Chapter 9

Heat Stress Management for Milk Production in Arid Zones

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Additional information is available at the end of the chapter

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1. Introduction

Arid and semi-arid zones account for one third of the earth's surface land area and cover most parts of the developing nations in the world including Latin America, Africa, and parts of India and South East Asia. Nevertheless, these ecosystems are not exclusive of developing countries because they also exist in developed nations such as United States of America, Spain, Australia, and Israel, among others. Arid zones are characterized by excessive heat loads and an insufficient and erratic pattern of precipitation. Also, actual evapotranspiration equals rainfall and recharge of groundwater is relatively infrequent. In general, summers are very hot and intense, but winters have commonly cold weather. In many countries with arid zones, high environmental temperatures during summer seasons may last up to 6 months, with average temperatures over 30°C. This is important because approximately one third of the cattle population in the world is located in arid zones, and according to IPCC predictions, the global average surface temperature may increase between 1.8 and 4°C by year 2100 (IPCC, 2007). The negative effects of global warming will be manifest in animal agriculture of both developed and developing countries, but the pressure will be greater on developing countries because of their deficiency of resources, their lack of veterinary and extension services, and their limitations on research technology development (FAO, 2007).

One of the chief problems facing dairy producers located in arid regions is thermal stress. In temperatures above 28°C, even without humid conditions, lactating cows show evidence of hyperthermia and emerges a condition called heat stress, so that the events feed intake, milk yield, milk fat and protein production, as well as fertility rate are reduced. Meanwhile, body temperature and respiration rate show a significant increased (West, 2003).

There are a number of options to assist in minimizing the negative effects of heat stress on dairy cows. Some of these options are feeding management, housing and facilities adjustments, and selection of tolerant breeds. Rations should be adjusted to increase energy and protein intake while maintaining rumen and cow health. The purpose is to increase the quantity of grain fed and decreased the quantity of forage in the ration. Also, environmental modifications that help to alleviate heat stress problems are structure orientation, structure ventilation, use of shades, and use of cooling systems in different sections of the dairy farm. Evaporative cooling means a combination of wetting and forced ventilation drying the cow's coat to maximize the cooling effect. Milking parlors with adequate holding pens can employ the use of subsequent sprinkling and forced air in the pens. In dairies with adequate drainage and housing, evaporative cooling can be provided above the feed bunks in addition to or instead of in the holding pen (Armstrong, 1994).

Therefore to reduce heat stress on dairy cattle it is required a multi-disciplinary approach and should include nutrition, environmental modifications, and management practices. This chapter will focus on these strategies with special reference to arid zones.

2. Global warming and dairy farming

Emissions to the atmosphere of the gasses carbon dioxide, methane and nitrous oxide are believed to be a major cause of global warming. These gasses are able to absorb and emit infrared radiation, so they restrict the rate of thermal energy flowing out of the earth, causing the greenhouse effect. In addition, most of the observed increase in globally averaged temperatures since the last 200 years is very likely due to the increase in anthropogenic greenhouse gas concentrations. The animal agriculture sector is responsible for almost 40% of annual methane emissions that are consequence of enteric fermentation in ruminants and from farm animal manure (Koneswaran & Nierenberg, 2008). So is common to hear that livestock are important contributors to climatic change.

A resultant rise in the earth's temperature may boost the occurrence and concentration of severe climate events, as well as to intensify desertification of arid and semi-desert regions which results in warmer and more intense summers. The frequency and severity of extreme climatic events such as drought, flooding, and long heat waves would have substantial impacts on crop and livestock productivity, and therefore in food production and security. As a result of global warming, the prospective for food production from livestock is expected to decline because of high mortality, less productivity and more competition for animal resources (IFAD, 2010).

Dairy cattle are specially affected by climate change because most of the high production breeds were originated in cold regions. For instance, the breed Holstein was developed in Europe, in a cold region what is now The Netherlands, and then introduced to many ecological zones of the world such as tropical and desert regions. Because of that this breed is well adapted to cold environments, thus harsh ambient conditions like hot temperatures or elevated relative humidity make this breed difficult to reproduce and produce under these circumstances. Furthermore, Holstein breed is recognized as the world's highest milk production cattle nowadays. So many approaches have been made to adapt this breed to adverse conditions like those prevalent in arid and semi-arid zones (Place & Mitloehner, 2009).

