ISSN: 2456-2912
VET 2016; 1(3): 19-23

www.veterinarypaper.com
Received: 06-09-2016
Accepted: 07-10-2016

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Heat stress management in dairy bovines: An overview

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Abstract
With the consistent increase in milk consumption in the country, it is important to develop new technologies for higher milk production. However, the performance of dairy cows, including the yield and composition of milk, are depressed by heat stress. This paper reviews factors affecting the thermal balance as well as reproduction and production of lactating cows in hot environments. Thermal environments have several aspects, including air temperature, humidity, air movement, and radiation rate. However, the effective temperature is a simple and useful indicator for estimating the performance of lactating cows. Shade, fans, mist and fan systems, and night grazing and their effects, are presented as methods of modifying the environments of dairy cattle. Although heat stress causes a decline in dry matter intake, the cow's energy and protein requirements in hot environments increase. Therefore, it is important to increase the energy and by-pass protein contents of diets in order to maintain the performance of dairy cows in a hot environment.

Keywords: Dairy bovines, Heat stress, Milk production, Health, Reproduction

1. Introduction

Heat stress is brought about by any combination of high levels of temperature, humidity and solar radiation with little wind, so that temperatures are higher than the animal's comfort zone. Hot environments affect the performance of dairy cattle both directly and indirectly. To exploit the fullest genetic potential, environmental conditions and diets should be modified. In lactating Holstein cows, the comfortable temperature is within the range of 4-24°C (Hahn, 1981) [12]. The effects of heat stress on the cows begin to be observed above 24°C, and milk yield decreases markedly above 27°C (Johnson, 1965) [14]. In tropical countries, temperatures are generally in the thirties, and for short periods may be even higher than this.

The production of milk is directly related to the level of feed consumption. In hot weather, cattle generally reduce their feed intake. It has been estimated that at 40°C, feed intake (on a dry matter basis) is only about one half that eaten by cows living in their optimum temperature range. As a result, milk production falls. A decline in milk yield, fertility, and growth rate in hot environments is closely related to an increase in body temperature, which is a result of the balance between heat production and heat loss.

While heat stress causes a decline in dry matter intake, the cow's energy and protein requirements for maintenance and production is increased. It is important to increase the energy and protein content of diets, if dairy cows are to maintain their performance in hot environments. Careful management which can alleviate heat stress is the best way to maintain high production levels in lactating cows in a hot environment (Shibata, 1996) [27]. The same is illustrated in this review.

1.1 How does heat stress affect the reproduction?

- During high ambient temperatures, the dominant follicle develops in a low LH environment with reduced oestradiol secretion. Expression of oestrus is poor and fertility is reduced. Higher incidence of silent heat and anoestrus is most often reported in cows.
- On the other hand, a reduction in LH pulse and amplitude leads to prolonged follicular dominance, delayed ovulation and persistence of dominant follicles.
- Lower conception rate, the duration and intensity of oestrus are reduced. There is a markedly reduced quality of oocytes and reduced pregnancy rates.
- Development of larger number of bigger follicles probably leads also to an increased rate

Of double ovulations and twin calving (Sharma and Dhami, 2005) [23].

- Reproductive proficiency of lactating dairy cattle is greatly diminished. Dry cattle whose last 3 months of gestation occurred during hot weather had calves with smaller birth weights and more metabolic problems after calving. Also they produce 12% less milk in the next lactation (Sharma *et al.*, 2005) [23].
- Heat stress compromises uterine environment with decreased blood flow to the uterus and increased uterine temperature which can lead to implantation failure and embryonic mortality (Sharma and Dhami, 2005) [23].
- Heat stress is perceived as a major factor contributing to low fertility of dairy cows inseminated in the late summer months. The decrease in conception rate during the hot season can range between 20-30% as compared to the results obtained in the winter months.
- Heat stressed cows are less likely to exhibit standing oestrus and often only exhibit signs of oestrus at night when temperatures are cooler, but when they are less likely to be observed. In addition, duration of oestrus is shorter for cows subjected to heat stress (Sharma and Dhami, 2005) [23].

1.2 How does heat stress affect the milk production?

- The production of milk is directly related to the level of feed consumption. In hot weather, cattle generally reduce their feed intake. It has been estimated that at 40ºC, feed intake (on a dry matter basis) is only about one half that eaten by cows living in their optimum temperature range. As a result, milk production falls.
- Milk production may decrease as much as 50% (Sharma *et al*., 2005) [23].
- Dry matter intake starts to decline, and energy used for maintenance starts to increase, when environmental temperatures exceed 25°C. When ambient temperatures exceed 32.2°C, the dry matter intake (DMI) of cows might drop by 8-12%, and milk yield may fall by 20-30% (NRC, 1981) [21].

