Article 103

Nutritional Interventions to Combat Heat Stress in Dairy Animals

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Stress due to stressful environmental conditions especially during peak summers affects the production ability in dairy animals and this situation is further aggravated by humid climate. Extent of heat stress can be measured by the temperature-humidity Index (THI). A THI level above 75 is considered stressful and requires urgent management. Nutritional interventions are one of the vital tools to combat the heat stress situation. Provision of clean drinking water round the clock is the most important and primary requisite of management. Feeding nutrient dense meals at cool hours of day will help to compensate the reduced feed intake. Altered nutritional requirement during summer stress could be taken care by maintaining proper mineral balance and a healthy ruminal environment. Increasing the DCAD of diet (optimum level +25 to +30 mEq/100 g DM) also enhances intake and improves blood buffering capacity to overcome acidosis. Antioxidant rich diet supplementation checks cortisol level and induces antioxidant enzymatic activity, thus reduces incidences of reproductive losses.

KEY WORDS
Heat stress, nutrition, dairy animal.

INTRODUCTION

Extreme environmental conditions during the summer could have negative impact on the performance of the dairy animal (Hubbard et al., 1999). Cattle in general gain heat through metabolic heat production and environmental heat gain through solar radiation input and elevated ambient temperature. The environmental factors coupled with metabolic heat, create difficulties for the animal to maintain their thermal balance. Any disturbance in thermal balance may result in elevated body temperature, which in turn initiates compensatory and adaptive mechanisms to reestablish homeothermy and homeostasis. High relative humidity, lack of air movement and poor night cooling are additional factors of heat stress. Heat stress is a result of an imbalance between heat gain and heat dissipation in an animal, and when the heat load of a cow is greater than her capacity to lose heat (Wagner, 2001).

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THE TEMPERATURE-HUMIDITY INDEX: A TOOL TO MEASURE LEVEL OF HEAT STRESS

A temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress.

THI = 0.72 (W+D) +40.6,

Where W = Wet bulb temperature ^{o}C and D= Dry bulb temperature ^{o}C

The THI values of 70 or less are considered comfortable, 75-78 stressful and a value greater than 78 causes extreme distress with lactating cows being unable to maintain thermo regulatory mechanisms or normal body temperatures.

Humidity is the limiting factor of heat stress in humid climates, whereas dry bulb temperature is the limiting factor of heat stress in dry climates (Bohmanova et al., 2007). The severity of heat stress is correlated to both ambient temperature and humidity level (Figure 1). The bovine thermal comfort zone is -13ºC - +25ºC. Within this temperature range, the animal comfort is optimal, with a body temperature between 38.4ºC and 39.1ºC (Lefebvre and Plamondon, 2003). Above 25ºC, and even 20ºC for some authors, the cow suffers from heat stress; its health status and zoo-technical performance are affected.

BIOLOGICAL CONSEQUENCE OF HEAT STRESS

Heat stress on an overall basis reduces feed intake accompanied by reduced rumination and nutrient absorption and increased maintenance requirements which results into decrease in nutrient availability for production purposes (Collier et al., 2005). Such a thermal stress also alters endocrine status of animal (Collier and Beede, 1985). Heat stress showed a reduction in growth rate in growing calves which may be due to lower energy generation and impaired metabolism (Bahga et al., 2009). Amino acid turnover gets lowered while bone resorption/alkalosis occurs which is indicated by higher alkaline phosphatase activity (Bahga et al., 2009).

Heat stress has long been known to adversely affect rumen health. One way cows dissipate heat is via panting and this increased respiration rate results in enhanced CO_2 (carbon dioxide) being exhaled. In order to be an effective blood pH buffering system, the body needs to maintain a 20:1 HCO_3^- (bicarbonate) to CO_2 ratio. Due to the hyperventilation induced decrease in blood CO_2, the kidney secretes HCO_3^- to maintain this ratio. This reduces the amount of HCO_3^- that can be used (via saliva) to buffer and maintain a healthy rumen pH. In addition, panting cows increase drool which reduces the quantity of saliva that would have normally been deposited in the rumen. The reductions in saliva HCO_3^- content and the decreased amount of saliva entering the rumen make the heat-stressed cow much more susceptible to sub-clinical and acute rumen acidosis (Baumgard et al., 2006).

