12

Environmental management

This chapter discusses the principles and practices to minimise the adverse effects of heat stress on the performance of dairy stock.

The main points in this chapter

- The comfort zone of milking Friesians is 6–18°C. Outside this range, stock must modify their behaviour, their thermoregulatory processes or reduce milk production and fertility.
- The severity of heat stress depends on many factors such as diurnal temperature, housing conditions, breed and level of milk production.
- The Temperature Humidity Index is a quantitative comfort index that relates closely to cow performance.
- Respiration rate is a simple measure of heat stress that farmers can easily use to modify management if necessary. This has been developed further into a panting score.
- Cooling measures for milking cows include designing sheds for maximum ventilation, sprinklers, fans, allowing cows outside during the evening and modifying feeding management.

12.1 Heat stress in milking cows

The comfort zone for milking Friesian cows is 6–18°C. Within this range, there are no measurable fluctuations in their physiological processes, while the energy input to output shows good biological efficiency, in that all body processes will be functioning in their expected ranges. Between –5°C and +5°C, appetite will be stimulated, while at the upper level, above 27°C, appetite is depressed and both biological and economic efficiencies decline. Above 24°C, feed intakes decreases by about 3% for every rise of 1.2°C.

The extent of the effects of temperature on appetite depends on the:

- type and quality of forage; intakes of high-fibre forages are more depressed at high temperatures
- type and quality of concentrates; cows will selectively eat more concentrates and less forages when heat stressed

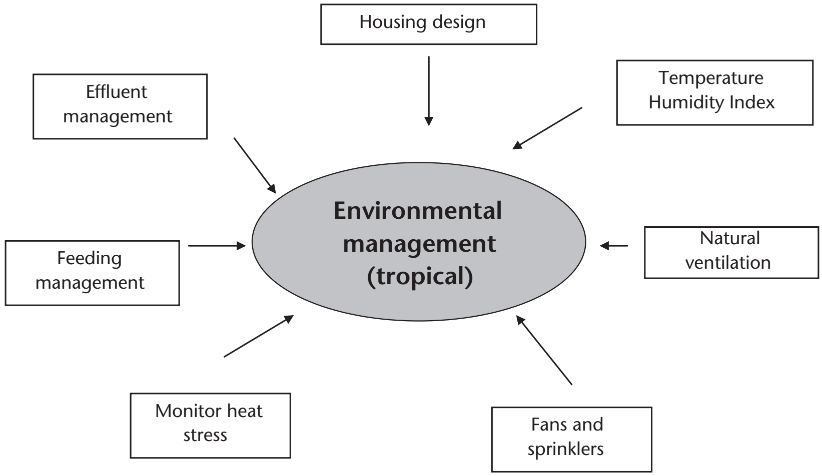

Figure 12.1. The key elements of environmental management on tropical dairy farms

- humidity; high humidity exaggerates the effect of high temperature
- stage of lactation; cows in early lactation are more susceptible to heat stress
- milk yield; high-yielding cows are more susceptible to heat stress
- actual appetite.

The basic thermoregulatory strategy of cows is to maintain a body core temperature higher than ambient temperature to allow heat to flow from the animal via four basic routes of heat exchange, namely:

- conduction, in which heat moves from a warmer to a cooler surface, so cows need direct contact with the surface
- convection, in which the layer of air next to the skin is replaced by cooler air
- radiation, in which heat can radiate from a warmer to a cooler environment
- evaporation, in which sweat or moisture is evaporated from the skin or respiratory tract.

The first three routes require a thermal gradient to operate in which air temperature must be lower than body temperature. Once air temperatures approach body temperature, the only viable method of heat loss is evaporation. This requires a vapour pressure gradient to be effective, so is very dependent on the humidity, or amount of moisture in the air.

Because cattle have a limited ability to sweat, the main route of heat loss in cattle during hot weather is evaporative cooling from the respiratory tract, namely the nasal passages and lungs. Cattle then increase their breathing rate to increase movement of air over the moistened surface of the upper respiratory tract and mouth. However, if humidity levels are high, the effectiveness of this evaporative cooling is decreased and cattle may be unable to dissipate accumulated body heat.