Climate change is projected to increase the number of days each year when dairy cows experience heat stress. Kadzere et al. (2002) defined heat stress in dairy cows as all temperature-related forces that encourage changes or adjustments which may occur from the cellular to the total animal level to help the cows stay away from physiological disorders and then to better adapt to an adverse thermal environment. Heat stress in dairy cows results in greater nutritional requirements, lower fertility, reduced milk production and milk quality, and increased frequency of health-related issues such as mastitis. Using simulation models in a dairy basin located in Australia, researchers estimated that by 2025, production of greenhouse gas emissions will increase 25% heat stress days, which could account for a decline of 35 to 210 kg of milk per cow per year. Projecting this scenario by year 2050, there will be a 60% increase in heat stress days, which may result in a decline from 85 to 420 kg of milk per cow per year (Crimp et al., 2010).

Few years ago, St. Pierre et al. (2003) conducted an extensive study on the economic losses from heat stress to USA livestock revealing convinced evidence to all dairy farmers of the importance of providing heat abatement practices for their cattle. For dairy cows, the equations to estimate the cost of heat stress on productivity included dry matter intake, milk production, change in days open, change in monthly reproductive cull rate, and change in monthly death loss. Equations were also developed for replacement heifers that considered dry matter intake loss, weight gain loss, and change in monthly death rate due to heat stress. It was estimated that hot weather costs dairy farmers $ 900/million per year considering milk production and fertility. This economic loss was higher in dairy cattle compared to any other livestock specie in that country. The general conclusion was that for dairy cows some type of heat abatement is always economically justified across all states, and the optimum environmental strategy is the use of spray and fans. However, in regions where heat stress is more intensive, the use of high-pressure evaporative cooling chambers could be economically necessary.

3. Physiological changes in dairy cows attributable to heat stress

Dairy cows are homoeothermic animals, so they exhibit optimum performance in their neutral environment which is known as thermoneutral zone (TNZ). For lactating dairy cows from European breeds, this TNZ ranges between -5 and 25°C, and are called lower critical temperature (LCT) and upper critical temperature (UCT). Within this temperature range, dairy cows require no additional energy above maintenance to cool or heat their body. LCT is the environmental temperature at which an animal needs to increase metabolic heat production to maintain body temperature. UCT is the environmental temperature at which the animal increases heat production as a consequence of a rise in body temperature resulting for inadequate evaporative heat loss (Fuquay, 1981; Johnson, 1987). Figure 1 shows LCT and UCT for dairy cattle. Thermoneutral zone depends on the age, breed, feed intake, diet composition, previous state of temperature acclimatization, production, and housing and stall conditions, tissue (fat, skin) insulation and external (coat) insulation, and the behavior of the animal. As ambient temperature increases, the cow's body temperature will also increase. The physiological mechanisms for regulating body temperature are under the control of a region of the brain called the hypothalamus, which acts like a thermostat. There are two main mechanisms used by dairy cows to increase the amount of heat loss from the skin when heat stress is increasing internal heat production. The first is dilatation of the blood vessels in the dermis so that blood flows close to the skin surface and heat loss to the environment comes about. The second is by sweat production from the sweat glands (Willmer et al., 2004). The evaporation of sweat on the skin surface produces a cooling effect. However, dairy cows sweats at only 10 percent of the human rate, so that they are more susceptible to heat stress and need mechanical ways to reduce heat.

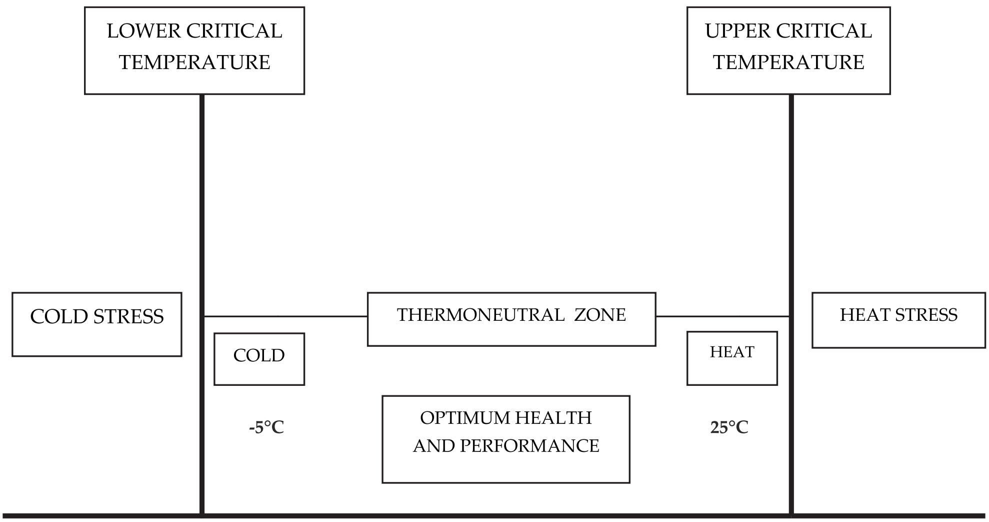

Figure 1. Critical temperatures and thermo-neutral zone in dairy cattle.

