodies in urine or milk. When a diagnosis of ketosis is made, a thorough physical examination should be performed, because ketosis frequently occurs concurrently with other peripartum diseases.

Especially common concurrent diseases include displaced abomasum, retained fetal membranes, and metritis.

Cow-side tests for the presence of ketone bodies in urine or milk are critical for diagnosis. Most commercially available test kits are based on the presence of acetoacetate or acetone in milk or urine. Dipstick tests are convenient, but tests aimed to detect acetoacetate or acetone in urine samples, are not suitable for milk testing. All of these tests are read by observation for a particular colour change. Care should be taken to allow the appropriate time for colour development as specified by the test manufacturer. Also, handheld instruments designed to monitor ketone bodies in the blood of human diabetic patients, are available. These instruments quantitatively measure the concentration of BHB in blood, urine, or milk and may be used for the clinical diagnosis of ketosis.

In a given animal, urine ketone body concentrations are always higher than milk ketone body concentrations. Trace to mildly positive results for the presence of ketone bodies in urine does not signify clinical ketosis. Without clinical signs, such as partial anorexia, these results indicate subclinical ketosis. Milk tests for acetone and acetoacetate are more specific than urine tests. Positive milk tests for acetoacetate and/or acetone usually indicate clinical ketosis. BHB concentrations in milk may be measured by a dipstick method that is available in some countries, or by the electronic device mentioned above. The BHB concentration in milk is always higher than the acetoacetate or acetone concentration, making the tests based on BHB more sensitive than those based on acetoacetate or acetone.

Treatment

Treatment of ketosis is aimed at re-establishing normal glycogen levels and reducing serum ketone body concentrations. Bolus intravenous (IV) administration of 500 mℓ of 50% dextrose solution is a common therapy. This solution is very hyper-osmotic and, if administered peri-vascular, may result in severe tissue swelling and irritation, so care should be taken to ensure that it is administered correctly. Bolus glucose therapy generally results in rapid recovery, especially in cases occurring near peak lactation (type I ketosis). However, the effect is frequently transient and relapses are common. Administration of glucocorticoids, including dexamethasone or isoflupredone acetate at 5 – 20 mg/dose, intramuscular (IM) may result in a more sustained response, relative to glucose alone. Glucose and glucocorticoid therapy may be repeated daily as necessary. Propylene glycol administered orally (250 – 400 g/dose) once per day acts as a glucose precursor and is effective as ketosis therapy. Indeed, propylene glycol appears to be the most well documented of the various therapies for ketosis. Overdosing propylene glycol leads to central nervous system (CNS) depression.

Ketosis cases occurring within the first two weeks after calving (type II ketosis) are frequently more refractory to therapy than cases occurring nearer to peak lactation (type I). In these cases, a long-acting insulin preparation given IM at 150 – 200 IU/day may be beneficial. Insulin suppresses both adipose mobilisation and ketogenesis, but should be given in combination with glucose or a glucocorticoid to prevent hypoglycemia. Use of insulin in this manner is an extra-label, unapproved use. Other therapies that may be of benefit in refractory ketosis cases are continuous IV glucose infusion and tube feeding.

Prevention and control

Prevention of ketosis is through nutritional management. Body condition should be managed in late lactation, when cows frequently become too fat. Modifying diets of late lactation cows to increase the energy supply from digestible fibre and reduce the energy supply from starch may aid in partitioning dietary energy toward milk and away from body fattening. The dry period is generally too late to reduce body condition score. Reducing body condition in the dry period, particularly in the late dry period, may even be counterproductive, resulting in excessive adipose mobilisation pre-partum. A critical area in ketosis prevention is maintaining and promoting feed intake. Cows tend to reduce feed consumption in the last 3 weeks of gestation. Nutritional management should be aimed at minimising this reduction. Controversy exists regarding the optimal dietary characteristics during this period. It is likely that optimal energy and fibre concentrations in rations for cows in the last 3 weeks of gestation vary from farm to farm. Feed intake should be monitored and rations adjusted to meet, but not greatly exceed, energy requirements throughout the entire dry period. For Holstein cows of typical adult body size, the average daily energy requirement throughout the dry period is between 12 and 15 Mcal, expressed as net energy for lactation (NEL). After calving, diets should promote rapid and sustained increases in feed and energy consumption. Early lactation rations should be relatively high in nonfibre carbohydrate concentration, but contain enough fibre to maintain rumen health and feed intake. Neutral-detergent fibre concentrations should usually be in the range of 28% – 30%, with nonfibre carbohydrate concentrations in the range of 38% – 41%. Dietary particle size will influence the optimal proportions of carbohydrate fractions. Some feed additives, including niacin, calcium propionate, sodium propionate, propylene glycol, and rumen-protected choline, may help prevent and manage ketosis. To be effective, these supplements should be fed in the last two to three weeks of gestation, as well as during the period of ketosis susceptibility. In some countries, monensin sodium is approved for use in preventing subclinical ketosis and its associated diseases. Where approved, it is recommended at the rate of 200 – 300 mg/head/day.

Ruminant animals are adapted to digest and metabolise predominantly forage diets; however, growth rates and milk production are increased substantially when ruminants consume high-grain diets. One consequence of feeding excessive amounts of rapidly fermentable carbohydrates in conjunction with inadequate fibre to ruminants is subacute ruminal acidosis, which is characterised by periods of low ruminal pH that resolve without treatment and is rarely diagnosed. Dairy cows, feedlot cattle, and feedlot sheep are at risk of developing this condition.

4. Acidosis

Ruminal pH fluctuates considerably during a twenty-four-hour-period (typically between 0.5 – 1 pH units) and is determined by the dynamic balance between the intake of fermentable carbohydrates, buffering capacity of the rumen, and rate of acid absorption from the rumen. In general, subacute ruminal acidosis is caused by ingestion of diets high in rapidly fermentable carbohydrates and/or deficient in physically active fibre. Subacute ruminal acidosis is most commonly defined as repeatedly occurring, prolonged periods of depression of the ruminal pH to values between 5.6 and 5.2. The low ruminal pH is caused by excessive accumulation of volatile fatty acids (VFAs) without persistent lactic acid accumulation and is restored to normal by the animal's own physiologic responses.

The ability of the rumen to rapidly absorb organic acids contributes greatly to the stability of ruminal pH. It is rarely difficult for peripheral tissues to utilise VFAs already absorbed from the rumen; however, absorption of these VFAs from the rumen can be an important bottleneck.

Ruminal VFAs are absorbed passively across the rumen wall. This passive absorption is enhanced by finger-like papillae, which project away from the rumen wall and provide massive surface area for absorption. Ruminal papillae increase in length when cattle are fed higher-grain diets; this presumably increases ruminal surface area and absorptive capacity, which protects the animal from acid accumulation in the rumen. Dairy cows are especially at risk in the transition period, because the ruminal mucosa needs several weeks to adjust to high-grain diets, and in peak lactation, when high levels of easily fermentable carbohydrates are fed to avoid excessive negative energy balance.

One mechanism by which affected animals resolve ruminal acidosis and return ruminal pH to normal is by selecting long forage particles, either by choosing to preferentially consume long dry hay or by sorting a mixed ration in favour of longer forage particles. Another mechanism is by reducing overall feed intake. Depressed dry-matter intake becomes especially evident if ruminal pH falls below ~5.5. Intake depression may be mediated by pH receptors and/or osmolality receptors in the rumen. Inflammation of the ruminal epithelium (rumenitis) could cause pain and also contribute to intake depression during subacute ruminal acidosis.

Absorption of VFA inherently increases as ruminal pH drops. These acids are absorbed only in the protonated state. Because they have a pK_a of ~4.8, the proportion of these acids that is protonated increases dramatically as ruminal pH decreases below 5.5. Lactate levels in the ruminal fluid of cattle with subacute ruminal acidosis, if measured, are usually not increased; however, the pathogenesis of excessive lactate production in the rumen is well-described. Ruminal carbohydrate fermentation shifts to lactate production at lower ruminal pH (mostly due to *Streptococcus bovis* proliferating and shifting to lactate instead of VFA production); this can offset gains from VFA absorption. Ruminal lactate production is undesirable, because lactate has a much lower pKa than VFAs (3.9 vs. 4.8). For example, lactate is 5.2 times less protonated than VFAs at pH 5. As a result, lactate stays in the rumen longer and contributes to the downward spiral in ruminal pH.

Additional adaptive responses are invoked if lactate production begins. Lactate-utilising bacteria, such as *Megasphaera elsdenii* and *Selenomonas ruminantium*, begin to proliferate. These beneficial bacteria convert lactate to other VFAs, which are then easily protonated and absorbed. However, the turnover time of lactate utilisers is much slower than that of lactate synthesisers. Thus, this mechanism may not be invoked quickly enough to fully stabilise ruminal pH. Periods of very high ruminal pH, such as during feed deprivation, may inhibit populations of lactate utilisers (which are sensitive to higher ruminal pH) and leave them more susceptible to severe ruminal acidosis.

Besides disrupting microbial balance, feed deprivation causes cattle to overeat when feed is reintroduced. This creates a double effect in lowering ruminal pH. Cycles of feed deprivation followed by overconsumption greatly increase the risk of subacute ruminal acidosis.