When planning feeding programs, consideration should be given to the number of hours each day when temperatures exceed 27°C and relative humidity exceeds 80%; feed intakes will decline once temperatures exceed 27°C or higher for 6 hr. Furthermore, high body temperatures reduce the efficiency of rumen digestion and increase body maintenance requirements, further increasing the energy deficit. The net effect on feed intake depends on the number of hours each day below 20°C, which allows cows to cool, hence restore their heat balance.

12.1.1 Symptoms of heat stress

There are many symptoms of heat stress (those more relevant to shedded cows are shown in italics) (Moran 2005). The initial signs are behavioural, while the last five signs are the more severe physiological ones due to a failure to cope, hence require immediate attention to reduce their adverse effects on cow performance. In order of increasing severity, they are:

- body aligned with direction of solar radiation
- seeking shade
- *refusal to lie down*
- *reduced feed intake and/or eating smaller amounts more often*
- crowding over water trough
- body splashing
- *agitation and restlessness*
- *reduced or halted rumination*
- grouping to seek shade from other animals
- *open mouthed and laboured breathing*
- *excessive salivation*
- *inability to move*
- *collapse, convulsion, coma*
- *physiological failure and death.*

As well as behavioural symptoms, heat-stressed cows will produce milk containing less milk protein or solids-not-fat. In addition, milk fat levels may decrease if cows markedly reduce their forage intakes.

The severity of heat stress depends on many factors. These include the :

- actual temperature and humidity
- length of the heat-stress period
- degree of night cooling that occurs
- ventilation and air flow
- cow breed and size
- level of milk production and dry matter intake prior to heat stress
- housing type, overcrowding and aspect
- availability of water
- coat colour, if exposed to sun
- hair coat depth.

Milking cows are maintained in a variety of environmental conditions. Without access to shade, the heat load on cattle grazing at pasture is generally lower than for cattle in dirt yards, because the dirt surface absorbs less heat then grass, thus radiates more heat onto the stock. For example, the surface of a dirt yard can reach 60–80°C (on a day with high solar radiation and ambient temperatures of 40–45°C), but it will cool down rapidly once the sun sets. Clearly, access to shade, whether at pasture or in yards, is highly desirable in regions with high radiation heat loads.

In addition, heat stress adversely affects reproductive performance in three ways:

- Acute stress can lead to embryo reabsorption, while chronic stress upsets normal cyclic status, through hormonal changes, particularly if cows are exposed for 6 hr or more to temperatures above 27°C.
- In late pregnancy, reduced foetal growth can also result from heat stress, leading to increased calf mortalities.
- The intensity of expression of oestrus is depressed, in that oestrus periods are shorter (for example 12 versus 17 hr) and, although cows do cycle during hot periods, the percentage of those actually observed can be as low as 35–40%. This can be partly overcome by more frequent observations, such as every 6 hr rather than 12 hr.

Most of the heat stress management research has been conducted with Friesian cows producing 25 kg milk/day or more. Many of the Friesians in Asia produce only 10–15 kg milk/day at peak yield. Such low levels of milk production are due primarily to poor feeding and water management. Poor feeding management involves the feeding of low-quality roughages, which will exaggerate heat stress because such fibrous feeds produce a lot of internal body heat during their digestion. Poor water management occurs when milking cows are rarely offered free access to drinking water and what volumes of water they are offered generally restrict feed intakes as well as water available for cutaneous evaporation.

Therefore one should ask how relevant are the heat stress guidelines for high-yielding cows to Asia's situation? The answer is that we really do not know until the relevant research has been undertaken. The data are just not available to develop heat stress guidelines for other temperate dairy breeds, such as Jerseys, let alone tropical dairy breeds. In the meantime, using the published guidelines for environmental management would be the best bet. Because reproductive efficiency is more sensitive to heat stress than is milk production, and poor calving performance is an all too common feature throughout Asia, current shed designs and cow cooling practices are clearly inadequate.