ECONOMIC LOSS

According to an estimate India is currently losing nearly two per cent of the total milk production among cattle and buffaloes i.e. 1.8 million tons at national level due to rise in heat stress among cattle and buffaloes because of the global warming. This loss in terms of cash is amounting to a whopping Rs. 2,661 crore. Among different states, UP (with high THI index), loses 25.4 million tons milk per year followed by Tamil Nadu (23.8 million tons), Rajasthan, Bihar, Gujarat, Andhra Pradesh and Haryana (Business Standard, Nov 26, 2010)

STRATEGIES FOR LIMITING THERMAL STRESS

There could be three possible strategies to minimize the effects of thermal stress:

1) Physical modification of the environment.
2) Genetic development of heat tolerant breeds.
3) Improved nutritional management practices.

NUTRITIONAL INTERVENTION TO COMBAT HEAT STRESS

Among all nutritional interventions could be one of the easier and promising options to minimize the effect of heat stress as during heat stress the nutrient requirements of animals are altered, which results in the need to reformulate rations. Thus, nutritional interventions should be tried with aim to improve the following attributes in a synchronized manner:

a) Maintenance of the altered nutritional need
b) Compensation for reduced DMI
c) Feeding meals at cool hours
d) Maintaining the mineral balance
e) Management of the oxidative stress
f) Maintenance of healthy rumen

To compensate the reduced dry matter intake there seems to be an urgent need to increase in nutrient density, side by side one must have to go for recalculation of mineral and water requirements due to increased loss of potassium through sweat during hot and humid environment (Collier et al., 2005).

Feeding Regimen

The feeding behavior of most of the animals changes during summers and they tend to consume more feed during cooler periods of the day i.e. evening hours (West, 1999). Thus, feeding animals at more frequent intervals and during the cooler periods of day will not only encourage them to maintain their normal feed intake but will also keep feed more fresh and thus, stimulate DMI. In very hot weathers. Also one can assume more frequent feeding might decrease the diurnal fluctuations in metabolites and increase feed utilization efficiency in the rumen (Robinson 1989). it is recommendable that at least 70% of the daily feed should be given fresh at night. Steers eat more frequent but smaller meals in a hot environment than in cool conditions (Hahn et al., 1999). Increasing the feeding frequency will also help to minimize diurnal fluctuations in ruminal metabolites (Soto-Navarro et al., 2000) and increase feed utilization efficiency in the rumen. Feeding regimen could be altered to enhance the animal's ability to cope with metabolic and climatic heat load during the summer (Mader and Davis, 2004). Feeding of animals in the later part of the day could prevent the co-occurrence of peak metabolic and environmental heat load (Reinhardt and Brandt, 1994).

Water

The very first step to reduce heat stress is to provide cool water for all lactating and dry cows plus heifers as water is the primary nutrient needed for milk production, accounting for over 85 percent of the milk content. It is also essential for thermal homeostasis through respiratory activity (Aleksiev, 2008). In contrast to common perceptions, heat stressed cows remain well-hydrated (via large increases in water consumption) and may become hyper-hydrated (Schneider et al., 1988). Water requirement increases significantly as the environmental temperature rises. Cows may drink up to 50 percent more water when the temperature/humidity index is above 80 percent. It indicates the importance of water and its cleanliness during the summer months. Thus, keeping water tanks clear of feed debris and algae is a simple and cheap strategy to help cows remain cool.

Management of DMI

High fibrous diet will lead to higher proportion of acetate, which is having more heat of nutrient metabolism as compared to propionate (Linn, 1997). Thus, it appears logical to feed low roughage and high concentrate diet to the ruminants during summer periods to reduce heat production inside body. Ruminant diets with grain and low in fiber cause less heat stress for lactating cows because of their lower heat of digestion (Pennington et al., 2004). However, a minimum quantity of good quality roughage should be fed to prevent acidosis condition. Hence, feeding more concentrates at the expense of fibrous ingredients will not only increase the energy density of rations, which will be helpful in compensating the reduced feed intake, but will also reduce heat increment (West, 1999). DMI and milk yield increased for cows fed diets containing 14 versus 17 or 21% ADF; however, milk yield was less sensitive to changes in daily temperature for cows fed the 14% ADF diet (Cummins, 1992). Feeding of diets containing decreased amounts of roughage (NDF) during the 3-wk pre-partum period may minimize the decrease in DMI and lipid mobilization and thus limits the effect of heat stress on peri-parturient cows (Kanjanapruthipong et al., 2010). Adin et al., (2008) observed that diet with 12 % NDF as compared to 18% NDF has improved DMI and milk yield of cows fed TMR under heat condition (Table 1). Therefore, feeding a minimum but adequate amount of total and effective fiber should be the objective during summer months.