Low ruminal pH during subacute ruminal acidosis also reduces the number of species of bacteria in the rumen, although the metabolic activity of the bacteria that remain is very high. Protozoal populations are particularly limited at lower ruminal pH; the absence of ciliated protozoa in ruminal fluid is often observed during bouts of subacute ruminal acidosis. When fewer species of bacteria and protozoa are present, the ruminal microflora are less stable and less able to maintain normal ruminal pH during periods of sudden dietary change. Thus, periods of subacute ruminal acidosis leave animals more susceptible to future episodes of ruminal acidosis.

The pathophysiologic consequences of ruminal acidosis have mainly been described in feedlot cattle and in cattle surviving acute ruminal acidosis. Low ruminal pH may lead to rumenitis, erosion, and ulceration of the ruminal epithelium. Once the ruminal epithelium is inflamed, bacteria may colonise the papillae and leak into the portal circulation. These bacteria may cause liver abscesses, which may eventually lead to peritonitis around the site of the abscess.

Subacute ruminal acidosis has traditionally been associated with claw horn lesions, assumed to be caused by subacute laminitis. However, this pathophysiologic mechanism has not been experimentally characterised or reproduced.

Clinical Findings

The main clinical signs attributed to subacute ruminal acidosis are reduced or cyclic feed intake, decreased milk production, reduced fat, poor body condition score despite adequate feed intake, and unexplained diarrhea. High rates of culling or unexplained deaths may be noted in the herd. Sporadic cases of caudal vena cava syndrome may also be seen. The clinical signs are delayed and insidious. Actual episodes of low ruminal pH are not identified; in fact, by the time an animal is observed to be off-feed, its ruminal pH has probably been restored to normal. Diarrhea may follow periods of low ruminal pH; however, this finding is inconsistent and may be related to other dietary factors as well.

Diagnosis

Subacute ruminal acidosis is diagnosed on a group rather than individual basis. Measurement of pH in the ruminal fluid of a representative portion of apparently healthy animals in a group has been used to help make the diagnosis of subacute ruminal acidosis in dairy herds. Animal selection should be from highest-risk groups: cows between ~15 - 30 days in milk in component-fed herds and cows between ~50 - 150 days in milk in herds fed total mixed rations. Ruminal fluid is collected, and its pH is determined using a pH meter. Twelve or more animals are typically sampled about 2 - 4 hr after being fed grain (in component-fed herds) or 6 - 10 hr after the first daily feeding of a total mixed ration. When more than 25% of animals tested have a ruminal pH below 5.5, then the group is considered to be at high risk of subacute ruminal acidosis. This type of diagnostic tool should be used in conjunction with other factors, such as ration evaluation, evaluation of management practices, and identification of health problems on a herd basis.

Milk fat depression is a poor and insensitive indicator of subacute ruminal acidosis in dairy herds.

Treatment and prevention

The key to prevention of subacute ruminal acidosis is allowing for ruminal adaption to high-grain diets, as well as limiting the intake of readily fermentable carbohydrates. This requires both good diet formulation (proper balance of fibre and non-fibre carbohydrates) and excellent feed bunk management. Animals consuming well-formulated diets remain at high risk of this condition if they tend to eat large meals because of excessive competition for bunk space or after periods of feed deprivation.

Field recommendations to feed component-fed concentrates to dairy cattle during the first 3 weeks of the lactation period are usually excessive. Subacute ruminal acidosis is commonly caused by feeding a diet containing high levels of concentrates and low levels of forages. The same situation may be seen during the last few days before parturition if the ration is fed in separate components; as dry-matter intake drops before calving, dry cows preferentially consume concentrates instead of forage and develop acidosis.

Including long-fibre particles in the diet reduces the risk of subacute ruminal acidosis by encouraging saliva production during chewing and by increasing rumination after feeding. The provision of adequate long-fibre particles reduces the risk of ruminal acidosis, but cannot eliminate it. If a total mixed ration is fed, it is important that the long-fibre particles not be easily sorted away from the rest of the diet; this could delay their consumption until later in the day or cause them to be refused completely. Sorting can be prevented by providing long-fibre particles less than ~5 cm in length, by having adequate (~50% - 55%) moisture in the mixed ration, and by including ingredients such as liquid molasses that help ration ingredients stick together.

Ruminant diets should also be formulated to provide adequate buffering. This can be accomplished by feedstuff selection and/or by addition of dietary buffers, such as sodium bicarbonate or potassium carbonate.

Supplementing the diet with direct-fed microbials that enhance lactate utilisation in the rumen may reduce the risk of subacute ruminal acidosis. Yeasts, propionobacteria, lactobacilli, and enterococci have been used for this purpose. Ionophore (e.g. monensin sodium) supplementation may also reduce the risk by selectively inhibiting ruminal lactate producers and by reducing meal size.

In closing

Metabolic diseases in dairy cows may be prevented through correct feed formulation and feeding management. Milk fever is triggered by the demand for Ca in colostrums and milk at calving. Cows should be prepared for this by feeding them correctly during the steam-up period. Bloat is caused by cows consuming lush legume-rich pastures when they are hungry. Bloat can be prevented by feeding management, such as feeding hay or silage before going onto suspect pastures. Ketosis is usually caused by a combination of intense adipose mobilisation and a high glucose demand, such as in early lactation. Subacute ruminal acidosis is caused by cows consuming diets high in rapidly fermentable carbohydrates and/or deficient in physically active fibre.

CHAPTER 55

VACCINES AND IMMUNISATION OF DAIRY CATTLE

Introduction

Maintaining an effective animal health programme is an essential part of a successful dairy enterprise. Good animal health is vital for maximum production since dairy cows must be healthy to reach their production potential. Since each dairy operation is unique, owners (or managers) must establish a herd health plan in cooperation with the herd veterinarian. It is important that appropriate records are correctly kept of animals that are being culled. It is also important to record the reason for animals dying, to keep record of ongoing treatments, as well as all aspects of herd health. This information should be used to plan a herd health programme involving vaccination, de-worming, dipping, calf rearing, prevention of metabolic diseases, metritis and reproduction management, and/or mastitis control, etc. Therefore, a sound vaccination programme is only part of a herd health plan and requires planning and consultation with the herd veterinarian who should be aware of the diseases of importance in a specific area.

Vaccination

Vaccination stimulates the immune system of the animal producing protective antibodies that will help to combat invading disease organisms in the body of an animal.

The most common vaccines available on the market are either killed or live vaccines. So when vaccines are prepared, it is essential that one of the following alternatives must be followed:

1. The organism should first be killed, or the toxin should be inactivated. These vaccines are known as killed or inactive vaccines.
2. Vaccines where the organisms are alive, but weakened, are referred to as live or attenuated vaccines.
3. In some cases, the organism used in the preparation of the vaccine is not altered, or certain strains are used that are not as virulent – these are also live vaccines.

In practice, for the dairy manager, the differences between killed and live vaccines are the following:

1. Killed vaccines are distributed as in suspension, and need only be shaken before they can be used. Live vaccines are distributed in small bottles and the live micro-organisms are freeze-dried into a pill or powder form. The pill or powder must be reconstituted to a fluid by adding sterile water just before use.
2. Killed vaccines can be stored at 20°C inside a cool and dark place while live vaccines must be kept at 4°C inside a refrigerator. Some live vaccines must even be stored at much lower temperatures. Killed vaccines can be stored in refrigerators, but they must not be frozen.
3. The immunity against killed vaccines is usually of short duration. For that reason, it is recommended to repeat vaccination after 3 - 4 weeks and thereafter annually. The immunity against some live vaccines is of a life-long duration and it is not necessary to repeat vaccinations annually.
4. Killed vaccines normally don't cause a fever reaction or symptoms of the disease, and they are safe to be given to pregnant and high producing milk cows. On the other hand, live vaccines may cause a mild form of the disease and even a fever reaction. Some live vaccines should therefore never be given to pregnant or high producing dairy cows.

It is critical to always read the vaccine instructions carefully and to follow them.

Due to the fact that vaccines are highly perishable products, they should be handled with great caution. In order to ensure good results, the following precautionary measures should be carried out very strictly:

1. When buying vaccines one must make sure that they are stored in the correct way. All vaccines have an expiry date printed on the container. Vaccines should be used before the expiry date has elapsed.
2. Vaccines should be kept in a cool bag/

container when being transported. They should never be left inside the cabin of a vehicle, because it can become extremely hot inside the cabin.
3. Exposure to direct sunlight must be avoided at all times, especially for live vaccines.
4. At home, vaccines should be stored under the prescribed conditions, i.e. inside a refrigerator at all times, but not frozen at any stage.
5. Live vaccines should be reconstituted using sterile water just before vaccination is to start. Killed or inactivated vaccines need only to be shaken before being used.
6. Only sterilised syringes and needles should be used when vaccinating animals. Due to the fact that disinfectants and alcohol substances especially can harm the organisms in live vaccines, they should never be used before and during the vaccinations. The boiling of syringes and needles in water for 30 minutes remains the best method of sterilisation. Only clean, unused needles should be used to penetrate the rubber stopper of the vaccine bottles.
7. It is essential that each animal be vaccinated with a clean needle, as some of the animals being vaccinated may be sick. In practice it often happens that more than one animal is vaccinated with the same needle, but this must be kept to a minimum. Needles need to be changed as often as possible. When vaccinating a sick animal, or when an abscess has been struck, the needle must be replaced at once.
8. The correct dose must be given, using the correct route of vaccination. Most vaccines are administered under the skin (subcutaneous) or in the muscle (intra-muscular). Subcutaneous vaccination should be done in front of the shoulder in the neck area, and intra-muscular injections are done in the rump area.
9. At the end of the day, when only a portion of the vaccine is left in the container, the container and its contents must be destroyed, because pathogenic bacteria may easily enter the container where they will multiply and cause problems later on.