The physiological mechanisms for dealing with heat stress include sweating, more rapid respiratory rate, greater vasodilatation with increased blood flow to the skin surface, decreased dry matter (DM) and nutrient intake, reduced rate of metabolism, an altered water metabolism, and alterations of levels of numerous hormones. Maintenance of a high milk production during elevated ambient temperatures is determined primarily by the balance between metabolic heat production and heat loss. Metabolic heat production is relative to the amount of milk production plus the heat produced for maintenance. High producing cows exhibit more signs of heat stress than low producing cows because higher producing cows generate more heat as they eat more feed for higher milk yield (West, 2003).

The best recognized effect of heat stress is an adaptive depression of metabolic rate associated with reduced appetite (Silanikove, 2000). Reduced DM consumption, and consequently heat generated during ruminal fermentation and body metabolism, assists in maintaining heat balance. Furthermore, an elevated environmental temperature reduces gut motility, rumination, ruminal contractions and thereby depresses appetite by having a direct negative effect on the hypothalamus (Chaiyabutr et al., 2008; Kadzere et al., 2002).

As ambient temperatures get higher, the respiratory rate rises with panting growing to open mouth breathing. As a result cow enters in respiratory alkalosis resulting from a rapid drop of carbon dioxide. The cow counterbalances this situation by increasing urinary output of bicarbonate, and rumen buffering is affected by a reduction in salivary bicarbonate reservoir. The risk is that lameness, with individual ulcers and white line disease may emerge in a few weeks to a few months after the heat stress takes place (Wheelock et al., 2010).

The best approach to conclude that cows are being affected by heat stress is to measure the rectal temperature. Normal body temperature of the cow is about 38.5°C, and a cow that has a rectal temperature of 39°C or higher during the afternoon, and it is not sick, is possible to be heat stressed. Determining rectal temperature on group of cows in the afternoon can be a quick way to get a precise judgment of the degree of heat stress and the efficiency of any cooling system integrated into cow housing (West, 2003; Willmer et al., 2004).

Joint genetic selection for heat tolerance and milk production can be a possible way to reduce heat stress. Also, identification of genetic traits which enhance heat tolerance without affecting milk yield in dairy cattle breeds. Some of these traits would be coat color, hair length and genes controlling heat shock resistance n cells (Hansen and Aréchiga, 1999).

4. The temperature-humidity index (THI)

Usually, a reasonable assessment of cow's heat stress is the Temperature-Humidity Index, which combines ambient temperature and relative humidity to express an indicator of the degree of heat stress. This index was developed by environmental physiologists and it is shown in Table 1. It represents a general classification of different combinations of ambient temperature and relative humidity and is, at present, the most used stress index for use in animal production. There are different formulas to estimate the THI, being one of them as follows (Hahn, 1999):

$$\mathrm{THI} = \left(0.8 \times T_{db}\right) + \left[\left(RH/100\right) \times \left(T_{db} - 14.4\right)\right] + 46.4,$$

Where T_{db} is the dry bulb temperature in degrees Celsius, and RH the relative humidity