12.2 The Temperature Humidity Index

The best single descriptor of heat stress is the Temperature Humidity Index (THI), because this combines temperature and relative humidity into a single comfort index. The higher the index, the greater the discomfort, and this occurs at lower temperatures for higher humidities. The THI is presented in Appendix 1 of this manual, while its effect on cow performance is summarised in Table 12.1.

Heat load index

MLA (2006) has developed a heat load index to assess environmental heat load on feedlot beef cattle. This is based on a combination of measures of heat load, namely:

- black globe thermometer – a measure of radiation heat load that takes into account both ambient temperature and solar radiation

Table 12.1. Effects of Temperature Humidity Index (THI) on dairy cow performance

Comfort zone	THI	Stress	Comments
A	<72	None	–
B	72–78	Mild	Dairy cows adjust by seeking shade, increasing respiration rate and dilution of blood vessels. Cow performance is adversely affected with reproduction more so than milk yield.
C	78–89	Severe	Both saliva production and respiration rates increase. Feed intakes decrease while water intakes increase. Milk production and reproduction are both reduced.
D	89–98	Very severe	Cows will become uncomfortable due to panting, high saliva drooling and high body temperatures. Milk production and reproduction will markedly decrease.
E	>98	Danger	Potential cow deaths can occur

Comfort zone: A, No stress; B, Mild stress; C, Severe stress; D, Very severe stress; E, dead cows.

- relative humidity
- wind speed.

The index includes a number of adjustment factors such as genotype, coat colour, access to shade, water temperature in drinking troughs and whether the animal is sick or healthy. Use of this index over time allows for the calculation of an accumulated heat load and the required heat loss during the night to maintain zero heat balance. Developing such a heat load index for Asian small holder dairy cows, normally maintained in sheds, is unlikely to provide an additional useful management tool.

12.2.1 Adverse effects of heat stress

For Friesians producing 20 kg milk/day, a THI above 78 leads to a decline in milk yield. A THI of 78 occurs at 29°C with 50% humidity or at 27°C with 80% humidity. There is also a decline in milk composition (milk fat and milk protein contents), but this occurs at 1–2°C higher than corresponding break points for milk yield.

With regards reproduction, this declines before milk yield: namely at THI of 72, equivalent to 25°C plus 50% humidity or 23°C plus 80% humidity. Cows in early pregnancy (up to 3 weeks) can abort, while cows in mid-pregnancy can have reduced birth weights. Cows are also more likely to have shortened and/or silent heats (less than 8 hr). Heat stress delays heat (hence submission rates) and, at the time of insemination or during the following 3–5 weeks, it can reduce conception rates and increase embryo mortality. By comparing conception rates between seasons (hot versus cool or wet versus dry), heat stress may be diagnosed as a problem if seasonal conception rates differ by more than 10–12%.

Cows are particularly vulnerable at temperatures above 30°C or, above 25°C with high humidity. Cows producing more than 15 kg/day of milk are more susceptible to heat stress due to their higher metabolic heat load. Zebu cows are less susceptible than Friesians because of their dense flat coat and higher density of sweat glands, but exactly how less susceptible has not been documented. When planning strategies to minimise heat stress, it is important to give priority to non-pregnant cows, usually in early lactation.

The adverse effects of heat stress are delayed by several days. The effect of mean THI 2 days earlier has the greatest influence on milk yield, while the effect of mean temperature 2 days earlier has the greatest influence on feed intake.

Another good 'rule of thumb' when assessing heat stress for dairy cattle is that air temperature (in °C) added to humidity (in %) should be below 90.

12.3 Management practices to minimise heat stress

12.3.1 Clinical signs of heat stress

The following signs can be used to assess the degree of heat stress:

- mild heat stress: drooling, increased respiration to 80–100 breaths/min
- moderate heat stress: drooling, respiration of 100–120 breaths/min and occasional open mouth panting
- severe heat stress: drooling, respiration rate greater than 120 breaths/min and open mouth panting with tongue out. Cattle also have an agitated appearance, hunched stance and will often have their head down.

Cattle can move from mild to severe heat stress very quickly, within 30 min to a few hours. Therefore extra vigilance is required once mild heat stress is detected.