Animal vaccines are not to be used in humans and special care should be taken not to inject oneself by mistake. Accidental contact with the Brucellosis vaccine, for instance, either by a needle prick, or contact with drops of vaccine in the eyes, can infect the vaccinator with brucellosis. Brucellosis is a serious disease for humans. Symptoms may show up anytime from a few days to a few months after being infected. Signs and symptoms are similar to those of flu and include: fever, chills, sweats, general weakness, fatigue, joint and muscle pain and headaches. In some people, brucellosis becomes chronic with symptoms persisting for years.

The basic principle in compiling a vaccination programme for a dairy herd is to divide the type of vaccines to be used into three major categories.

A. Vaccination of cows during the dry period

The aim of vaccinating cows in the pre-partum period (before calving down) is to stimulate colostrum immunity to protect the new-born calf up to three to four months of age. The following diseases of calves can be protected through colostrum immunity:

- *Escherichia coli,*
- Rota/Carona virus infection causing scours,
- *Salmonella* infection causing scours,
- *Pasteurella* lung infection, and
- Bovine viral diarrhoea (BVD).

These vaccines are administered to the cows at least one month to a fortnight before calving to ensure enough antibodies are excreted through the colostrum.

The absorption of maternal antibodies through the digestive tract of the new-born calf takes place within the first four to eight hours after birth. It is therefore important for the survival of the newborn calf to receive at least one to two litres of colostrum within the first four to eight hours of their lives.

B. Vaccination of calves and heifers from one month of age to 15 months

The vaccination programme for calves and heifers from one month of age should protect them against diseases like:

- *Pasteurella,*
- BVD,
- Bovine herpes virus 1 (Infectious bovine rhinotracheitis or IBR),
- Para-influenza virus type 3,
- *Salmonella,*
- All the *Clostridium* diseases, like Botulism,

Black Quarter,
- Anthrax, Brucellosis, Leptospirosis, Lumpy Skin Disease.

Tick-borne disease vaccines can also be administered in this age group. Deep frozen blood vaccines that are available include:

- Babesiosis (Redwater),
- African and Asiatic Anaplasmosis (tick-borne gallsickness), and
- Heartwater (Ehrlichiosis).

The blood vaccines cause the respective disease in animals, which may require appropriate differential treatment to prevent clinical symptoms, but at specific times in order to allow sufficient immunity to develop. The vaccination of pregnant animals is not advised.

When young animals are vaccinated using blood vaccines, the treatment of vaccine reactions should be unnecessary.

- Redwater – vaccinate calves when they are 3 to 9 months of age.
- Anaplasmosis – vaccinate calves when they are 3 to 9 months of age.
- Heartwater – vaccinate calves when they are 4 to 6 weeks of age.

C. Annual vaccination programme for the adult cow herd

This annual vaccination programme should protect cows against diseases like:

- Lumpy skin disease,
- Anthrax,
- *Clostridium* diseases,
- Rift Valley fever,
- Ephemeral fever, and
- *E. coli* mastitis.

In closing

For the best results with regards to vaccination and dosing programmes in dairy herds, the manufacturer's recommendations with regards to dosage amounts, methods of administration, number of times treated, and storage of products, should always be followed. To set up a vaccination programme, the local or herd veterinarian should be consulted as he would be familiar with the animals in the herd.

CHAPTER 56

BIO-SECURITY ON DAIRY FARMS

Introduction

Every dairy farm is unique in its layout, number of animals, the way it is being managed, and challenges to be faced. A practical bio-security programme should be developed individually for each farm in close collaboration with the herd veterinarian. This should be based on risk-assessment. A bio-security programme basically involves the management of a dairy herd in such a way that the introduction and spreading of infectious diseases is prevented. It is the responsibility of the farmer or herd owner to develop and apply a bio-security programme at all times.

Know the risk

Dairy farmers have to be aware of all diseases of concern to cattle in the local area, as well as endemic and foreign diseases that may occur in cattle. A risk assessment of the farm should be done by carefully scrutinising the layout and design of the farm, all on-farm activities, as well as activities of service providers and visitors to identify all hazards. The risk associated with each different hazard should be carefully analysed. Appropriate ways to eliminate or control hazards and include those measures in a bio-security programme for the farm should be determined. As a general guideline biosecurity measures should include the following principles:

1. **Keep a closed herd**
   Keeping a closed herd is probably the best way to protect cattle being exposed to infectious diseases. A herd is not closed when cattle are purchased or rented or boarded from other herds or owners, when cattle have attended and returned from agricultural shows, or when cows use commonages or have attended and returned from performance testing centres. The herd is also not closed when bulls are purchased, borrowed or loaned, when cattle utilise pasture that shares a fence line with cattle on pasture on a neighbouring farm, or when cattle from the herd are transported by someone else or in someone else's vehicle. When any of the above actions take place on the farm, measures should be added to the bio-security plan towards minimising the risk of introducing diseases to the farm.

2. **Isolate "new" animals**
   Cattle, embryos or semen should only be bought from reputable sources. The introduction of "new" dairy cattle usually presents the greatest risk, since these animals' disease status is unknown. All "new" cattle to the farm should be isolated for a minimum period of 30 days (the incubation period of the majority of diseases) in an area at least 10 metres away from the milking parlour and herd. These animals should be observed daily for signs of diarrhoea, reduced feed intake, weight loss, breathing difficulty, lameness, strange behaviour, etc. In addition, these animals' temperature should be recorded every day or at least every other day for signs of fever. Any problems should be reported to the herd veterinarian. The isolation period should be used to de-worm and treat animals against external parasites. A comprehensive vaccination programme should also be applied during this period. The sooner this process is started, the sooner "new" animals can be introduced into the herd.

3. **Prevent contact with the neighbour's cattle**
   Fences should be kept in a good condition; this will keep animals in and the neighbour's animals outside the farm. In addition, pastures should preferably not be used that share a fence line with cattle on pastures on a neighbouring farm. Any animal that has been off the farm or that has come into contact with non-resident cattle should be considered as a "new" animal and treat them as described above.

4. **Recognise susceptibility and maintain separation**
   There are a number of different systems and groups of animals on a dairy farm. The distinctive production areas and their risk levels should be identified, and contact between these areas should be minimised. Keeping the younger, more

susceptible animals away from the older ones, separating the sick animals from the healthy ones and the "new" from the resident animals, can go far in preventing the transmission of diseases.

Monitor regularly for any sign of disease

Cattle should be observed regularly for early detection of signs of possible diseases. Animals must be tested regularly for diseases. The following principles should apply:

- ***Vaccinate strategically***
  Strategic vaccination is an essential component of disease prevention. An Animal Health Management Plan should be developed in consultation with the herd veterinarian. Such a plan must determine what diseases occur in the area, which animals are the most susceptible and when to vaccinate to get the best protection. Cattle should be vaccinated according to the recommendations of the manufacturer and herd veterinarian.

- ***Isolate sick animals***
  Pathogens can spread by direct animal-to-animal contact through secretions and faecal material. Sick animals should be isolated immediately from the rest of the herd and kept in a "hospital" camp or stall. Any unusual or unknown cases of diseases should be reported immediately; sick animals should be subjected to clinical examinations and get an accurate and prompt diagnosis by the herd veterinarian. Animals should be treated as soon as possible after diagnosis and sick animals should not be allowed back into the herd. All cases of diseases should be recorded, as well as treatments administered. This data should be summarised and analysed at regular intervals so as to revise the effectiveness of the on-farm biosecurity programme.

- ***Be aware of possible "carriers" of disease***
  Resident cattle that have seemingly recovered from a disease can still be "carriers" and could therefore pose a threat to other cattle. The herd should therefore be observed for any symptoms of diseases for at least 4 weeks after "healthy" animals have been returned to the herd.

- ***Minimise contact with dead cattle***
  Most infectious agents can survive in a carcass for a considerable period of time, so as to prevent spreading of pathogens, carcasses should be removed carefully as quickly as possible from places where they have been sick and died. No material related to the diseased and dead animals should be left behind. In order to rule out exotic disease, an accurate and prompt diagnosis of the cause of death by the herd veterinarian through a post mortem should be determined. The number of animals that have died should be recorded, as well as the cause of their death.

- ***Limit contact with other farm animals and pets***
  Animals, other than cattle of the appropriate age, should not be permitted access to cattle rearing or holding facilities. No animals (including home pets) should have access to buildings that is used to store feed, equipment, or the milking parlour. Potential risks posed by other farm animal species should be considered. Salmonellosis has been reported to be transmitted from feral cats, dogs, pigs, goats and poultry. Cats can spread toxoplasmosis, a frequently incurable protozoan disease.

- ***Control insects***
  Flies, blowflies, and other Arthropods are reservoirs and vectors of a wide variety of pathogenic organisms. Moist manure in cattle rearing facilities presents an ideal habitat for the development of large populations of the house fly and related species of flies normally found in manure. Breeding of flies should be controlled by regularly cleaning out rearing facilities and by minimising the accumulation of manure (e.g. spreading it out on pastures or by having it removed).