Protein

Raising the protein content with highly degradable materials apparently stresses the cows further, causing an additional heat load. The excess of nitrogen supplied by protein must be detoxified to urea in liver for excretion through a metabolic pathway, which is very high in energy demands (1g urea = 7.3 Kcal). The higher level of protein and degradability in the diet of ruminants may lead to reduction in feed intake, which results into reduced milk production (Higginbotham et al., 1989). Feeding Low level of less degradable protein also encourages animal for DMI (Table 2). The animals adjusted by reduced feed intakes and thus lowered production. Feeding of low degradable protein has shown to improve milk production during heat stress, provided the un-degradable protein is of good quality (Taylor et al., 1991). Both the quantity and form of protein in the diet need to be considered when feeding heat stressed cows (Linn, 1997). Keeping all point in view, it can be recommended that the level of crude protein (CP) in the diet should not exceed 18% while the level of rumen-degradable protein should not exceed 61% of crude protein (Huber et al. 1994).

Fats

Adding fat to the diets of lactating dairy cows is a common practice. The greater energy density and high energy conversion efficiency of high-fat diets could be beneficial during hot weather. As compared to other feeds, fats have a low heat increment. However, research on the effects of dietary fat during hot weather gives inconsistent results. Cows fed the high fat diet during hot summer produced milk much more efficiently and had a significantly lower early morning respiration rate than cows fed a high grain and fiber diet (Linn et al, 2004). Supplemental fat at 5% of diet DM enhances lactation performance under thermo-neutral and heat stress conditions (Knapp and Grummer, 1991). In a study, 3% prilled fatty acids (inert) supplementation was compared with shade plus evaporative cooling to relieve heat stress in dairy cows. Results revealed that milk yield improved only by the cooling not the fat treatment, supplementation (Chan et al. 1997). Although the results seem contradictory, but biological principles argue in favour of fat supplementation under conditions of heat stress. Nutritionists still suggest fat supplements to give a final fat content of 6 - 7 % of diet DM, especially for high-producing cows. Sources of fat supplements may include whole oilseed, tallow and protected fat products.

Minerals

The negative effects heat stresses are associated with changes in mineral metabolism. 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 results in a 3 - 9% increase in milk yield, and also an increased DMI. Increasing the concentration of sodium in the diet from the NRC recommended level of 0.18% to 0.45% or more improved milk yield by 7 - 18% (Sanchez et al. 1994).

For heat-stressed cows, alkaline diets are more preferable. Thus, Sodium bicarbonate and magnesium oxide have proven very effective in alleviating to some extent the drop in milk fat associated with heat stress conditions (West et al. 1992). Sodium bicarbonate will also increases ruminal pH, thereby establishing a more favorable environment for fiber digestion (Santra et al., 2003). A diet with high chloride content depressed DMI and was associated with low blood pH and reduced blood buffering (Escobosa et al., 1984). Researchers recommend that the level of dietary chloride should not exceed 0.35% of DM (Sanchez et al., 1994).

Dietary cation-anion difference (DCAD)

DCAD = (Na+ + K+) - (Cl-+ SO4-) meq/100 g DM

It has been observed that increasing DCAD of diet increases DMI in heat-stressed cows (Block, 1994). The hypothesis behind this result could be that the increase in blood buffering capacity with higher DCAD was responsible for the increase DMI. A positive DCAD diet also helps to overcome the acidosis related to panting by increasing blood pH. This DCAD can be elevated by using sources of Na and K that are free of Cl or S. Thus, it is recommendable that in summer rations, one should use potassium carbonate instead of chloride/sulfate to increase DCAD. A DCAD of +25 to +30 mEq/100 g DM is considered to be optimum to for milk production in heat-stressed cows (Wildman et al., 2007). Recommendations pertaining to different important mineral level in diet of dairy animals during summers are presented in Table 3.

Feed additive

Feed additive are ingredient or combination of ingredients added to diets of dairy animals to improve their performances. They are usually used in micro quantities and proven to be effective in improving feed conversion efficiency, milk production and provide protection against untoward environmental influences.