Temperature,	Relative Humidity, %																				
°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
23.3																72	72	73	73	74	74
23.9														72	72	73	73	74	74	75	75
24.4												72	72	73	73	74	74	75	75	76	76
25.0											72	72	73	73	74	74	75	75	76	76	77
25.6										72	73	73	74	74	75	75	76	76	77	77	77
26.1									72	73	73	74	74	75	76	76	77	77	78	78	79
26.7							72	72	73	73	74	74	75	76	76	77	78	78	78	79	80
27.2						72	72	73	73	74	74	75	76	77	77	78	78	79	80	80	81
27.8						72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
28.3					72	73	73	74	74	75	76	77	78	78	79	80	80	81	82	82	83
28.9				72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
29.4			72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
30.0			72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
30.6		72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	86	85	85	86	87
31.1	72	72	73	74	75	75	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
31.7	72	73	74	75	76	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
32.2	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
32.8	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
33.3	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
33.9	74	75	76	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91	92	93
34.4	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
35.6	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
36.1	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
36.7	76	77	78	79	80	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97	98
37.2	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	96	97	98	99
37.3	77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	
38.3	77	79	80	81	82	83	86	86	87	88	89	90	92	93	96	95	96	97	99		
38.9	78	79	80	81	83	86	85	86	87	89	90	91	92	96	95	96	97	96			
39.6	78	79	81	82	83	86	86	87	88	89	91	92	94	96	96	97					
40.0	79	80	81	82	86	85	86	88	89	90	91	93	96	95	96						
40.6	79	80	82	83	86	86	87	88	89	91	92	93	96	96	97						
41.1	80	81	82	86	85	86	88	89	90	91	93	94	95	97	98						
41.7	80	81	83	86	85	87	88	89	91	92	94	95	96	98							
42.2	81	82	83	85	86	87	89	90	92	93	94	96	97								
42.3	81	82	86	85	87	88	89	91	92	94	95	96	98								
43.3	81	83	86	86	87	89	90	91	93	94	96	97									
43.9	82	83	85	86	88	89	91	93	94	95	96	98									
44.4	82	86	85	87	88	90	91	94	94	96	97										
45.0	83	86	86	87	89	90	92	95	95	96	96										
45.4	83	85	86	88	89	91	92	94	96	97											
46.1	86	85	87	88	90	91	94	95	96	98											
46.7	86	86	87	89	90	92	94	95	97												
47.2	85	86	88	89	91	93	94	96	98												
47.3	85	87	88	90	92	93	95	97													
48.3	85	87	89	90	92	94	96	97													
48.9	86	88	89	91	93	94	96	98													
49.4	86	88	90	92	93	95	97														
50.0	90	89	90	92	94	96															

No stress

Mild stress

Moderate stress

Severe stress

Death

Table 1. Temperature-Humidity Index combining ambient temperature (°C) and relative humidity to determine the degree of heat stress (Adapted from Armstrong, 1994).

Below 72 units, which can be reached with 25 °C of ambient temperature and values below 50% of relative humidity, lactating dairy cows express their optimum productivity performance, so there are no evident signs of heat stress. Slight heat stress can be reached between 72 and 79 units of THI; dairy cows are likely to begin experiencing heat stress; cows start looking for shade to cover them from solar radiation, respiration rate increase but there is a minimum effect on milk yield. This heat stress level can be reached with combinations 25°C of ambient temperature and relative humidity values above 50%; or with 30°C and more than 30% of relative humidity. Moderate heat stress occurs from 80 to 89 units of THI, and cows show and increased in respiration and salivation rate. Reduction in feed intake is evident as well as an increase in water consumption. Body temperature increases and milk production and reproduction parameters are seriously affected. This level of heat stress can be reached with combinations of 35°C and 40% of ambient temperature and relative humidity respectively, or with 40°C of ambient temperature and 35% of relative humidity. The next level of heat stress ranges from 90 to 98 units of THI and is considered severe. Dairy cows feel very uncomfortable because of a dramatic increase in body temperature and respiration rate. Panting and drooling are common events under this level of heat stress and some cows even hang out her tongue. There are significant losses in milk yield and cows rarely become pregnant. When THI is above 98 units, heat stress is extreme and some dairy cows may die during this conditions, which are characterized by combinations of ambient temperature and relative humidity of 40°C and 60% or 49°C and 35% of relative humidity. These levels of heat stress are very excessive but not uncommon in arid zones during heat waves in summer months (Avendaño, 1998; Bohmanova et al., 2007).

5. Effects of heat stress on production and reproduction of dairy cattle

5.1. Effects on production

Dairy cows automatically will reduce their feed intake during period of heat stress, and this reduction could increase as weather becomes hotter. Typically, early and high producing cows are more directly and severely affected than late or low producing cows. The reduction in nutrient intake has been identified as a major cause of decline milk synthesis because has been associated to a negative energy balance state, regardless of the stage of lactation but under heat stress conditions (Wheelock et al., 2010). Nevertheless, in order to know the exact contribution of reduction feed intake to the overall reduced milk yield during heat stress, Rhoads et al. (2009) used a group of thermo-neutral pair-fed dairy cows to eliminate the confounding effects of nutrient intake. The cows were in mid-lactation and were either subjected to a THI of 80 units for 16 h/d (cyclically heat-stressed) during 9 d or kept under a THI of 64 units during 24 h/d (constant thermoneutral conditions). Both groups of cows were pair-fed to maintain similar nutrient intake. Heat-stressed cows showed a rapid reduction of 5 kg/d of DMI, reaching the nadir in DMI by day 4, and keeping constant afterward (Figure 1). Milk production was reduced in 14 kg/d and production steadily declining in the first 7 d and then reaching a plateau (Figure 2). In summary, these results indicate that the reduction in dry matter intake can only account for about 40 to 50% of the reduction in milk yield when cows are under heat stress conditions and that the remaining 50 to 60% could be explained by other changes induced by heat stress.

