SECTION 2
HOUSING FOR DAIRY CATTLE


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:

$$\text{THI} = 1.8T_a - (1 - RH)(T_a - 14.3) + 32$$

where $T_a$ is ambient temperature in degrees Celsius ($^\circ\text{C}$) 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 $^\circ\text{C}$, was also developed to indicate heat stress levels, the equation being $\text{THI} = T_a + 0.36T_{dp} + 41.2$.

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.

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.
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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Environmental temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18°C</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>38.6</td>
</tr>
<tr>
<td>Respiration rate/min</td>
<td>32</td>
</tr>
<tr>
<td>Metabolic heat production (MJ/h)</td>
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</tr>
<tr>
<td>Water intake per day (l)</td>
<td>58</td>
</tr>
<tr>
<td>Concentrate intake per day (kg)</td>
<td>9.7</td>
</tr>
<tr>
<td>Hay intake per day (kg)</td>
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</tr>
<tr>
<td>Milk production per day (kg)</td>
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</tr>
<tr>
<td>Fat (%)</td>
<td>3.42</td>
</tr>
<tr>
<td>Fat production per day (kg)</td>
<td>0.63</td>
</tr>
</tbody>
</table>

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](image)

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)](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>With a wall</th>
<th>Without a wall</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total lying down time (min)</td>
<td>646</td>
<td>758</td>
<td>*</td>
</tr>
<tr>
<td>Total standing time (min)</td>
<td>380</td>
<td>254</td>
<td>*</td>
</tr>
<tr>
<td>Time standing in the manure alley (min)</td>
<td>174</td>
<td>107</td>
<td>*</td>
</tr>
<tr>
<td>Standing - perching (min)</td>
<td>156</td>
<td>113</td>
<td>ns</td>
</tr>
<tr>
<td>Standing in free stalls (min)</td>
<td>50</td>
<td>34</td>
<td>*</td>
</tr>
<tr>
<td>Total feeding time (min)</td>
<td>319</td>
<td>311</td>
<td>ns</td>
</tr>
</tbody>
</table>

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.

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.

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.

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.
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 holding 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](image)

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](image)

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>
<thead>
<tr>
<th>Feed barrier</th>
<th>Animals</th>
<th>Measurement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throat rail</td>
<td>Calves</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Heifers</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Mature cows</td>
<td>600</td>
</tr>
<tr>
<td>Neck rail</td>
<td>Calves</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Heifers</td>
<td>500 – 600</td>
</tr>
<tr>
<td></td>
<td>Mature cows</td>
<td>600 – 700</td>
</tr>
<tr>
<td>Feeding space</td>
<td>Calves</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Heifers</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Mature cows</td>
<td>650 – 750</td>
</tr>
</tbody>
</table>

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](image)
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.

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.

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.

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.

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.

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.

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 25.4. 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
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.