12.3.2 Monitoring respiration rates

Observing the behaviour of cows is important in deciding when to modify management. If respiration rates reach 70 breaths/min, milk yield and reproduction may be compromised; this corresponds to 39°C body temperature, in contrast to a normal body temperature of 38.5°C. Higher yielding cows have faster respiration rates, because of the extra body heat production associated with higher feed intakes and milk yields. For such animals, if respiration rates exceed 80 breaths/min in 70% of the cows, it is indicative of heat stress. Certainly, when they exceed 100 breaths/min, cooling strategies should be introduced.

Respiration rates are easy for farmers to monitor. The farmer should ensure the cow is standing or lying in a relaxed state and preferably cannot see the farmer. To improve accuracy, the farmer could move his hands in time with abdominal movements until they are at a steady rate. Using a watch, the farmer should count the abdominal movements for 10 seconds, repeating the exercise to ensure the count is consistent. Multiplying this by six will give the respiration rate in breaths per minute.

Monitoring respiration rates at various times of the day is a useful tool in assessing the suitability of sheds for milking cows. If rate exceed, say, 60 breaths/min in the morning, prior to the shed heating up, it is likely that the cows would benefit from simple modifications in their environmental management. It is unlikely that major modifications in shed design could be justified, such as increasing roof height or pitch or shed height at the side, although serious consideration should be given to constructing roof vents. If minor improvements cannot be made in the shed's natural ventilation, such as removing obstructions to the prevailing breeze, fans and/or sprinklers should be installed.

Table 12.2. Panting score to quantify heat stress

Panting score	Breaths/ minute	Breathing condition
0	<40	Normal with no panting. Difficult to see chest movement.
1	40–70	Slight panting, mouth closed with no salivation. Easy to see chest movement.
2	70–120	Fast panting with salivation present. No open mouth panting.
2.5	70–120	As for 2 but with occasional open mouth panting. Tongue not extended.
3	120–160	Open mouth panting and some drooling. Neck extended and head usually up.
3.5	120–160	As for 3 but with tongue out slightly, occasionally fully extended for short periods and excessive drooling
4	>160	Open mouth with tongue fully extended for prolonged periods and excessive drooling
4.5	Variable	As for 4 but head down. Cattle breathe from flank. Drooling may cease.

One enterprising farmer in Vietnam constructed a small shelter away from the cow shed, which maximised natural ventilation through a high roof and its location, making best use of prevailing wind. Whenever he noted cows with high respiration rates, he hosed them down then moved them to the small shed to alleviate their heat stress.

Panting score

The Australian beef industry has developed a panting score for use with feedlot beef cattle (MLA 2006). This could also be used by dairy farmers to asses heat stress in milking cows. Table 12.2 summarise the key features of the panting score.

Guidelines for lot-fed beef cattle are as follows:

- If more than 10% of the cattle exhibit panting scores of 2 or more, cattle handling should cease and only resume when conditions become cooler and cattle have returned to normal.
- Cattle with panting scores of 3.5 or more are in danger of death.
- If more than 10% of the cattle exhibit panting scores of 3.5 or more, there is potential for a serious problem to develop unless measures are taken to cool the stock.
- The transition from 2.5 to 4.5 can happen quickly – in less than 2 hr – under extreme conditions.

The panting score was developed primarily for lot-fed beef cattle often kept outside in dirt yards, with or without access to shade. This is not the normal situation with milking cows, which are either grazing at pasture (where heat loads are not as extreme as in dirt yards) or are maintained in sheds. Furthermore, the type of heat load is often different. In Australia, feedlot beef cattle are usually maintained in dry regions with high solar heat loads, whereas Asian dairy cows are usually kept in sheds where the heat load is more from high humidity and often poor air movement. However, there are some dairy regions in Asia, such as Punjab in Pakistan, where dairy cows are subjected to the same type of environmental management and heat stress as Australian lot-fed beef cattle.