1) Buffer: Na-bicarbonate is the most prevalent and important ruminal buffer used to prevent acidosis, which is common during summers due to higher intake of concentrate (Hutjens, 1991)
2) Niacin: Niacin is a well-known subcutaneous vasodilator in a many sp. and could be effective for reducing body temperature. Unprotected niacin may be degraded in the rumen. Niacin helps to alleviate heat stress both by increasing evaporative heat loss from the body and also by reducing the effects of heat at the cell level (Lundquist, 2008). Feeding protected niacin increased free plasma niacin levels, evaporative heat loss during peak thermal load and associated with a small but detectable reduction in rectal and vaginal temperatures in dairy cows experiencing a mild thermal load (Zimbelman et al., 2010).
3) Antioxidants: Thermal stress generates disequilibrium of the oxidative balance, with important consequences over the vital function, life and death of the affected cells. Treatment of buffaloes with antioxidants (Viteselen) before the beginning of months of heat-stress and also during the stress period may increase the pregnancy rate correct the infertility due to heat-stress. through the decrease in cortisol secretion and a decrease in the oxidative stress (Megahed et al., 2008). Brahma Rasayana (a non-toxic polyherbal preparation) supplementation during thermal stress brings about enhanced action of enzymatic and non-enzymatic antioxidants, which nullified the undesired side effects of free radicals in heat stressed animals (Ramnath et al., 2007). Supplementation of vitamin C and vitamin E have a negative effect on cortisol levels during heat stress, which relieved the severity of heat stress in goats (Shivakumar et al., 2010). The reduction in cortisol levels by vitamin E and C is not yet fully understood but may be achieved by reducing the synthesis and/or secretion of cortisol or by breaking it down (Webel et al., 1998). Supplemental beta-carotene may increase pregnancy rates for cows in the summer and can increase milk yield (Arechiga et al., 1998).

4) Fungal culture: Yeast culture supplementation increases DMI in transition cows resulting in higher milk yields and less weight loss during thermal loads (Robinson and Garrett, 1999). Yeast (*S. cerevisiae*) maintains rumen health by
   a) Improving rumen pH: reduces acidosis risk
   b) Improved fiber digestion and nitrogen utilization: increased feed efficacy
   c) Rumen microflora stabilization

CONCLUSION

Nutritional modifications and interventions seems to be a potent option to combat heat stress, if practiced with strategically. There should always be provision of clean water, which is simple and cheap strategy to keep cows cool. The concentration of all nutrients should need to be increased in diets to compensate the reduced DMI during heat stress. The CP in the diet should not exceed 18% while the level of rumen-degradable protein should not exceed 61% of crude protein. More frequent but smaller meals should be offered in the cooler hours of day time to encourage the DMI. Maintenance of proper mineral balance with special care of K and Na and positive DCAD is of utmost importance to minimize the effect of heat stress. Some feed additives like niacin, herbal preparation, fungal cultures, buffers etc. may be beneficial while the the oxidative stress could be managed by supplementing antioxidants.

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TABLES

Table. 1. Performance of cows fed the two TMRs under heat load conditions. (Adin et al., 2008)

Variable	EXP (NDF 12%)	CON (NDF 18%)
Milk yield, kg/d	34.6a	32.3b
Production efficiency (kg milk/kg DMI)	1.61	1.65
Daily DMI (kg/day)	21.5a	19.6b
Daily NDF intake (kg/day)	7.05a	6.04b
Rumen pH	6.56	6.75

Table 2. Influence of protein level and degradability on performance of heat stressed cows (Higginbotham et al., 1989)

	Treatments			
Protein (%)	19	19	16	16
Degradability	57	50	57	50
Milk yield (lb./day)	59.1a	64.3c	63.4c	62.6b
Milk persistency (%)	84.0a	93.2b	91.5b	91.8b
DM intake (lb./day)	51.0a	54.8b	56.4c	55.8b

Table 3. Dietary mineral recommendation for dairy cattle in summers (Griswold, 2007)

Minerals	% of DM in diet
Potassium (K)	1.4
Sodium (Na)	0.4
Magnesium (Mg)	0.35
Chloride (Cl)	0.25
Sulphur (S)	0.22
DCAD	+25 mEq/100 g DM