1.3 Clinical signs of heat stress

Cows under heat stress will seek out shade, reduce their feed intake (>10-15% reduction), increase their water intake and respiration rate, body temperature (>102.6°F), panting >60 breaths per minute (25-45 normal) and increase their production of saliva, sweat and urine to try to cool down. The results of heat stress are a lower milk yield (10-20% or more), reproduction disturbance and health problems in the dairy cows, and a severe economic loss of dairy business. High-producing cows are even more sensitive to heat stress, because of their high feed intake.

1.4 How to reduce heat stress

Careful management which can alleviate heat stress is the best way to maintain high production levels in lactating cows in a hot environment. Good management includes the modification of the surrounding environment to reduce the impact of the environment and/or to promote heat loss from the animals (Shibata, 1996) [27].

Preventing an increase in body temperature in hot environments can be approached in three ways (Shibata, 1996) [27]; (1) Lowering the environmental temperature by modifying the structure of the shed where the cattle are kept, or by introducing cooling facilities, (2) Increasing heat loss from animals by sprinkling them with water, using fans and so on, and (3) Increasing the efficiency of feed energy utilization, and reducing the heat increment of animals from feeding.

I. Shade – a Natural Cooling System

Shading is one of the most important and cheapest ways to modify the cow's environment during hot weather. Even for dry cows, providing shade can be a big help. Simple shade is the basic method in summer of protecting animals from direct solar radiation during the day. The most effective sources of shade are trees and other plants. They provide not only protection from sunlight, but also create a cooling effect through the evaporation of moisture from their leaves.

It was estimated that total heat load could be reduced from 30 to 50% with a well-designed shade (Bond and Kelly, 1955) [5], and shading is one of the more easily implemented and economical methods to minimize heat from solar radiation. Cows in a shaded versus no shade environment had lower rectal temperatures (38.9 vs 39.4°C) and reduced respiratory rate (54 vs 82 breaths/min), and yielded 10% more milk when shaded (Roman-Ponce *et al*., 1977) [24]. Cattle with no shade had reduced ruminal contractions, higher rectal temperature and reduced milk yield compared with shaded cows (Collier *et al*., 1981) [8].

II. Artificial Cooling Systems for Dairy Cows

Although shade reduces heat accumulation from solar radiation, there is no effect on air temperature or relative humidity and additional cooling is necessary for lactating dairy cows in a hot-humid climate. A number of cooling options exist for lactating dairy cows based on combinations of the principles of convection, conduction, radiation and evaporation.

Various cooling systems have been evaluated, and air conditioning dairy cows for 24 h/d improved 4% FCM yield by 9.6% in Florida (Thatcher, 1974) [32]. Missouri work showed that air conditioning was not an economical venture (Hahn and Osburn, 1969) [11]. Zone cooled cows (cooled air blown over the head and neck) averaged 19% greater milk yield than controls (Roussel and Beatty, 1970) [26], though other scientists concluded that a well-designed shade structure provided greater economic returns than the additional benefits derived from zone cooling (Canton *et al*., 1982) [7]. An 11.6% improvement in milk yield was reported when cows were sprayed for 1.5 min of every 15 min of operation (Strickland *et al*., 1988) [29].

Dry cows do suffer the deleterious effects of heat stress and may benefit from protection from the environment (Moore *et al*., 1992) [18]. When cows shaded during the dry period were compared with unshaded controls, the shaded cows delivered calves that were 3.1 kg heavier and yielded 13.6% more milk for 305 d lactation, even though all cows were handled similarly following parturition (Collier *et al*., 1982) [9]. The shaded cows had lower rectal temperature, respiratory rate, and heart rate and altered hormone patterns during the dry period. Similarly, cows that were cooled using sprinklers and fans during the dry period maintained lower body temperatures and delivered calves that were 2.6 kg heavier and cows averaged 3.5 kg more milk daily for the first 150 d of lactation than shade only (controls).

(1) Evaporative Cooling Pads and Fan System:

This method is effective in areas of low or high humidity, and cools the air, while raising the relative humidity. This system requires fans, evaporative cooling pads, and pumps to circulate water to the pads.