12.3.3 Shed design

Assuming the sides of the shed are open to allow maximum ventilation, greater use can often be made of the principles of air movement when designing the roof. Because hot air rises, and considerable heat is produced by a concentration of milking cows in a shed, there should be an opening along the top of the roof, with a cap over it to restrict rain entering the shed. The roof slope should be greater than for feed sheds, namely 3–4° per 2.3 m, with the opening at least 50 cm wide, and the full length of the shed. A second design is a roof slope of 33° (4 in 12), with a vent at the top of 30 cm plus 50 mm per 3 m of width for sheds more than 6 m wide. The lowest point of the roof should be 3 m from the ground. The steeper roof pitch increases air flow across and above the roof, thus creating negative pressure over the opening. This hastens the flow of air out the top, as well as creating turbulence of air movement around the cows. If farmers are concerned about rain entering the shed through the vent, a gutter system can be installed below the ridge opening, while the concrete floor can be sloped away from the feeding area.

The shed should be sited so that wind breezes are not blocked by any obstacles or other buildings. Ideally, it should be on the highest ground possible, which will also be good for drainage of effluent, with other buildings located downwind on the site. There should be a minimum of four times the height of the nearest wind barrier as a horizontal separation. The ideal orientation, from a ventilation point of view, would allow the prevailing winds to hit the shed perpendicular to the side. This allows the wind to travel the shortest distance before exiting the shed, to improve the rate of air exchange and provide the cows with fresh air. The longer the shed, the more important is this perpendicular orientation to the prevailing winds. Other factors to consider are exposure of the outside stalls to sunshine, future expansion plans, cow flow, traffic flow and manure flow.

A north–south orientation is preferable to allow the sun to dry underneath both sides of the shed. An east–west orientation is not recommended because the southern side will have less opportunity to dry out. Trees should be planted on the western side of the shed to reduce solar radiation. Shade cloth, which blocks 80% of the light, can also provide protection provided it does not interfere with ventilation within the shed. I have seen mosquito netting across many shed openings in some regions, but such a decision would depend on recommendations of local veterinarians as to the potential animal health dangers of mosquito infestations. Eaves that extend one-third the side height will provide good sun protection.

White painted buildings reflect solar radiation better than dark painted buildings. Reflecting roof materials such as galvanised or aluminium are good long-term investments. Insulation under the roof can reduce the heat load, and one cheap and effective method is to use old egg cartons from poultry farms because these create large air gaps in the roof space. Spraying water on the roof may only be effective in reducing roof and shed temperatures in areas with low humidity.

12.3.4 Cooling cows

Garden hose

The easiest method to cool a cow is to hose it down for several minutes. Water should be applied to the head and back of the animal with enough applied so it runs off the back

Sprays to cool milking stock should consist of large water droplets (Pakistan).

and down the sides. This should reduce respiration rates to 60 breaths/min. If the cow is severely stressed prior to cooling, with open-mouthed and laboured breathing and excessive salivation, she may return to the feed trough and start eating.

Sprinklers

Evaporative cooling is an efficient way of cooling cows, provided it is effective. In hot humid areas, sprinklers should always be accompanied by some form of ventilation.

Sprinklers have the disadvantage of increasing humidity and making the floor wet. Many studies show that, although they are beneficial, without forced ventilation, in the short term they do not lead to significant gains in feed intake, milk yield or expression of oestrus over a full 24 hr period. Their effectiveness depends on the humidity because the drier the air, the greater the decrease in temperature.

Sprinklers need to be suspended 2.3 m from the ground above the feed troughs with the water directed to the back of cows. The droplet size should be medium to large, depending on the humidity. It is important to install a filter at the beginning of the waterline and the sprinkler nozzles should be easily removed for cleaning. The nozzles should be directional, if possible, so that for major prevailing wind shifts, they can be adjusted to reduce wetting of feed.

Applying water to cows every 5 min reduces heat stress more so than every 10–15 min. Ideally, cows should be sprinkled for 1–3 min, applying 1–2 mm of water per 15 min cycle. The pipe size depends on the length and area of the shed to be sprinkled, the number of sprinklers and the flow rate. Farmers should use 32 mm diameter pipe for up to 30 m length or 51 mm diameter pipe for 60–150 m length. Nozzles should be spaced at twice the radius of their throw; for example, every 2.4 m for nozzles with a 1.2 m radius.