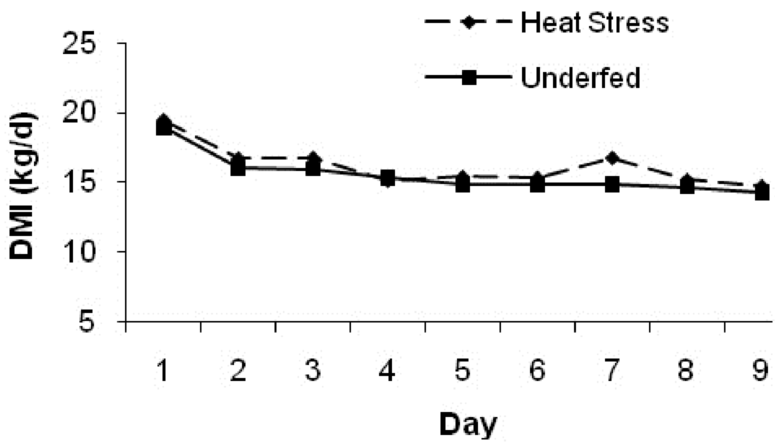

Figure 2. Effects of heat stress and pair-feeding thermoneutral lactating Holstein cows on dry matter intake (Adapted from Rhoads et al., 2007).

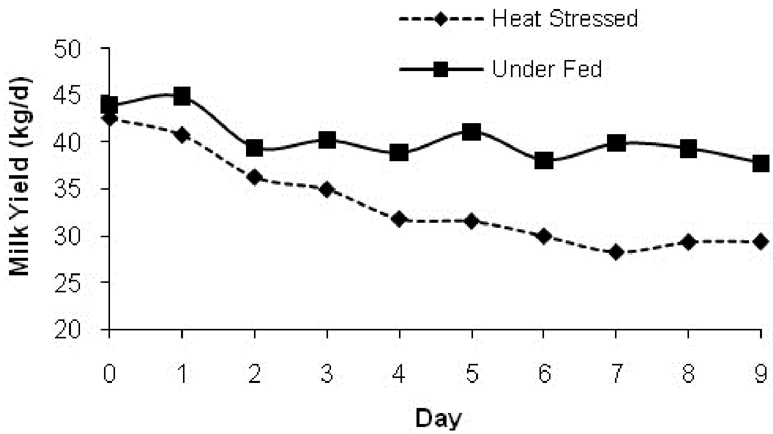

Figure 3. Effects of heat stress and pair-feeding thermoneutral conditions on milk yield in lactating Holstein cows (Adapted from Rhoads et al., 2007).

The mammary gland requires glucose to synthesize milk lactose, which is considered the primary osmoregulator and thus determinant of milk yield. However, in an attempt to generate less metabolic heat, the body (primarily skeletal muscle) appears to use glucose at an increased rate. As a result, the mammary gland may not receive adequate amounts of glucose; thus mammary lactose production and subsequent milk yield are reduced. This may be the primary mechanism which accounts for the additional reductions in milk yield that cannot be explained by decreased feed intake (Wheelock et al., 2010).

Acute stress in response to dehydration resulted in more intense inhibition of lactose and fluid secretion than of fat and protein secretion, which is reflected in increased fat and protein concentrations in milk, though these increases did not compensate for the overall reduction in their yields (Kadzere, 2002; Wheelock et al., 2010).

Silanikove (2000) states that heat stress stimulates a short-term rapid regulatory response, since in lactating cows under commercial conditions, the effects of heat stress that may be experienced under exposure to high ambient temperatures during the day appears to be alleviated when temperatures drop at night, and that lack of a cool night-time ambient temperature intensifies the reduction in milk yield.