- ***Control rodents-rats/mice***
  Rodents should be discouraged as far as possible from entering the milking parlour, feed stores, other stores, etc., by keeping areas around the buildings free from unwanted vegetation and debris that could attract or harbour pests. Rodents should be controlled by maintaining baited poison stations. If possible, feed should be stored in rodent-proof containers as rodent droppings can harbour disease-causing organisms such as Salmonella.

- ***Safe disposal of carcasses***
  Carcasses should be carefully transported and disposed at a secure disposal site. Rodents, flies, wildlife and other scavengers (including pets e.g. dogs and cats) should be prevented from coming into contact with carcasses as they can serve as mechanical vectors, spreading disease all over your farm and to neighbouring farms. Potential disease-agents should be contained by burying carcasses at a depth of at least 4 - 5 m, but not lower than the water-table. The carcass should be covered with 400 mm of soil, and on top of that, a layer of chalk should be added. This will ensure that earthworms do not carry pathogens to the surface. In addition, at least 2 m of soil should be added to cover the carcass to ensure containment of the disease-agent. Please note that in case of a notifiable disease, methods of disposal as prescribed by the Provincial State Veterinarian, or as prescribed by other legislation applicable to the disposal of dead animals, will apply.

- ***Sanitise facilities***
  To disinfect buildings used for cattle rearing, the following steps should be taken:

  1. Clean the building by removing all old feed, manure, loose dirt, cobwebs, etc.; scrub all surfaces with a detergent and then rinse detergent and organic matter from surfaces (a steam or high-pressure water hose may be helpful).
  2. Sanitise the building by applying disinfectant and allow it to dry completely, before reapplying the disinfectant and allowing it to dry a second time.
  3. Rinse all water and feeding equipment before refilling them. Use only detergents and disinfectants registered for use in dairy production operations.

- ***Limit access to the farm***
  Access to the farm should be controlled to ensure that only authorised persons and vehicles enter the production areas. A dedicated parking area or "Visitors parking", which is isolated from the production areas, should be provided and clearly identified. Commercial vehicles that move between farms transporting and delivering bulk feed should be prevented from entering the production area by storing bulk feed supplies as far away as possible from the production area. Warning signs should be posted at the main entrance to the production area to indicate the concern for the spreading of diseases. The number of visitors from other farms should be restricted.

- ***Prevent introduction and spreading of infectious agents by visitors and personnel***
  Infectious agents can be spread on shoes, clothing and the hands of people who move from farm to farm, between production areas or from one herd to the next herd. Visitors from urban areas or visitors who have no contact with livestock, present very little risk of introducing disease or pathogens to the farm. However, neighbouring farmers, veterinarians, and some sales representative coming in direct contact with dairy cattle or other farm animals are considered high risk visitors. Such visitors should preferably shower and change into clean clothes and footwear before entering production areas on the farm. As a general preventative measure, clean coats or overalls and footwear should be supplied to all visitors to the production areas. As infectious agents remain viable in soil for a long period, footwear should be disinfected before entering a unit and all demarcated areas in a production unit. Although strategically placed foot baths for visitors may help to decrease the transfer of organisms by footwear, a poorly managed foot bath may become a source of infection. The disinfectant solution in the foot bath should be changed on a regular basis to ensure its efficacy. The disinfectant's dosage, whether in a hand spray or in the foot bath, should be according to the manufacturer's recommendations. Production area personnel and visitors can either use a properly maintained disinfectant foot bath or a boot spray.

  Production area personnel must wear freshly laundered overalls every day. Overalls and footwear should not be shared between one production area and the next. All visitors and production area personnel should, on entering a production unit, as well as on leaving the unit, wash their hands with soap and water or sanitise them using a disinfectant while also disinfecting shoes.

- ***Manage on-farm activities: Personnel***
  Although not always feasible, it would be best to appoint dedicated personnel for each production area or for a specific

group of animals, like young calves, heifers, dry cows, and sick animals normally kept in isolation. Therefore, as standard practice, production area personnel must, on a daily basis, start with the most susceptible animals (usually young calves) and then only move on to the ones that are not as susceptible. Personnel responsible for taking care of sick animals should only work with them after they have finished their tasks concerning healthy animals and preferably as the last task of the day. Movement between these groups should not be done without a change in overalls and shoes, and before hands and shoes have been properly washed and/or disinfected.

- ***Manage on farm activities: Usage and movement of vehicles***
  In a farming environment, it is well accepted that some vehicles have a multi-purpose use. Small trucks or trailers are often used to transport feed bales, bales of bedding material, and newly-born calves from the maternity area to the calf pen area, as well as young calves to auction yards. Such vehicles may also be used to transport dead animals to the veterinarian's office for post mortem examinations. The risk of spreading infectious agents should be considered when using such multi-purpose vehicles. The route should be planned to reduce this possibility by visiting the most susceptible animals first and then only move on to the rest of the animals. The potential spreading of diseases by using the same piece of road repeatedly should also be considered. The sick animals or animals in isolation should be checked up on after being to the "healthy" animals. Any vehicle entering the "isolation area" or "hospital camp" must be cleaned and disinfected before moving unto the rest of the farm. Cattle should only be transported in vehicles specifically adapted for this purpose. Vehicles should be cleaned and disinfected prior to loading a consignment of animals. Vehicles used for the disposal of dead cattle must be properly cleaned and disinfected before using it for anything else.

- ***Manage on-farm activities: Usage of equipment***
  Pathogens can be transferred on farm equipment that is being shared between units. Any equipment leaving the unit should be cleaned and disinfected prior to being returned to the unit. It is preferable that each unit should have dedicated equipment. The usage of drinking troughs, feed troughs as well as all other equipment in the isolation area or "hospital camp" should be limited to their respective areas to prevent possible transfer of infectious agents. The equipment should be painted in specific colours to identify it as belonging to the respective areas. Your own halters and ropes should always be used.

- ***Minimise contact with waste coming from cattle***
  Potentially infectious material and material that is known to provide a pathway for pathogens (e.g. manure and body fluids, discarded milk, soiled bedding, and spilled or leftover/excess feed) should be removed. Alleyways should regularly be scraped and manure and waste should be removed from housing and milking areas. Manure and waste should be handled with equipment that is not used for other functions, or that is cleaned and disinfected between uses. Waste should be moved to a secluded area to minimise contact with cattle and to limit contamination of pathways and production areas. The storage area should be constructed so as to ensure that runoff will not reach and contaminate active production, feed storage or feed transfer areas. Other waste should be removed to municipal landfills or to a hazardous waste site as appropriate.

Water

Water supplied to cattle must be according to the standard for drinking water for livestock. Water troughs should be cleaned and disinfected on a weekly basis.

Feed

Feed could be contaminated or become contaminated by raw materials being used, during transportation, post-production, or by exposure to rodents and birds. Bacteria and mould in poor quality or damaged feed are also a concern. Commercial feeds should be acquired from officially registered feed mills. Feed should be stored in clean and sealed containers (silos or bags). New batches of feed should be stored separately from previously bought feeds. All documents should be kept for traceability purposes. It should be ensured that feed bins and containers are free of vermin and that wild birds do not have access to stored feed.

Recordkeeping

Up-to-date records of all movements of cattle (on and off farm), all on-farm actions (e.g. cleaning and disinfection, rodent control, etc.), and all transactions (feed, semen, etc.) should be maintained for traceability purposes in case of a disease outbreak. Records should also be maintained on an individual animal basis and include data on identification, animal health, production, medications, withholding-period, vaccination, mortality, and surveillance.

In closing

Dairy farms are unique in their layout, number of animals, management style, and challenges. A practical bio-security programme, based on risk-assessment, should be developed for each farm by the farmer in collaboration with the herd veterinarian. Bio-security is managing the herd in such a way to prevent the introduction and spreading of most infectious diseases. For successful on-farm bio-security, everyone on the farm should be appropriately trained in bio-security measures while committing to apply it totally.

CHAPTER 57

LAMENESS IN DAIRY CATTLE

Introduction

Due to ever-increasing production costs and erratic farm-gate milk prices, dairy farmers today must always find alternative ways to keep farming profitable and sustainable. Due to economic pressures, modern dairy farms have become highly intensive. Increasing numbers of cows are kept on the same farm for the benefit of economy of scale for a higher dairy farm income towards financial sustainability. However, this inevitably leads to increased health and welfare problems among dairy cows. This is because dairy cows are increasingly kept under more intensive production systems, being exposed for longer periods to concrete surfaces and with their hoofs in daily contact with manure. This has resulted in lameness becoming the third largest problem in dairy cows following reproductive failure and mastitis.

Lameness reduces herd income

Lameness not only causes major economic losses in dairy herds, it also causes considerable pain to cows leading to serious welfare issues in dairy herds. Farm output is affected when cows are lame. Lame cows are in pain and stressed, and therefore eat less, start to lose live weight, and show a reduction in milk yield. Cows may lose up to 1.5 kg of milk/day when suffering from lameness problems. Lame cows need veterinary attention (incurring veterinarian cost) and treatments like antibiotics that cost extra money. Because of the antibiotic treatment, milk has to be discarded during the treatment period and up to the end of the withdrawal period. The farmer needs to spend extra time caring for the sick cows that he could have used more productively. Cows, to be culled for lameness, often have a lower price at the abattoir due to the reduction in live weight. The withdrawal period of antibiotic treatments for lameness could also affect the time of slaughter. Therefore, lameness not only affects milk yield, but also the value of the culled cows at sale.

