Review Article

Nutritional Strategies to Alleviate Heat Stress in Dairy Animals – A Review

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Abstract

Due to increased average temperatures and humidity, severe heat stress in dairy animals is observed, which leads to loss in milk production and health problems. Some of the most common signs of heat stress in cows are reduced feed intake, reduced milk yield and milk fat, reduced activity but increased respiration rate, increased body temperature and impaired reproductive performance. As the animal productivity decreases during the summer due to consequences of heat stress, it is one of the costliest issues facing animal producers and certainly one of the primary constraints to efficient and profitable animal husbandry in developing countries. The interventions to combat heat stress in animals include changing the physical environment, genetic improvement and nutritional interventions. The nutritional strategies like increasing water availability, energy and nutrient densities, providing specific supplementation such as trace minerals, vitamins niacin, chromium, selenium, antioxidants, electrolytes and rumen fermentation modifiers that have proven to alleviate heat stress in diary animals.

Key words: Dairy Animals, Heat Stress, Nutritional Strategies, Temperature Humidity Index

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Introduction

India ranks first in the world milk production with annual milk production of 132.4 million, and contributes about 16% to the world milk production (BAHS, 2014). For the rural people dairying has been playing a major role by providing livelihoods. However, nowadays environmental extremes are the major constraints in dairy animals which severely affecting production of milk. Because of the climate change effects, summer temperatures have been increasing worldwide, and this trend will continue in near future also (IPCC, 2007; Luber and McGeehin, 2008). Among the livestock animals dairy animals are likely to be impacted greatly by the effects of climate change. The IPCC (2007) predicts that by 2100 the increase in global average surface temperature may be between 1.8°C to 4.0°C. India also experiencing increased average temperatures and humidity, and more hot spells recently. Severe heat stress in dairy animals is observed due to hot days, followed by hot nights as cows accumulate heat and cannot adequately dissipate this body heat. In extremes deaths from heat exhaustion may occur during very hot and humid periods. As the animal productivity decreases during the summer due to consequences of heat stress, it is one of the costliest issues facing animal producers and certainly one of the primary constraints to efficient and profitable animal husbandry in developing countries. The interventions to combat heat stress in animals include changing the physical environment, genetic improvement and nutritional interventions. The nutritional strategies should be aimed at maintaining water balance, nutrients and electrolytes intake and/or to satisfy the special needs during heat stress such as vitamins and minerals. Aim of this review is to discuss some of the important nutritional strategies to alleviate heat stress in dairy animals.

Heat Stress and Its Assessment in Dairy Animals

Heat stress is the state at which physiological mechanisms get activated to maintain an animal's body thermal balance, when it is exposed to intolerable temperature and/or humidity. In other words, heat stress is used to describe influences outside of a body system, which can shift the internal mechanisms away from their normal or resting state (Lee, 1965). The environmental factors associated with heat stress which affect the physiological systems regulating thermal balance are primarily ambient temperature, relative humidity (RH, %) and radiant energy. Assessment of heat stress level in farm animals can be done by measuring degree of temperature and relative humidity (RH%), which are the most closely involved with heat balance. Such measurement is termed as temperature–humidity index (THI). The THI is defined by several equations based on measurement of temperature in Celsius or Fahrenheit. When temperature is measured in Celsius, the equation of THI is as follows (Marai *et al.*, 2001)-

$$\text{THI} = \text{db°C} - \{(0.31 - 0.31\ \text{RH})(\text{db°C} - 14.4)\}$$

Where, db°C = dry bulb temperature in °C and RH = relative humidity percentage (RH %) / 100.

The values obtained indicate the level of heat stress in animals as: < 22.2 = absence of heat stress, 22.2 to < 23.3 = moderate heat stress, 23.3 to < 25.6 = severe heat stress, and > 25.6 = extremely severe heat stress. The above equation is applicable in cattle as well as in buffaloes, goats and sheep. In addition to THI, body temperature and respiratory rate are recommended to be used as parameters to determine heat

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stress (Perez, 2000). When temperature is measured in Fahrenheit, the equation of THI is as follows (LPHSI, 1990)-

$$THI = db°F – \{(0.55 – 0.55\ RH)\ (db°F – 58)\}$$

Where, db°F = dry bulb temperature in Fahrenheit and RH = relative humidity (RH %) / 100. The obtained values indicate the heat stress as: < 72 = absence of heat stress, 72 to < 74 = moderate heat stress, 74 to < 78 = severe heat stress, and > 78 = very severe heat stress.