5.2. Effects on reproduction

The detrimental effects of heat stress on reproduction processes of Holstein cattle have been well documented and include in cows: a) reduction in the intensity and duration of estrus, b) reduction in the pulse and amplitude of luteinizing hormone, c) reduced estradiol secretions, d) delayed ovulation, e) low progesterone concentrations, f) reduced quality of oocytes, g) decreased blood flow to the uterus, h) increased uterine temperature, i) higher follicular persistency, j) changes in endometrial prostaglandin secretions, k) increased embryonic mortality, and l) reduced fertility rates (Jordan, 2003). In bulls we have: a) hyperthermia of the scrotum, b) deterioration of semen quality as evidenced by reduced semen motility, semen concentration, percentage of motile sperm, and percentage of intact acrosome; as well as increased of abnormal sperm, c) decreased testosterone levels, and d) reduced spermatogenesis (Hansen & Arechiga, 1999; Wolfenson, 2009). So it is evident that the negative effects of heat stress on reproduction efficiency is the result of direct impact on reproduction functions and embryonic development, as well as indirect influences mediated by changes in energy balance. The negative energy balance is caused by a reduction in dry matter intake, and if this physiological status is prolonged may reduce plasma concentrations of insulin, IGF-1, and glucose, which finally can lead to retarded follicle development, poor estrus expression, and low quality of oocytes (Jordan, 2003). The effect of using cooling systems during summer on milk production performance and reproductive efficiency differs considerably, because of summer cooling is capable of substantially improves summer milk yield, while summer fertility is only slightly enhanced. Flamenbaum & Ezra (2003) conducted several trials during 4 consecutive summers in dairy herds located in an arid region of the Middle East to compare productive and reproductive traits during summer and winter. They found that milk production during summer months was almost similar (difference of 2 - 4%) to that during winter season, which means that cooling systems are capable of minimize the drop in milk production attributable to heat stress. In contrast, conception rates were only somewhat improved during summer, so that reproduction efficiency was still low in summer compared to the observed during winter. These results suggest that additional hormonal treatments are required during summer to further improved summer fertility. In addition, other studies in arid and semi-arid conditions have shown that fertility of Holstein dairy cows drop from 40 to 20% during summer months (Wolfenson, 2009).

Embryo transfer has been mentioned as a possible solution for improving summer fertility because it has shown a considerably progress in pregnancy rates during the summer months. This is because embryo transfer can escape the period in which the embryo is more susceptible to heat stress, considered before day 7 after AI (Jordan, 2003). However, embryo transfer is not a commonly adopted technique, consequently there is the necessity to improve events such as *in vitro* embryo production techniques, embryo freezing, timed embryo transfer, and decreasing the cost of commercially available embryos before this technique becomes a viable solution. In addition, altering biochemical properties of the embryo, or even its genetic modification before the embryo transfer, could be a possible way to improve thermo-tolerance and enhance summer fertility.

6. Nutritional and feeding strategies to minimize effects of heat stress in dairy cattle

Dairy cows reduce their feed intake during heat stress, so more nutrients need to be consumed into a smaller volume of feed. Maintaining adequate nutrient intake becomes vital to avoid a reduction in milk production. Some alternatives to increase dietary nutrient density include feeding high quality forage, feeding more grain and use of supplemental fats. Reducing the forage to concentrate ratio may result in more digestible rations that may be consumed in greater amounts. However, feeding more concentrate would have problems of acidosis and cows stop feeding. Sodium bicarbonate may help buffer the rumen to adapt to a higher levels of concentrate. Other feed additives that have been successful in heat stress conditions to stabilize rumen health from dietary modifications are yeast, which improves fiber digestion, and fungal cultures and niacin, which improves energy utilization. As a practical recommendation, do not use together these additives (Escobosa et al., 1984; Zimbelman et al., 2010).

Dairy cows experiencing heat stress often shows a negative N balance because of reduced feed intake. Increasing the level of crude protein may increase energy requirements and excess of dietary protein is converted to urea and excreted, causing problems of environmental pollution. It is suggested that during heat stress the level of crude protein in the diet should not exceed 18%, while the level of rumen-degradable protein should not exceed 61% of crude protein or 100 g/N/d (Huber et al., 1994).

The feed manager can provide shades in the feed bunk for added comfort to the cows while they are eating and feeding. It is also recommended to add a water sprinkler system and fans that are directed towards the cows to further reduce the heat felt in the place. Do not spray water on the feed as dry matter intake is important. As much as possible, keep the udders of the cows dry to reduce the possibility of having mastitis. Also make sure that the floor is still good enough for the cows to walk on and prevent injuries due to slipping.

Other strategies that dairy managers consider when feeding lactating dairy cows during heat stress periods are feeding frequency, time of feeding, and adequate feed bunk space. Feeding frequency consists of increasing an extra feeding or two during the day, obviously these extra feedings should be provided during the cooler times of the day. This strategy promotes a reduction of flies around the feed, therefore decreasing the insect population in the dairy barn. Also, increasing the amount of feed during these cooler periods of the day (early morning or late evening) is another alternative to avoid the reduction in feed intake during summer. Providing between 60 to 70 percent of the ration from 20:00 to 08:00 h has proven to have a positive impact on milk yield during periods of hot weather. The objective to provide enough space in the feed bunk is that all dairy cows can eat together without crowding (Hahn, 1999; West, 2003).