Fans and water cooling in the hot dry tropics (Pakistan).

Cows can be hosed down at the same time as their udders and teats are cleaned in preparation for milking, but this should occur at least 30 min prior to milk harvesting to minimise water contaminating the milk.

Cooling fans

Providing a cooling fan increases the rate of cooling. A simple electric fan, which can be moved around the shed to be strategically placed behind any cow, is an effective method to increase the cooling rate of heat-stressed cows after being hosed down.

Permanent ceiling fans can be arranged in many ways. A 0.5 horse power, 0.91 m diameter fan rated at 5–6 m^3/min will blow a distance of 9 m, while a 1.0 horse power, 1.21 m diameter fan rated at 9–10 m^3/min will blow a distance of 12 m. The direction of the fans should be with the prevailing wind. In wide sheds, the side-by-side spacing width of 0.9 m fans should be about 6 m, whereas 1.2 m diameter fans should be spaced 9 m apart. They should be positioned about 2–2.2 m above the floor. Fans should be tilted so they blow down to the floor directly under the next fan (about 30° from the vertical).

Exhaust fans, that do not require external power, may be worth considering to encourage greater heat removal through the roof. Household fans on stands may be used to improve heat loss from the higher yielding cows.

12.3.5 Allowing cows outside overnight

Management systems can reduce heat stress by providing access outside the shed during the cooler afternoon and evenings, say after 1700 or 1800 hr. This will promote more effective conductive heat loss than inside, hence restoration of body comfort.

Moving cows outside following the afternoon milking could be combined with a change in routine milking management on small holder dairies: namely having a specific milking area within the shed, rather than milking cows where they are tethered. Milking parlours are easier to keep clean than the entire shed and the facilities can be sterilised periodically to improve milking hygiene.

It is difficult to monitor signs of oestrus in tethered cows. Providing cows with the opportunity to mingle in outside yards will allow them to seek out any cows on heat.

12.3.6 Feeding management

The digestion of fibre produces more heat in the rumen than the digestion of other carbohydrates. Therefore, offering most of the daily forages during the cooler periods of the evening will reduce internal heat production, particularly if the forages are high in fibre, which tropical forages usually are. Rations high in rumen-degradable protein can also depress appetite during periods of heat stress. Cows consume about two-thirds of their feed during the cooler evening and night. Feeding smaller amounts more frequently will reduce the likelihood of forages drying out and losing its palatability. Feed the best quality forages at night and feed more concentrates during hot periods.

The cooler the drinking water the better for both intake and temperature balance in the body. Offer more salt to replace the minerals lost in sweat.

When given continual access to feed, cows actively seek it from 0500 to 0900 hr and again from 1700 to 1900 hr. Milkings should be finished prior to 0600 and 1800 hr. Cows prefer feeding and watering following milking, after which they should be offered a dry surface on which to rest, preferably dirt. It is important that cows stand for at least 30 min after milking so the teat end can close to protect the teat canal from bacterial invasion.

Heat stress can lead to higher incidences of lactic acidosis. Depressed feed intakes will, firstly, reduce saliva production, which buffers the rumen against rapid changes in pH, and, secondly, reduce rumen contractions, hence movement of digesta out of the rumen. Furthermore, rapid respiration rates for lengthy periods can reduce the concentration of sodium bicarbonate in the saliva, reducing its buffering capacity even further. Cows may also preferentially select concentrates and reject forages, predisposing them to acidosis.

Reduced forage intakes can decrease milk fat contents, while milk protein (or SNF) contents may fall due to lower dietary energy intakes. The immune system of heat stressed cows being under greater strain, would make them less able to cope with sub-clinical mastitis, which would become apparent in higher levels of somatic cells in the milk. Not only would heat stress reduce milk yield, but its lower milk solids and higher somatic cell counts would reduce milk returns even further through lower unit returns for the milk.

Feed manger height is best when cows are eating with their heads down, to minimise wastage and obtain highest intakes. Cows produce 17% more saliva in this position compared with feeding with their head in a horizontal or raised position.

This page intentionally left blank