(2) Fog Systems
A fog system sprays small water droplets into the air and cools the air as the droplets evaporate. When an animal inhales the cooled air it can exchange heat with the air and remove heat from its body. High-pressure foggers disperse very fine water droplets, which quickly evaporates and cools air while raising the relative humidity.

(3) Mist and Fan System
This is an evaporative system which uses water mist and a fan. Mist particles are sprayed onto the cow's body to wet the hair. A fan is then used to evaporate the moisture, as a way of cooling the cows. The results showed an increase in milk production of 0.66 - 1.90 kg/day for cows producing 20 - 25 kg/day (Aii *et al*., 1998).
Large droplets from a low-pressure sprinkler system that completely wet the cow by soaking through the hair coat to the skin were more effective than a misting system (Armstrong, 1994) [3]. A combination of misters and fans was as effective as sprinklers and fans, where intake and milk yield were similar for the misted cows (Lin *et al*., 1998) [15].
Evaporative cooling systems improve the environment for lactating dairy cows in arid climates (Takamitsu *et al.,* 1987; Ryan *et al*., 1992) [30, 25], and the reduced air temperature results from the removal of heat energy required to evaporate water.

(4) Cooling Ponds
The cooling ponds have been found to effectively reduce body temperature with no apparent adverse effect on udder health or other diseases. The cattle were cleaner and easier to milk, with lower somatic cell and bacteria counts; perhaps resistance was enhanced by lower heat stress (Sharma *et al*., 2005) [23].

III. Night Grazing
Although air temperature and the level of solar radiation begin to fall after about 2 pm, the temperature of the roof remains high. As a result, the body temperature and respiration rate both rise. Cattle kept in a shed maintained a rapid heartbeat during the night. However, when the cattle were allowed out into a pasture at night, these physiological responses decreased immediately. This is the result, both of the reduction in radiation heat from the surrounding cattle, and the rise in heat loss from the cattle.

IV. Feeding of High Energy Diet and Feed Supplements
It includes use of fatty feeds, or the calcium salts of fatty acids, as way of improving the energy supply for cows in summer. Cows fed such a diet in hot weather had a higher milk yield, and a lower body temperature and respiration rate (Terada, 1996) [31].
Timed AI in combination with β-carotene supplementation improved pregnancy rates during periods of heat stress in dairy cows. Supplementation with selenium and vitamin E was found to have a beneficial effect on fertility in cows in hot environment (Arechiga *et al*., 1998) [2]. On the other hand, Ealy *et al*. (1994) [10] reported that cooling improved pregnancy rates slightly in heat stressed cows, but supplementation with vitamin E had no evident positive effect on pregnancy rates.

V. Selection of Heat Resistant Breeds
It is well established that *Bos indicus* breeds and their crosses show better resistance as compared to *Bos taurus* breeds to indirect negative effects of heat stress on production and reproduction performance.

VI. Hormonal Therapy to Augment Fertility during summer
Hormonal therapy does not address the causative effects of heat stress, however amelioration of some of its direct effects on the endocrine reproductive axis offers an opportunity to overcome the decrease in reproductive performance in cattle and buffalo during summer and early autumn (Borkhatariya *et al*., 2016; Mungad *et al.,* 2016) [6, 20]. The approaches include:

(1) Oestrus synchronisation for timed AI: Ovsynch protocol has been advocated as the method of choice for reproduction management in dairy cattle exposed to high ambient temperatures.

(2) GnRH administration at oestrus: Induction of ovulation with GnRH not only decreases the incidence of delayed ovulation (one of the major consequences of the heat stress), but also provide additional luteotrophic support for early CL.

(3) GnRH or hCG administration post-AI: Administration of hCG or GnRH post-AI supports the luteal function through a creation of additional corpora lutea and prevents precocious luteolysis through elimination of growing luteal phase follicles.

VII. Drinking Water
Water is the most important and critical nutrient needed by the animals. A loss of only one-fifth of body water is fatal. Cow bodies normally contain 55 - 65% of water (by weight). Lactating dairy cows need more water than other livestock, because 87% of milk is water. Drinking water is the major source of water, and satisfies 80 - 90% of dairy cows' total water needs. Water consumption is variable, and depends on ambient temperature, DMI, milk yield, sodium intake, physiological stage, and other factors. Under heat stress, water intake could significantly increase by 120 - 200%. High-producing HF cows are capable of consuming 190 liters of water each day (Beede, 1992) [4].
Water intake will increase by 30% or more during heat stress. Clean water should be provided to cows where they congregate during the day and while in the holding pen and return alley from the milking parlor. Using wet feeds in the ration or adding water to the ration can also help. Offering chilled drinking water enhanced milk yield for lactating cows (Milam *et al*., 1986) [17] by reducing body temperature through absorbed heat energy.