The increase in respiration rate and perspiration can cause an excessive loss of water, therefore reducing mineral levels in the cow. The recommendation is to increase K content from 1.3 to 1.5% of the total dietary dry matter, Na to 0.3% and Mg to 0.5%. Feed complete mineral mixes with higher K and Na levels only to the milking cows. If fed to dry cows, these mineral mixes may cause increased udder edema.

Water is really a priority when the temperature rises. We can say that management and the feeding of the cows are also part of the process in reducing heat stress in dairy cows. Some responses of the cows, though, can help reduce heat production in them, like selective consumption of feeds and cooling strategies. The dairy cows can only do so much and the dairymen are the one controlling their environment.

Before performing any critical modification to the diet during heat stress periods, be sure to ask for advice from a feed consultant. This is because we have to remember that dairy cows are under severe heat stress and any drastic change could be detrimental. Maintaining cows comfortable is the key to hold them eating which is critical in keeping them productive.

7. Environmental modifications to minimize effects of stress in dairy cattle

Use of environmental modifications such as shade and cooling systems is critical in arid and semi-arid zones affected by heat stress in order to maintain milk production, milk component levels, reproductive performance, and animal welfare.

The most basic attempt to reduce heat load from direct solar radiation in cattle is the use of shades. They can be from natural or artificial materials and are considered practical and economical ways for reducing heat stress. Trees are considered the most effective shade since they protect from the sun and capture radiation through the evaporation of humidity in the leaves (Avendaño, 1995). The wood or leaves of palms are materials also used for shade although corrugated steel sheets are the most widely used material because they last longer and of low maintenance costs (Armstrong, 1994).

Buffington et al. (1983) pointed out that painting of white color the upper part of the shade unit and installing a 2.5 cm thick of isolating material may considerable reduce solar radiation. For arid and semi-arid zones, areas of 3.5 to 4.5 m^2 per lactating cow are recommendable. A more reduced area could provoke lesions in the udder due to competition of cows for shade space, while an area greater than 4.5 m^2/cow have little or no benefit (Armstrong, 1994; Berman, 2006). Height of shades in the corral must be from 3.6 to 4.2 m^2 in order to guarantee reduction in solar radiation. However, the shade structure should be high enough from the ground to allow circulation and tractor access for corral cleaning.

Orientation of shades is also important to minimize heat load during summer months. North-South orientation will expose the surface to the sun under the shade during the morning and the afternoon, helping to maintain it dry, but under extremely hot conditions and low rainfall (10 to 12 cm), the East-West orientation could be preferable, although it requires greater labor for maintaining the surface under the shade in dry conditions. In any case, shades must be placed in the center of the corral and should avoid accumulation of humid material under the structure. If concrete floors are used, shade orientation is indistinct (Avendaño, 1995). Figure 4 shows an example of a shade for dairy cattle made from artificial material.

Figure 4. A group of cows seeking for shade during hot weather. Shade structure is from artificial materials.

Cooling systems alleviate heat load from dairy cows by using the principle of evaporation, combining water misting and forced ventilation through use of spray and fans, and are frequently placed inside free-stall barns or under shades in open space corrals (Berman, 2006). Even though responses have varied, cooling techniques have consistently improved feed intake and milk production in areas with high environmental temperatures (Armstrong, 1994; Ryan et al., 1992).

In general, cooling systems based on spray and fans consist of conventional fans of variable diameter (60 to 90 cm) suspended from the ceiling of the shade. There are lines with water sprinklers in front of them, that creates a kind of breeze with small water droplets which completely moisture the cow surface and skin and support loss of heat by evaporation. These cooling systems can operate at different time intervals which vary according climatic conditions. One disadvantage is the accumulation of moisture under the cooling area because cows spend hours under this area, so urine and feces build up very easily. More labor is required to maintain clean resting areas where the cooling is installed (Avendaño, 1995). Figure 5 shows a cooling system based on spray and fans located in a free stall barn to improve comfort of cows during feeding.

Figure 5. A cooling system based on spray and fans placed over the head-locks, next to the feedbunk.

Traditionally, dry cows are provided little or no protection against heat stress because they are not producing milk and it is erroneously assumed they are less prone to heat stress. However, dry cows are experiencing many physiological changes (milk-producing tissue formation, colostrum secretion, accumulation of antibodies, and final fetal growth) that may increase their susceptibility to hot weather and have a critical impact on postpartum cow health, milk yield and reproduction (Avendaño-Reyes et al., 2010a). Avendaño-Reyes et al. (2006) allocated a group of dry cows in a pen with a cooling system based on spray and fans and compared them to a group with just shade in the pen. Cooled dry cows showed better physiological status than control dry cows. Fat content and fat-corrected milk production at eight week postpartum was significantly higher in cooled cows, as well as conception rate; however, calf birth weight and milk yield showed a trend to be higher in the cooled group. In addition, culling rate was higher in the control group and there was a benefit for using the cooling system during 60 d prepartum in Holstein cows. The physiological rationale for improved postpartum productivity in response to prepartum cooling is not entirely clear, but heat stress was found to negatively influence secretory function of the udder by decreasing mammary blood flow, thereby reducing the efficiency of energy utilization for milk fat precursor synthesis (Kadzere et al., 2002).