Effects of Heat Stress on Dairy Animals

The evidence of heat stress in dairy animals is often very subtle. Farmers see their cows standing quite contentedly huddled under the tree or near the water tank or at the far end of the paddock. Some of the most common signs of heat stress in cows are reduced feed intake, reduced milk yield and milk fat, reduced activity but increased respiration rate, increased body temperature and impaired reproductive performance. The most important effects of heat stress are discussed below (West, 2003; Najar *et al.*, 2010).

Dry Matter Intake

During the periods of heat stress in dairy animals, dry matter intake is reduced by 9 – 13%. The reduced feed intake is mainly due to panting, which reduces cud chewing, slows the breakdown of feed, and reduces the amount of water and buffers from saliva reaching the rumen. Early lactating and higher yielding cows are affected more quickly and severely. In grazing animals, standing in the shade to keep cool also restricts grazing time and decreases intake.

Milk Production

As the feed intake decreases, so does the milk production. Milk production drops further if water is limiting. Cows divert water from milk production to facilitate cooling.

Milk Fat

Milk fat content declines by up to 0.3% units during summer.

Fertility/Reproduction

During the summer season fertility rate is decreased in dairy animals as compared to winter season. Early embryonic deaths account for significant losses in heat stressed cows.

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Rumen Health

Recent research indicates that heat stressed cows have reduced rate of passage, lower rumen pH, higher rumen ammonia and change in volatile fatty acids. This affect appears to be independent of changes in dry matter intake. Heat stress can slow rumen contractions, which in turn slows digestion.

Nutritional Strategies to Alleviate Heat Stress

There are several nutritional strategies which can be used to mitigate heat stress in dairy animals. Increasing water availability to cows is one of most important strategy to alleviate heat stress. As feed intake is markedly decreases during heat stress, a common strategy is to increase the energy and nutrient densities (increased concentrates and supplemental fat) of the diet. In addition to the energy balance, reducing the fiber content of the diet is thought to improve the cow's thermal balance and may reduce body temperature. However, increasing ration concentrates should be considered with care as heat-stressed cows are highly prone to rumen acidosis. The nutritional needs of the cow change during heat stress, and ration reformulation to account for decreased DMI, the need to increase nutrient density, changing nutrient requirements, avoiding nutrient excesses and maintenance of normal rumen function is necessary.

Water, the Forgotten Nutrient

Water is undoubtedly the most important nutrient for dairy cows subjected to heat stress. Milk contains about 87 percent water, and water is critical for dissipation of excess body heat. Moreover, water intake is highly correlated with milk yield and dry matter intake (Dado and Allen, 1994). The consumption of water increases sharply as the environmental temperature increases because of greater water losses from sweating and from water vaporization with more rapid respiratory rates (panting), both efforts aimed at increasing evaporative cooling for the cow. So, the normal water supply recommendations are inadequate in the summer. Water intake increases by up to 50% as the THI approaches 80. Supply unlimited clean, cool and fresh water under shade within easy walking distance for the cow. Water in tanks long distances from the feeding area, especially if tanks are not shaded or the area between the feeding area and the tank is not shaded may force the cow to choose shade over water, limiting performance. So, place extra water points close to where the cows spend most of the time.

Fat Supplementation

Increasing the amount of dietary fat has been a widely accepted strategy in order to reduce basal metabolic heat production. The heat increment of fat is less (up to 50%) than the forages, so it is seemingly a rational decision to supplement additional fat and reduce fiber content of the diet. Studies where fats have been fed to heat-stressed cows have shown inconsistent responses in improving milk

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production; some have improved milk production, and others have shown no response. Recently, Melo *et al.* (2016) reported that supplementation of palm oil significantly reduced rectal temperature and respiratory frequency, increased milk yield, reduced DM intake and increased feed efficiency in lactating cows. Similarly, Wang *et al.* (2010) observed that supplementation of saturated fatty acids improved milk yield and milk fat content and yield and reduced peak rectal temperatures in mid-lactation heat-stressed dairy cows. In contrast, Moallem *et al.* (2010) indicated that cows fed additional fat increased rectal temperatures and respiratory rates. Other researchers reported little or no differences in rectal temperatures (Knapp and Grummer 1991; Chan *et al.*, 1997; Drackely *et al.*, 2003).