Lameness also affects the reproductive performance of dairy cows. Cows that are lame would be hesitant to allow other cows to mount them when they are on heat, mainly because they are unstable as moving around would be painful. This would make heat detection very difficult. Conception from artificial insemination may be low because the body is fighting the infection caused by the lameness. Such cows require more services per conception or may not conceive at all, having to be replaced by expensive heifers. These factors can lead to increased calving intervals. The extra heifers that need to be raised use up valuable land space that could have been used to produce own feeds like forages. Lame cows are culled at a greater rate than healthy cows, increasing the overall herd culling rate. Therefore, more cows must be put in calf by using semen from dairy bulls instead of semen from beef bulls, reducing the total bull calf income considerably. If too much extra culling is enforced on the farm, a reduction in the genetic level of the herd can be the result.

Although studies determining the incidence of lameness occurring in South African dairy herds are limited, anecdotal observation indicates that approximately 20% of the average dairy herd could be affected by lameness at any time. In an earlier study conducted in England during the 1992/1993 calving season, it was found that 27% of the costs of production diseases were due to lameness problems. Due to the economic and reproductive impact that lameness has on dairy herds today, it is imperative that more attention and research needs to be focused on lameness in dairy herds.

Lameness and its associated claw lesions

Lameness is caused by foot lesions on the claws of cows. To prevent lameness from occurring in a dairy herd, it is necessary to understand the different types of lesions on the claws causing lameness. For this purpose, a dairy cow claw lesion identification information sheet was developed by The International Lameness Committee to help dairy farmers identify the type of lesion occurring on the claw of cows. This claw lesion guide includes photographs and descriptions of the 14 most commonly found claw lesions in dairy cows, which all lead to lameness being observed in the cows.

Lesions on the claws of dairy cows are divided into infectious and non-infectious lesions. To manage lameness in a herd, managers should know which category of lesions is most prevalent in the herd. Records must be kept of which lesion of the two categories occurs in which claw zone of the cow. This information will enable veterinarians and managers to determine the correct treatment, as well as shedding some light on the potential factor(s) causing lameness. Each lesion within each category has its own potential cause associated with it. Preliminary data from an evaluation conducted among South African dairy herds suggests that infectious lesions, such as digital dermatitis, heel erosion, inter-digital dermatitis and foot rot, occur more in confinement dairies, while pasture dairies show more non-infectious lesions. These include white line lesions, sole ulcers, sole haemorrhages, toe ulcers, corkscrew claws, horizontal hardship grooves, vertical and axial grooves, inter-digital growth, and thin soles.

Factors affecting lameness in dairy cattle

Lameness is a disease that is multi-factorial in origin as there are a range of factors affecting it which are inherent to dairy farms. The management of lameness in dairy cows is therefore very challenging. The basic net result of all the factors causing lameness is that claws become increasingly soft and therefore more prone to injuries and damage that may occur in the day-to-day life of the dairy cow. The causes and sequence of events during lameness is shown in Figure 57.1.

The flow chart shows that there are a number of factors that can, on their own, cause lameness, but some of these factors can also play a combined role in causing lameness. For example, non-infectious lesions can be triggered by trauma to the claw, increased standing times, and/or shearing forces on the white line of the claw (associated with cow flow), nutritional problems like sub-clinical acidosis, or by changes occurring at calving. These triggers will result in very similar lesions at the sole surface (e.g. sole, toe and heel ulcers, white line disease, and sole haemorrhaging). Therefore, every lesion may have a number of factors that can trigger its development usually associated with specific factors on the farm which can be managed to reduce the incidence of lesions. Different factors are responsible for the development of non-infectious and infectious lesions.

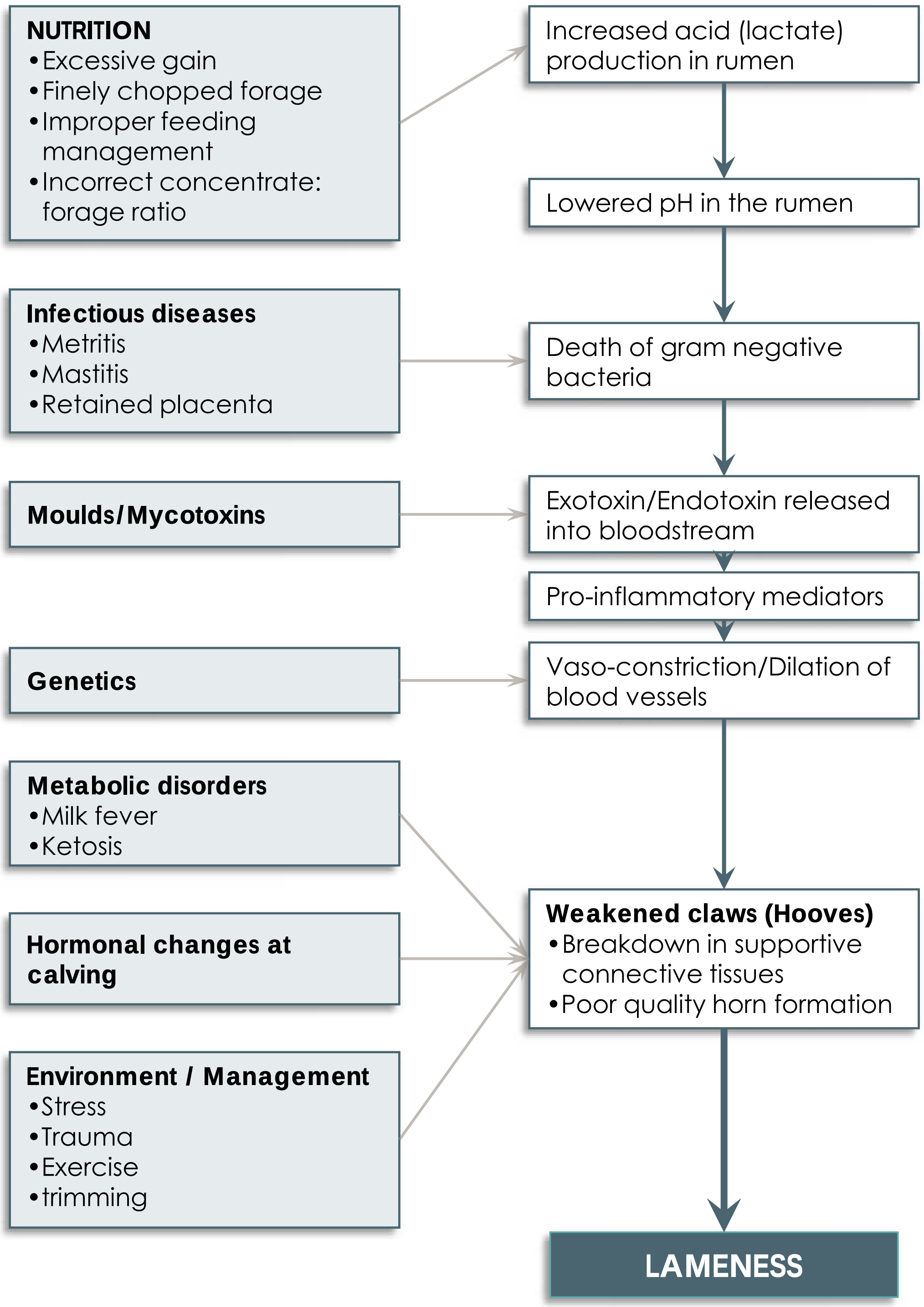


Figure 57.1. Causes and sequence of events resulting in lameness in dairy cows

Factors affecting non-infectious lesions

1. Nutrition

The ingestion of large amounts of ruminal fermentable carbohydrates (high levels of concentrates) often leads to the over-production of volatile fatty acids in the rumen. This overproduction of fatty acids eventually exceeds the buffering capacity of the rumen. The increase in acidity in the rumen leads to the fermentation process in the rumen slowing down, which results in acidosis when high levels of carbohydrate consumption continue. Acidosis causes the death of certain gram negative bacteria in the rumen. Furthermore, in situations where the rumen comes to standstill because of acidosis, certain endotoxins are produced and released which triggers the release of histamine. Histamine causes vasoconstriction and dilation of blood vessels, destruction of the laminar layers in the claw and eventual claw deterioration. Acidosis simultaneously leads to depressed fibre digestion, reduced feed intake, reduced butterfat in the milk, and increased metabolic diseases like laminitis.

Since effective fibre stimulates rumination, which stimulates the secretion of saliva, a small amount of effective fibre in the diet leads to less chewing, less saliva production, and therefore a decrease in ruminal pH. The problem is similarly aggravated by too short effective fibre pieces in the diet.

Other nutritional factors associated with faster digestibility in the rumen and therefore more acid being produced include the grain source in the concentrate mixture, i.e. wheat is digested quicker than maize grain, smaller particle size of grain, treatment of the grain (grinding, steam flaking, and cooking), and moisture content of the grain (especially if high moisture grains are ensiled). Poorly ensiled and mouldy feed should also be avoided due to histamine and mycotoxin release.