VIII. Nutrition (Energy and Minerals):
The most limiting nutrient for lactating dairy cows during summer is usually energy intake and a common approach to increase energy density is to reduce forage and increase concentrate content of the ration. The logic is that less fiber (less bulk) will encourage intake, while more concentrates increase the energy density of the diet. High fiber diets may indeed increase heat production.
Rations need to be formulated to compensate for reductions in dry-matter. Lower fiber diets produce less metabolic heat, though care must be taken to ensure that adequate fiber is still

provided. Additional fat is an option when needing to increase energy while maintaining necessary fiber.

Minerals may need adjustments as well. Cows sweat just like other mammals, but unlike humans, who sweat more sodium, cow's sweat contains a large amount of potassium. Mineral recommendations during heat stress include: Potassium: > 1.4% of DM, Sodium: 0.35 to 0.45% of DM, Magnesium: 0.35 to 0.40% of DM and Chlorine: < 0.40% of DM. Mineral adjustments should be made several weeks before the onset of high temperatures so minerals are present in the body when needed.

Lactating cows subjected to hot climatic conditions and supplemented with K well above minimum NRC recommendations (NRC, 1981) [21] responded with greater milk yield (Mallonee *et al.*, 1985; West *et al*., 1987) [16, 33].

Electrolyte minerals, sodium (Na) and potassium (K) are important in the maintenance of water balance, ion balance and the acid-base status of heat-stressed cows. When heat-stressed cows sweat, they lose a considerable amount of K. Increasing the concentration of dietary K to 1.2% or more result in a 3 - 9% increase in milk yield, and also an increased DMI.

Feeding very high-quality forage to lactating cows in hot summer is recommended, because it reduces heat build-up and supplies necessary long fibers. Another option is high-fiber, easily fermented feed by-products. Soybean hull, brewers' grain and beet pulp pellets are all rapidly degraded in the rumen. The greater energy density and high energy conversion efficiency of high-fat diets may be particularly beneficial during hot weather.

It has been reported that cows fed a diet supplemented with fat could improve their fat-corrected milk yield by 22% compared with the control group (40.5 vs 33.2 kg kg) during warm weather but not during cool weather (Skaar *et al*., 1989) [28].

IX. Feed Additives

Niacin can prevent ketosis, and is involved with lipid metabolism. Cattle fed with 6 g niacin per day in summer increased their milk yield by only 0.9 kg/day. However, with cows yielding more than 34 kg a day, there was a clear improvement in milk yield (2.4 kg/day) (Muller *et al.*, 1986) [19].

Most research with lactating cows concerned with microbial or "probiotic" products deals with either *Aspergillus oryzae* (a mold classified as a fungus) or *Saccharomyces cervisiae* (a yeast). The effect of *A. oryzae* on cows under heat stress was reviewed. Results indicated that three grams of *A. oryzae* supplementation had little effect on rectal temperature, respiration rate, or milk composition, but gave a 4% increase in milk yield (1 kg/day) (Huber *et al.*, 1994) [13].

X. Bunk Management

Wet feeds spoil faster in the bunk during hot weather. Keep feed fresh by feeding during early morning hours and in the evening when cows have better appetites. Consider feeding only a third of the ration during the day and two thirds in the evening when temperatures are cooler. Adding a TMR preservative, like Mold Zap, will retard feed heating in the bunk. Keep bunks free of spoiled feed to maximize the cow's appetite.

XI. Time of Feeding and Feeding Frequency

The feeding behaviour of animals changes when it is hot. Animals consume more feed during cooler evening hours (West, 1999) [34]. The quantity of feed and the feeding schedule should be adjusted to accommodate this behaviour. Having fresh feed in the mangers after milking is a good way to encourage DMI. When the weather is very hot, at least 70% of the daily feed should be given fresh at night.

2. Conclusions

While there are many methods of reducing heat stress, selection of the most appropriate technique and its proper application is essential. If one method proves successful in one place, this does not guarantee success elsewhere. There are also limitations related to the local climate, the educational level of farmers, and the amount of money farmers can afford to invest. A combination of fans, wetting, shade and well-designed housing can help alleviate the negative effect of high temperatures on dairy cows. Careful milking management, feeding strategies and sensitivity to animal behaviour are also important in achieving efficient reproduction and milk production in tropical dairy herds.

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