Fiber Level in Ration

One common nutritional strategy involves reducing dietary fiber during an increased heat-load. However, adequate fiber in the diet is essential to maintain rumen health, and high quality forage helps to maintain feed intake. NRC (2001) recommended that minimum dietary neutral detergent fiber (NDF) of 25% with the proportion of NDF from roughages equaling 75% of total NDF. However, its digestion and metabolism create more heat than compared to concentrates (Van Soest *et al.*, 1991). Grant (1997) demonstrated that a roughage NDF value of 60% still provides sufficient fiber for production of fat-corrected milk. Cows fed diets containing NDF from soya hulls and cassava residue produced more 4% fat-corrected milk, lost less body weight, and had lower rectal temperatures (Kanjanapruthipong *et al.*, 2015).

Protein Level in Ration

As feed intake is progressively depressed due to heat stress, it is necessary to increase the protein level of the ration (West, 1999). However, the proportion of the dietary protein that must be provided as rumen un-degradable protein (bypass protein) must be increased, since the net passage of microbial protein from the rumen declines with lower DM intake. The oversupply of rumen degradable protein will lead to its inefficient use in the rumen which in turn will require the animal to expend energy to convert this wasted protein (as nitrogen) to urea which will largely be excreted in the urine. The negative effect of increased dietary protein agrees with recent recommendations which suggest that addition of dietary crude protein is not helpful during heat stress (Arieli *et al.*, 2006). How heat stress affects dietary protein requirements is not well defined and more research is needed in order to generate more appropriate recommendations.

Selenium Supplementation

Natural and synthetic antioxidants in the feed as well as optimal levels of minerals, principally selenium, help to maintain efficient levels of endogenous antioxidants in tissues. Selenium protects tissues against oxidative stress, as it is a component of the glutathione peroxidase (GPX) enzyme, which destroys free

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radicals in the cytoplasm. Calamari *et al.* (2011) reported an improvement in the preventive antioxidant systems in terms of the prevention system of free radical formation and chain breaking antioxidants in cows fed selenium-yeast, with a lower lipid peroxidation during hotter periods, when animals are subjected to more oxidative stress. Similarly, Thatcher (2006) reported an increase in immune-competence at parturition, an improvement in uterine health and second service pregnancy rate during the summer months in cows fed selenium-yeast prior to calving.

Chromium Supplementation

Chromium is a micronutrient that facilitates insulin action on glucose, lipid, and protein metabolism (Mertz, 1993). Spears *et al.* (2012) reported that heifers supplemented with increasing amounts of chromium had increased insulin sensitivity, suggesting that chromium plays an essential role in glucose metabolism in ruminants. Because glucose use predominates during heat stress, chromium supplementation may improve thermal tolerance or production in heat-stressed animals. In addition, supplementing heat-stressed early lactation dairy cows with chromium reduced the degree of weight loss, improved milk production, reduced plasma NEFA concentrations, and improved rebreeding rates (Soltan, 2010; Mirzaei *et al.,* 2011). Dietary inorganic chromium supplementation in summer-exposed buffalo calves improved heat tolerance, immune status and potency of insulin hormone (Kumar *et al.,* 2015). However, further research using varying concentrations and lengths of chromium supplementation should be done to determine the ability of chromium to alleviate the deleterious effects of heat stress in dairy animals.

Niacin Supplementation

Niacin (vitamin B_3) is known to increase peripheral vasodilation to increase sweat gland activity in dairy cattle (Gille *et al.,* 2008). Recently, Zimbelman *et al.* (2010) demonstrated that cows supplemented with encapsulated niacin at a dose of 12 g/cow/d during acute thermal stress had a lower core body temperature and increased sweating rates, which are adaptive mechanisms to allow for dissipation of more body heat to the surface area through peripheral or vasomotor function and/or increased sweating. This prevents some of the decrease in DM intake due to heat stress thereby improving milk production (Di Constanzo *et al.,* 1997). Di Constanzo *et al.* (1997) reported that cows undergoing mild to severe heat stress fed encapsulated niacin at 12 and 24 g/cow/d had reduced skin temperatures and increased milk production during summer heat. Feeding encapsulated niacin had different responses on milk production and milk components depending on the degree of heat stress and/or, possibly, the stage of lactation of the cows (Zimbelman *et al.,* 2013). However, Yuan *et al.* (2011; 2012) found that supplementation with 12 g/cow per day of the rumen protected niacin modified lipid metabolism but did not affect milk yield

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over the first 3 weeks of lactation or oxidative stress of transition dairy cows. Rungruang *et al.* (2014) also observed that supplementation of encapsulated niacin did not improve thermo-tolerance of winter-acclimated lactating dairy cows exposed to moderate thermal stress.