The amount of protein in the ration may also affect the incidence of lameness, but little information is available to identify the role protein might play in the development of lameness.

Deficiencies in certain trace minerals, like copper, zinc, and manganese, can lead to lameness because of their role in horn formation. Certain vitamins, like Vitamin A, beta-carotene, Vitamin E, and biotin, also play a role in cell replication and formation of hoofs. If rations are high in concentrates, biotin synthesis in the rumen is reduced, leading to softer claws.

According to some studies, the incidence of acidosis is highest during the first month after calving, while being almost non-existent during the last trimester of pregnancy. This is probably due to higher concentrate diets containing high levels of highly fermentable carbohydrates being fed during early-lactation, while less concentrates are fed during the dry period. Due to the tremendous hormonal and nutritional changes that occur before and during parturition, it is advisable that feeding management be changed during these times to limit the incidence of lameness during early lactation.

Whenever switching from one diet to another, like from the dry period to early lactation, the transition in diets should be gradual. Usually, during the dry period, cows are fed no or small amounts of concentrates per day. For this reason, concentrate feeding of cows should gradually be increased from about three weeks before the expected calving date for the rumen bacteria to adapt to the higher concentrate feeding level. At and around parturition, it is also essential that cows consume sufficient amounts of fibre while maintaining a normal dry matter intake. During the milk production phase, dairy cows should be fed concentrates at least twice a day. When large amounts of concentrates have to be fed to high-producing dairy cows, this should be done three to four times a day. More incidences of lameness and lesions were observed when concentrate feeding was less frequent during the day, less time was spent at the feed bunk and when feeding concentrates before feeding roughages. Roughages, like hay or silage, should be fed before grain is offered or, preferably, it should be part of a total mixed ration (TMR). Total mixed rations must be mixed in such a way to minimise the sorting of feeds as cows tend to eat the more palatable feeds, such as the concentrate mixture, first, while eating roughages last. This is especially a problem when feeding low quality roughages, such as wheat straw or mature lucerne hay, as part of the total daily diet. When large amounts of concentrates are fed to dairy cows, dietary buffers should be included in the diet to aid maintaining rumen pH at acceptable levels and to keep the incidence of acidosis at a minimum. Cows in first lactation should be kept in a separate group receiving a specific diet which takes into account their smaller live weight and specific nutrient requirements as in many cases they are still growing towards their mature live weight. When cows have limited access to the feed trough because of overstocking or insufficient bunk space, they will most likely overfeed when they do get access to food.

2. Environment and herd management

Dairy cows should get the opportunity to lie down for 12 - 14 hours per day to ruminate.

Housing systems that are overcrowded and poorly designed with regards to ventilation with stalls that are uncomfortable (being too small) will result in cows not lying down, thereby increasing standing time. As cows are standing for longer periods, the possibility of their feet being injured increases, making them more susceptible to lameness. Stall space should be sufficient to allow cows to lie down and to ruminate. Proper clean bedding should be supplied; it must be soft without being abrasive and without small stones that can penetrate the horn of the sole as cows lie down and get up. Studies have shown that bleeding of the soles decreases when rubber flooring, rather than concrete floors, is used. The floor surface used in housing systems and the milking parlour must not be conducive to excessive horn wear. This is especially the case in concrete floors.

When cows are standing for long periods in the holding areas before and after milking in addition to being milked, it can lead to the development of lesions. This is because the mechanical overload and tissue compression (associated with long standing times) inside the claw can interfere with the movement of fluids inside the claw or the supply of nutrients to the horn-producing tissues within the claw. This is often the case that when large groups of cows are being milked that the time standing before, during, and after milking could be more than three hours per day for each milking session.

When cows are rushed on their way to and from the milking parlour, they do not have time to look where to put their front feet. Cows have to put their front feet on an even and stone-free walking surface, because this enables them to put their hind feet in the same place, minimising the chances of punctures to the claws. When cows are rushed into the milking parlour and/or around stalls, they often have to twist and turn on unyielding surfaces, like concrete, putting extreme shearing forces on their claws or across the white line region. Putting rubber mats on concrete floors in turning areas can reduce the shearing forces on their claws. A slow and non-rushing cow flow is required in preventing claw injuries. Cows bullying each other in the housing system can also lead to sharp twists and turns when the bullied cow has to move away from the dominant cow. The condition of the walkways should be good with no loose stones that may cause hoof punctures.

Lesions can develop when the claws are not trimmed at all or when they are not trimmed regularly. However, trimming of claws must also be done properly by a trained hoof trimmer. Experts suggest that claw trimming should be done every six months in dairy herds that are prone to the development of lameness. Caution against over-trimming is also necessary as claws that have been over-trimmed can lead to unbalanced weight bearing, as well as thin soles, which in turn increases the cow's risk in developing lesions.

To prevent laminitis in first lactation cows, it is essential that they are managed separately from older cows. The sudden introduction of first lactation cows to a group of older cows often upsets the social structure (or pecking order) of the group of cows. This may also result in overcrowding, while first lactation cows may be introduced for the first time to long-term exposure to concrete floors, especially if they have been kept outside on pasture as heifers. The higher concentrate feeding level during early lactation combined with these housing factors may result in a higher incidence of laminitis in first lactation cows. Usually because of overcrowding and being of a lower social order, first lactation cows may not find space at the feed bunk. They may therefore only eat 3 - 4 times a day instead of the normal 13 - 14 meals per day. This may predispose them to rumen acidosis. Any stress on the cows through management, like vaccination, transportation, and/or reduced or increased exercise imposes stress on their bodies. Stress depletes the body's nutrient reserves and reduces the animal's resistance to diseases, leading to lameness. This is why first lactation cows are more susceptible to lameness and laminitic challenges than multiparous cows.

Cows close to parturition experience an increase in the elasticity of the connective tissue that suspends the pedal bone in the claw capsule. The hypothesis around this is that this increase in elasticity is due to the hormone, relaxin, which is being released around parturition. This helps in the expulsion of the calf during the birth process. However, the increased elasticity of the connective tissue allows for greater movement of the pedal bone in the claw capsule. This puts increased pressure on the corium between the sole of the claw and the pedal bone itself, increasing the risk of claw lesions in cows.

While too little exercise can decrease the blood flow to the claws, leading to swelling or oedema, too much exercise (especially on unyielding floors like concrete) can lead to contusions in the claws.

At high ambient temperatures (above the thermal neutral zone), cows will start panting and drooling saliva. The increased respiration rate may lead to alkalosis. The body's response to this is an increasing urinary output of bicarbonate. Drooling, because of heat stress, results in cows losing saliva which should have been used to buffer the rumen. Cows also stand for longer periods to alleviate heat stress. This increases time on their feet. Since there is less saliva and bicarbonate to buffer the rumen against a low pH, acidosis can develop, which in turn, can lead to a risk for laminitis.

3. Infectious diseases & metabolic disorders

Metabolic disorders, like milk fever and ketosis, and infectious diseases, like mastitis and metritis, which develop after calving lead to toxins being circulated in the blood. This causes thrombosis in the capillaries and narrowing of the blood vessels in the corium of the claw. This increases the development of haemorrhaging in the claws.

4. Genetics

The physical characteristics of feet and legs in dairy cattle are fairly heritable. Good feet and leg conformation has huge value in the long-term prevention of lameness occurrences. Therefore, the breeding programme followed by the dairy herd should include choosing bulls and cows with good feet and leg conformation to prevent lameness as far as possible. It is advisable to not breed herd replacements from chronically-lame cows or cows that have a history of mobility problems.

5. Age and stage of lactation

The susceptibility of dairy cows to develop laminitis seems to increase with age. Some studies showed that 10-year-old cows were four times more likely to develop laminitis than 3-year-old cows. Other studies have also shown that lameness is more common during the first 120 days post-partum. Therefore, non-infectious lesions can be prevented by implementing a sound nutritional plan, implementing a regular hoof trimming programme, ensuring cow comfort, and ensuring less trauma to the claws by ensuring that walkways and holding areas are comfortable; namely, level without loose gravel on the floors. Special attention needs to be given to the claws of cows that are in milk, and especially first lactation cows due to the hormonal changes occurring during this time.

Factors affecting infectious lesions

Whereas the previous non-infectious lesions are mostly lesions of the claw horn or sole of the claws, the infectious lesions mostly affects the skin close to the claws. The following are potential factors on the farm that may cause infectious lesions:

1. Wet and poor hygienic conditions

When cows have to stand for long periods in wet, dirty- or manure-filled holding areas (holding pens outside in the rain), the skin of the claws above the bulbs and in between the claws are in contact with this wet, unhygienic environment. This usually leads to the softening of the skin, allowing bacteria to penetrate into the superficial layers of the skin, causing digital dermatitis and interdigital dermatitis in the interdigital space between the claws. Rough and uneven walking surfaces may also traumatise the interdigital skin and leave it more prone to infection risk.

2. Presence of infected animals in the herd

These infectious lesions could be transmitted from cow to cow in the same herd. Therefore, it is very important to make sure that these lesions are contained by keeping cows separate so as to not infect the whole herd. New animals brought into the herd may also infect other cows.

3. Poor foot bath management

Implementing a proper intensive foot bath programme should contain and control infectious lesions. The anti-bacterial treatment, which is put into the foot bath, should specifically help in controlling digital dermatitis and interdigital dermatitis. The design of the foot bath should promote cow flow. It must be long enough to increase the number of foot immersions as cows walk through the bath. The passage way with the foot bath should have a removable or drop-down barrier to enable reaching and helping cows that have fallen down while walking through the foot bath.