Using a cooling system based on spray and fans and installed in the holding pen, previous to the milking parlor, in an arid zone with extreme hot temperatures, Avendaño-Reyes et al. (2010b) provided 1, 2 or 3 h of cooling to a mid-lactating Holstein cows bringing the cows to that site. They found that even though cows under the cooling management system with the highest time of cooling per day showed better milk yield (+2 kg/d of milk), their physiological status did not correspond to a those non-heat stressed lactating cows. So they conclude that is necessary to increase the time of cooling to effectively reduce heat load during severe summer heat conditions. Figure 6 illustrates an installation of a cooling system on the roof of the parlor holding pen, and Figure 7 exemplifies a cooling system based on evaporative environmental chambers.

Figure 6. A cooling system based on spray and fans installed in the roof of the holding pen, prior to the milking parlor.

Figure 7. A cooling system based on evaporative chambers. Note at the curtains in one side of the corral to avoid water misting goes out the shade.

With milk production increases between 5 and 10% the benefits for investment in cooling equipment (spray and fans) is from 2 to 3 years. As production increases approach to 20%, the profit on cooling investment could be one year or even less. Management strategies that reduce the impact heat stress has on milk peak production can produce large economic returns to cows that are in their second or higher lactation. The benefit of reducing heat stress in first lactation cows is considerably less because of their inherent lower productivity (Avendaño, 1995; Berman, 2006).

In Table 2 are presented several results of milk production from the use of three environmental modifications against heat stress in different regions of the world. It can be noted that the milk production from the use of spray and fans has a obvious advantage over the use of just shades in the corrals. However, there is no clear evidence that cooling chambers has an advantage over the use of spray and fans, recalling that the cooling chambers are characterized by a considerable investment cost.

In general, Livestock Environmental Management is an emerging area in Animal Science that is getting more acceptance due to the Climatic Change. This new area is an attempt to avoid adverse environmental impacts on animal production systems and is also an effort to minimize the need for expensive environmental protection measures for domestic animals.

Place	Shade	Spray and fans	Evaporative cooling chambers	THI	Cooling time	Reference
Missouri	23.3 [a]	25.3 [b]	--	76	24	Igono et al., 1987
Israel	37.2 [a]	40.7 [b]	--	80	9	Wolfenson et al., 1988
Saudi Arabia	--	26.8 [a]	27.7 [b]	88	12	Ryan et al., 1992
Mexicali	27.0 [a]	31.0 [b]	--	89	8	Correa et al., 2002
Arizona	31.0 [a]	39.1 [b]	37.9 [b]	85	11	Correa et al., 2004
Mexicali	19.1 [a]	21.1 [b]	--	88	4	Avendaño-Reyes et al., 2010b
Arizona	--	38.3 [a]	42.2 [b]	76	12	Burgos et al., 2008

[ab] Milk yield means with different superscript differ (P<0.05)

Table 2. Milk production of Holstein cows cooled with different environmental modifications in several studies in arid and semi-arid zones of the world.

8. Conclusions

It is clear that farm animals are not the cause of climate change. If livestock is managed and their feed production properly, cattle actually can help us take carbon out of the air and store it in the soil. Environmental issues will become more important and we need to make sure people understand that farm animals are part of the solution and not part of the problem. Tell people how cows are helping our farming systems to be more environmentally friendly and more sustainable.

The productive and reproductive efficiency of dairy cattle is notably reduced under conditions of high temperature. The temperature-humidity index is an indicator of the degree of heat stress on the animal. Hest stress is a heavy load for the cow's zootechnical performance and health status that costs the diary industry millions of dollars every year. Implementing adapted herd management strategies as early as possible before the problems are visible at production level is the key. These management strategies include primarily diet manipulation and environmental modifications. Summer environmental adjustments in arid zones mean to provide shades and cooling systems to efficiently reduce the negative effects of heat stress. Those environmental strategies have demonstrated to increase production performance during heat stress periods. However, an economical analysis helps to determine the best cooling system for a specific production system in arid ecosystems.

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