Dietary Cation Anion Difference (DCAD)

Dietary cation anion difference (DCAD) is the difference between certain dietary minerals nominated as cations (Na, K) and anions (Cl, S) on the basis of charges they carry and is usually measured as milliequivalents of (Na+K)-(Cl+S) per kilogram of DM (Sarwar *et al.*, 2007). Wildman *et al.* (2007) stated that keeping the DCAD at a healthy lactating level (200 to 300 mEq/kg DM) remains a good strategy during the warm summer months. Animal productivity is influenced more by the difference between these cations and anions than their individual effects when fed as a sole independent mineral source. In addition, Shahzad *et al.* (2007; 2008) reported that a diet having DCAD 330 mEq/kg DM has promoted feed consumption, water intake and resulted in greater milk yield and milk fat in early lactating buffaloes.

Electrolyte Supplementation

Unlike humans, bovines utilize potassium (K^+) as their primary osmotic regulator of water secretion from sweat glands. As a consequence, K^+ requirements are increased (1.4 to 1.6% of DM) during the summer, and this should be adjusted for in the diet. Kumar *et al.* (2010) reported that supplementation of electrolyte relieved oxidative stress and improved cell mediated immunity in heat stressed buffaloes. In addition, dietary levels of sodium (Na^+) and magnesium (Mg^+) should be increased as they compete with K^+ for intestinal absorption (West, 2002).

Rumen Fermentation Modifiers

Monensin (an ionophore) is a well-described rumen fermentation modifier that increases the production of propionate, which is predominate gluconeogenic precursor in ruminants and thus improve the glucose status of heat-stressed cows (Baumgard *et al.*, 2011). The use of live yeast cultures (*Saccharomyces cerevisiae*), has been extensively used to enhance nutrient utilization in ruminant animals (Francia *et al.*, 2008). Many studies with dairy cows (Schingoethe *et al.*, 2004; Bruno *et al.*, 2009; Shwartz *et al.*, 2009) reported that yeast culture supplementation increased feed intake during heat stress. In addition, supplementation of yeast culture (Bruno *et al.*, 2009; Singh *et al.*, 2011) and other fungal cultures (Huber *et al.*, 1985; Gomez-Alarcon *et al.*, 1991; Higginbotham *et al.*, 1993) decreased rectum temperature and respiration frequency during heat stress. Bruno *et al.* (2009) and Huber (1998) reported that the supplementation of increased milk production in dairy cows during heat stress.

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Control and Prevention Measures

The most important control and prevention measures to avoid heat stress in dairy animals are listed in Table given below (Noordhuizen and Bonnefoy, 2015).

Farming Area	Control and Prevention Measures
Nutrition	Increase the frequency of feeding to 4-6 times a day; give the highest proportion at late evening or during the night
	Reduce the effects of a negative energy balance around calving: maintain feed intake at a normal level during close-up and fresh cow period. Take care of optimal claw health.
Drinking water	Increase the number of drinking places. Total width of drinking places must be 600 to 900 cm for 100 cows. Provide water of low temperature (< 15°C) and clean troughs every 2 days. Check water quality beforehand (chlorates, sulfates, microbes) regularly.
Barn climate	Create shadow over feed bunks (at 4-5 m^2 per cow) at 4 m height
	Install and use appropriate fans
	Install and use showers, water spray producing devices, or sprinklers
	Increase the number of sprinkling and drying cycles per day

Summary

Dairy animals are more sensitive to heat stress, which has significant economic impact for the farmers in terms of decreased productivity and health problems. Implementing heat stress mitigation strategies is crucial to minimize fiscal losses. In addition to physical environment management, nutritional strategies can be implemented to help ameliorate heat stress induced losses. Nutritional strategies to alleviate heat stress in dairy animals are summarized below-

- Water is the most important nutrient of all to minimize heat stress, provide access to plenty of clean fresh water.
- Encourage maximum DM intake and increase density of energy and other nutrients to compensate for reduced DM intake.
- Supplement fat to the diet to improve energy density and to improve efficiency.
- Use high quality forages to increase the energy content of the diet and to maintain adequate rumination, and decreases the heat of fermentation associated with feeding lower-quality forages.
- As protein quality is important during hot weather, increase rumen un-degradable protein in ration and avoiding excessive rumen degradable protein.
- Consider specific supplementations such as niacin, chromium, selenium, antioxidants, electrolytes and rumen fermentation modifiers that have proven beneficial during heat stress.
- Heat-stressed dairy cows should be fed adequate amounts of trace minerals and vitamins.

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