The control of infectious lesions is based on keeping feet (claws) clean and dry. An effective foot bath programme will help towards this goal. Treating infected animals and keeping them separate from the rest of the herd should prevent the spread of bacteria.

Where does laminitis fit into the lameness picture?

In the past, sole haemorrhages, sole, heel and toe ulcers, and white line disease have been grouped together and referred to as "laminitis". However, laminitis is only one cause of lameness and as stated previously, these specific lesions can also be caused by trauma to the claw, increased standing times, and/or shearing forces on the white line of the claw or by changes occurring at calving. Although they are most likely connected to nutritional challenges, they could also be caused by metabolic and digestive disorders, stress associated with parturition, mastitis, metritis, hard or poorly bedded stalls, too little exercise, and excessive bodyweight. Non-infectious lesions are clinical signs seen on the surface of the sole, which reflects a disease process within the animal which can alter the structure of the claw. This is why these lesions can be caused by more than one trigger factors. Of all the lesions identified in dairy cow lameness, approximately 62% could be associated with laminitis in some form. Cows may display these lesions on their claws, while not displaying any signs of lameness, i.e. sub-clinical laminitis. This can develop into more serious lesions such as sole ulcers and sole abscesses. The lesions associated with laminitis all fall within the non-infectious category in the dairy claw identification poster and therefore all the factors affecting the development of non-infectious lesions will also affect the development of laminitis. The lesions most connected to laminitis include white line disease, sole and toe ulcers, sole haemorrhage, corkscrew claws, horizontal, vertical or axial grooves, interdigital growth, and thin soles.

What happens in the cow during laminitis?

To understand what happens when laminitis occurs in the claw, it is necessary to understand what the claw looks like. The anatomy of cow's claw is shown in Figure 57.2.

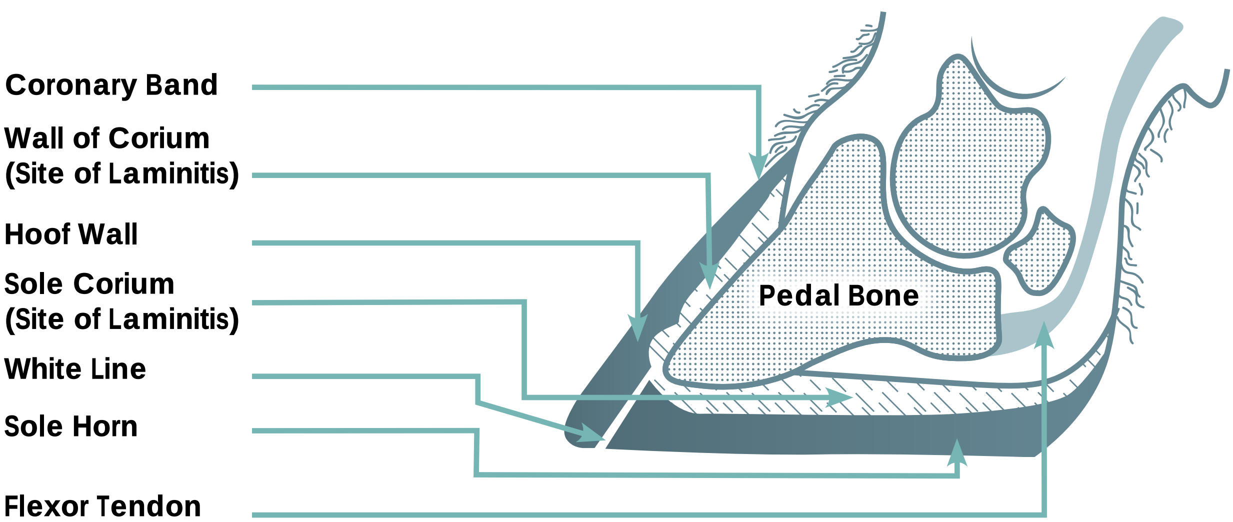


Figure 57.2. A description of the anatomy of the claw of a cow

Looking at the cow's claw from the outside going inwards, the hard outer covering of the claw, known as the hoof wall or horn, is seen. This is a hard surface and the cells that form the horn are produced by the tissue directly underneath the hoof wall. This is known as the corium, which is a nutrient-rich tissue that contains all the blood vessels and nerves of the claw. The corium continuously produces new cells, which are pushed away from the corium. These cells eventually die, producing the hard outer growth known as the hoof. The cells have therefore been keratinised and the new growth appears from the coronary band. Very often rings can be seen on the claws of animals which indicate that the horn was produced at different rates. These rates differ due to nutritional factors, health status, and living conditions. Generally, the claw grows at around 0.6 cm per month.

Underneath the claw is a slightly softer region, called the sole, which is also formed out of the corium layer. Where the sole is bound to the claw wall is a flexible junction, called the white line. This allows the cow's claw to be more flexible as she moves. There are two soft bulbs at the back of the claw, which acts as a shock absorber when the cow moves. Between the corium and the sole of the claw is the digital cushion, which is a pad of fatty tissue which protects the corium and aids in blood transport in the leg. Within the claw of the cow, the four bones (phalanx 1, 2, 3 and navicular bone) rest within the claw capsule. These bones play a key role as a support structure for the leg and the rest of the body. The pedal bone, also known as phalanx 3, is situated directly above the digital cushion. The pedal bone is attached to the corium of the claw by sensitive connective tissue known as the laminae. Therefore, the laminae hold the cow suspended within her claw. The pedal bone is the only bone that is completely inside the actual claw and provides the framework for the general shape of each claw.

Factors affecting laminitis

Laminitis is a multi-factorial metabolic disorder that occurs when the laminae within the corium layers in the claw wall becomes inflamed. As mentioned earlier, these layers produce the horny tissue of the claw wall and sole. Any disruption in the blood flow to these folds will damage the tissues, impairing their ability to produce high-quality horn. This disruption can be caused by any of the previously mentioned factors.

The primary, but not only, cause of laminitis in cows is rumen acidosis. Acidosis occurs when cows are fed too much carbohydrates and too little effective fibre (as described earlier). This is a systemic metabolic challenge that causes a decrease in ruminal and systemic pH. The reduction in pH activates the circulatory system into increased blood flow and pulse. Due to the increased blood pressure, the corium and laminae swell, as well as damaging the vessel walls within the corium. Fluid seepage occurs through the vessel walls, resulting in oedema, internal bleeding of the solar corium from thrombosis, and ultimately expansion of the corium layer, leading to severe pain. All of this puts pressure on the claw wall and cuts off the circulation in the blood vessels of the corium. The laminae become starved for blood, oxygen, and nutrients, leading to abnormal claw formation, reducing elasticity, and inhibiting blood supply to the claw. As these tissues die, the bond that holds the pedal bone to the claw wall becomes weak and the pedal bone begins to separate from the claw wall. Because the pedal bone now has less support and a weaker bond to the wall, it begins to sink and rotate within the claw capsule. This causes compression of the soft tissue between the sole and pedal bone. It now becomes very susceptible to mechanical damage like penetration by sharp stones or long standing times on unyielding surfaces. Claws that are afflicted with laminitis also begin to grow at abnormal rates due to the increased circulation in the blood vessels. This alters the shape of the claw, causing cows to have an uncomfortable gait.

Laminitis, therefore, occurs as a result of blood vessel dysfunction, as well as softening of the ligaments of the suspensory apparatus, leading to rotation of the pedal bone, and compression of the digital cushion. This leads to haemorrhaging in the soles, as well as the formation of lower quality horn in the claw. As soon as the pedal bone separates from the claw wall, it can cause the sole to separate from the wall at the white line; this is known as white line disease. When the white line pulls too far away from the sole, it can expose the claw to infections. The reduction in ruminal pH also causes the death of rumen bacteria, which releases endotoxins and histamines into the blood stream. This further increases vascular constriction and dilation. Therefore, laminitis puts the claw of the cow in a weakened state and will pre-dispose it to the other risk factors as depicted in Figure 57.1 (e.g. compromised cow comfort, stress, trauma to the claws and improper trimming of claws).

The most common form of laminitis occurring in dairy herds is sub-clinical laminitis, which often goes undetected because cows may not show any obvious signs of lameness. During sub-clinical laminitis, serum seepage and bleeding in the corium are evident, as well as inadequate blood and oxygen supply to the claws. It is this damage that leads to the production of poor-quality horn, and the wall and sole of the claw becoming softer and prone to wear and physical damage. The signs of sub-clinical laminitis include sole haemorrhages and yellow discoloration, white line separation, double soles, and sole ulcers.

Sub-clinical laminitis is mostly a problem in high-producing, intensively managed dairy herds. This is mostly due to the feeding of too much concentrates in the diets of lactating cows, which leads to acidosis in the rumen and therefore predisposes cows to develop laminitis. As the production level of the cow increases, she becomes more sensitive to all the risk factors depicted in Figure 57.1, especially trauma to the claws and, therefore, development of laminitis.

Western Cape dairy feeding programmes

Feeding large amounts of concentrates to dairy cows is a standard practice for dairy farmers in the Cape Winelands and Swartland regions of the Western Cape Province. These regions have a winter rainfall pattern with cold, wet winters and hot, dry summers. This creates the problem that mainly cereal crops, such as oats, barley, and triticale, can be grown here which, in comparison to lucerne hay and maize silage, are low to medium quality roughages having lower protein and energy levels while forage production is also less. Furthermore, because of seasonal droughts, there is a lack of water for irrigation purposes in the summer months. This makes the production of higher quality summer growing crops, like maize and lucerne, as well as ryegrass or legume pastures, very difficult.

Harvesting cereal crops for hay is also problematic, as late winter rains may interrupt harvesting or may result in extended harvesting dates. Roughages harvested at a late maturity stage have a poor quality, having low protein and energy levels while containing high levels of fibre which reduces roughage digestibility. Such roughages require large amounts of concentrates to support high milk yield levels. Using cereal roughages increase the cost of total diets since a more expensive concentrate containing a higher crude protein level must be used. The higher feeding cost of total mixed ration (TMR) production systems increases the vulnerability of these systems. To combat higher feeding costs, TMR systems require higher milk yields per cow and increased cow numbers. Both these factors may increase the probability of cows developing laminitis.

In closing

Lameness is a disease that causes great economic losses in dairy herds today. Nutrition plays a major role in the development of acidosis while there is a distinct link between acidosis and the development of laminitis. Sub-clinical laminitis without cows showing signs of lameness complicates the management of the disease. Laminitis can be controlled through nutrition by feeding higher fibre diets, although this reduces milk yield. Increasing the concentrate intake leads to higher milk yields which may improve financial sustainability. Because dairy farmers maximise energy intake to increase milk production, it remains a challenge to manage acidosis and laminitis profitably. Management in the following areas is critical in preventing laminitis: the diet being fed and feeding management, comfortable cow environment, and routine trimming and care of claws.

SECTION 7

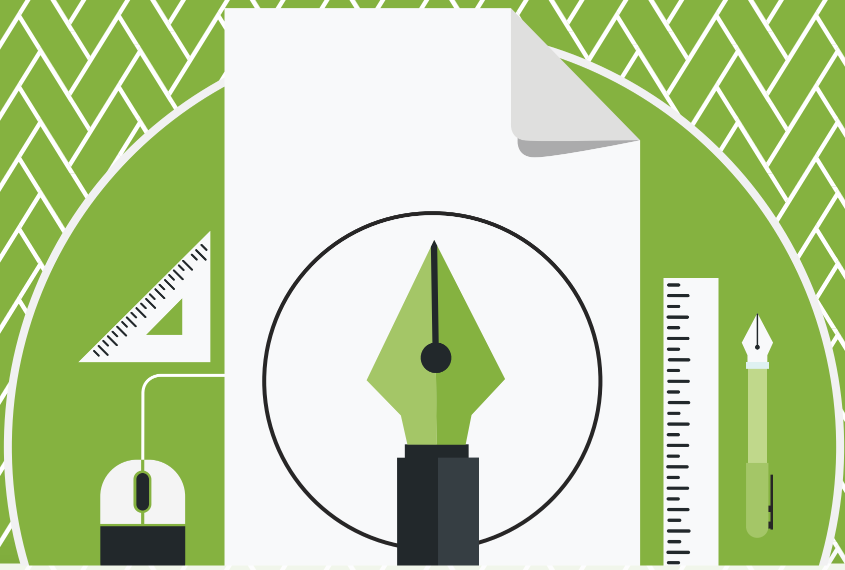
Abbreviations and Acronyms

SECTION 7

Abbreviations and Acronyms

ADF	acid detergent fibre
ADG	average daily gain
AFC	age at first calving
AI	artificial insemination
B	boron
BGH	bovine growth hormone
BST	bovine somatotropin
BV	breeding value
C	carbon
Ca	calcium
CF	crude fibre
CFS	calving to first service
CH_4	methane
CI	calving interval
CIDR	controlled internal drug release
CO_2	carbon dioxide
CP	crude protein
CSOCM	cotton seed oil cake meal
Cu	copper
DIM	days in milk
DM	dry matter
DMI	dry matter intake
DO	days open/interval from calving to conception
EBV	estimated breeding value
EE	ether extract
FCM	fat corrected milk
FSH	follicle stimulating hormone
GHG	green house gas
GnRH	gonadotropin-releasing hormone
HE	hay equivalent
HPC	high protein concentrates
ICAR	International Committee for Animal Recording
IHG	internal herd growth
INTERGIS	Integrated Registration and Genetic Information System
K	potassium
LH	luteinizing hormone
ME	metabolisable energy
Mg	magnesium
MgO	magnesium oxide
MJ	mega joules
Mn	manganese
MOET	multi-ovulation embryo transfer
MUN	milk urea nitrogen
N	nitrogen
Na	sodium
$NaHCO_3$	bicarbonate of soda
NDF	neutral detergent fibre
NDP	non-degradable protein (bypass protein)
NFC	non-fibre carbohydrates
NH_3	ammonia
NPN	non-protein nitrogen

OM	organic matter
P	phosphorous
PRR	pasture replacement rate
RDP	rumen-degradable protein
RFI	residual feed intake
RH	relative humidity
RPM	rising plate meter
RUP	rumen-undegradable protein
S	sulphur
SCC	somatic cell count
SNF	solids-not-fat
SPC	services per conception
TDN	total digestible nutrients
THI	temperature humidity index
TMR	total mixed rations
TS	total solids
VFA	volatile fatty acids
WSC	water soluble carbohydrates
Zn	zinc



SECTION 8

SELECTED REFERENCES

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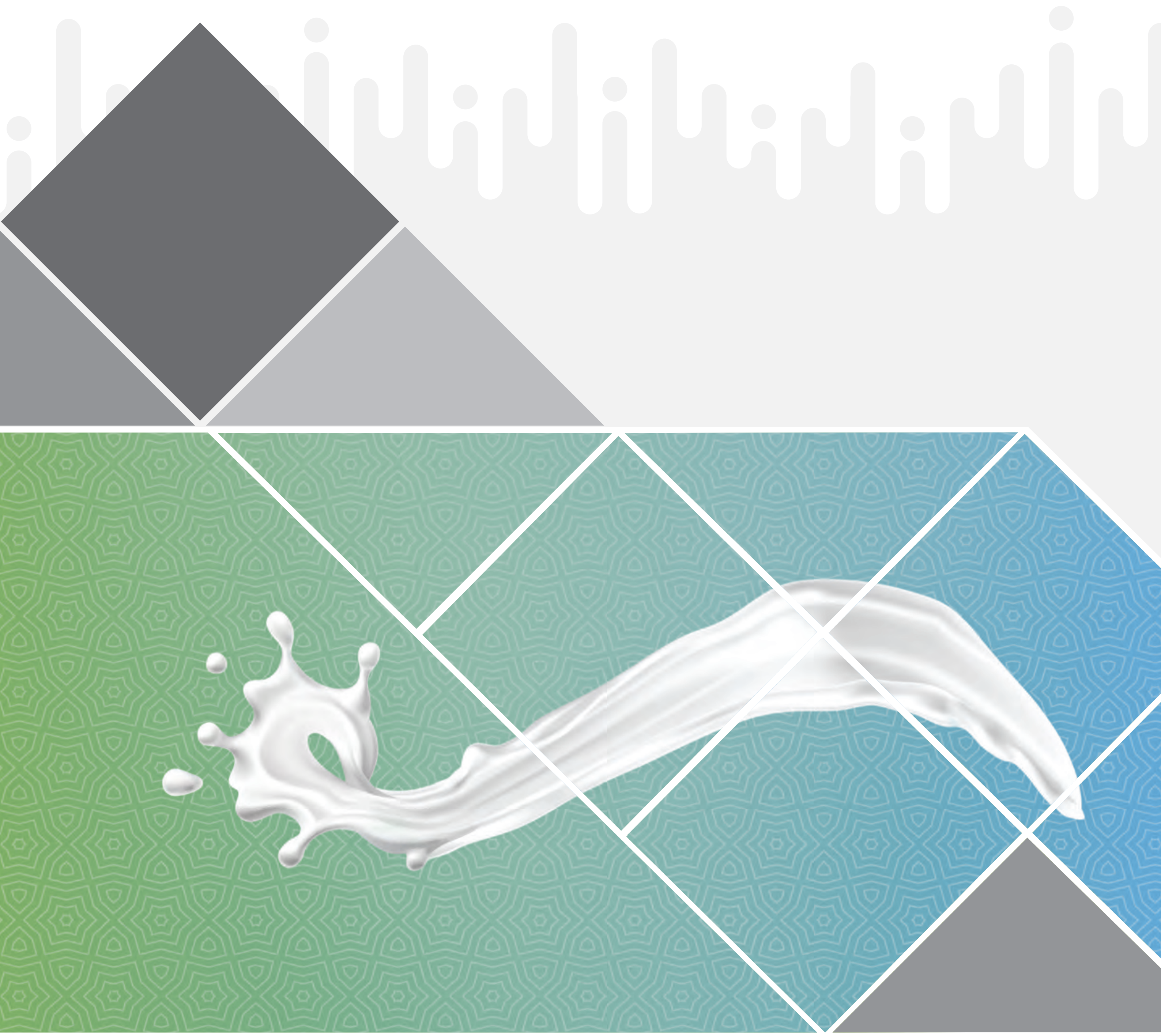

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