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Nutritional management to ameliorate heat stress in dairy animal

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Abstract

Heat stress is a major challenge in dairy production systems, negatively affecting milk yield, physiological functions, health status and reproductive performance of dairy cows. Exposure to elevated ambient temperature and humidity induces several behavioral and physiological adaptations aimed at maintaining thermal homeostasis. Early detection of heat stress is essential to minimize its adverse effects on animal productivity and welfare. Common physiological indicators of thermal stress include increased respiration rate, elevated heart rate, and increased rectal or core body temperature. Recent advances in precision livestock farming have enabled the development of monitoring technologies for evaluating environmental and physiological parameters associated with heat stress. Among these, the Temperature Humidity Index (THI) is widely used as a reliable indicator of thermal load in dairy animals. Increasing THI values are generally associated with greater thermal discomfort, reduced feed intake, impaired physiological functions, and decreased productive efficiency. Dairy cows can maintain body temperature within a range defined by the lower and upper critical temperatures; however, optimum productive and reproductive performance is achieved only within the thermoneutral zone (TNZ). The TNZ for dairy cows generally ranges from 5°C to 25°C, within which animals maintain a normal body temperature of approximately 39°C without significant additional metabolic energy expenditure for thermoregulation. Exposure to temperatures beyond the TNZ increases physiological and metabolic stress, leading to higher energy expenditure, reduced productivity, and compromised overall performance.

Understanding the Effects of Heat Stress

Heat stress (HS) can be described as a complex syndrome involving biochemical, metabolic, physiological, and behavioral alterations that occur when dairy cows are exposed to environmental conditions beyond their thermoneutral zone (TNZ) and are unable to



maintain normal body temperature. Maintenance of thermal homeostasis depends on achieving a balance between metabolic heat production associated with maintenance, growth, lactation, and other physiological processes and heat dissipation to the surrounding environment.

Under heat stress conditions, dairy cows attempt to regulate thermal energy balance by reducing metabolic activity, particularly within the rumen. One of the primary adaptive responses is a marked reduction in feed intake, which subsequently initiates a cascade of metabolic disturbances. Decreased feed consumption lowers nutrient availability and negatively affects rumen fermentation efficiency, resulting in impaired energy metabolism and reduced productive performance.

Rumination and microbial fermentation generate substantial metabolic heat due to mechanical activity and fermentation processes within the rumen. Consequently, cows with highly active and efficient ruminal fermentation may become more susceptible to heat stress because of greater internal heat production. Depression of forage fermentation under HS contributes to the development of negative energy balance. In addition, alterations in ruminal fermentation patterns reduce the acetate-to-propionate ratio and decrease ruminal pH, thereby increasing the risk of subacute ruminal acidosis and milk fat depression.

Heat stress-induced negative energy balance also reduces blood glucose availability, primarily because glucose synthesis in ruminants depends largely on propionate produced during ruminal fermentation. Since lactose synthesis is directly dependent on glucose supply, reduced glucose availability leads to lower lactose synthesis and consequently decreased milk yield. Furthermore, HS impairs amino acid metabolism and reduces amino acid availability to the mammary gland, thereby limiting milk protein synthesis. Alterations in metabolic and physiological processes during heat stress ultimately result in reduced milk yield, decreased milk fat and protein content, and compromised overall lactational performance.

Nutritional Strategies to Ameliorate Heat Stress

- 1. Increase Energy Density of Diet:** - During heat stress, dairy animals exhibit reduced dry matter intake, leading to decreased energy availability for maintenance and production. Therefore, increasing the energy density of the diet is essential to meet metabolic demands without elevating heat increment. This can be achieved through supplementation of bypass or rumen-protected fats, inclusion of high-quality concentrate feeds, and reduction of excessively fibrous roughages. These dietary modifications provide readily available energy, improve feed efficiency, support milk



production and body condition, and help alleviate negative energy balance under thermal stress conditions.

- Supplement bypass fat or rumen-protected fat
 - Include high-quality concentrates
 - Reduce excessive fibrous feed
 - Avoid poor-quality roughages
2. **Protein Management:** - Heat stress adversely affects protein metabolism by reducing protein synthesis efficiency and increasing nitrogen losses in dairy animals. Therefore, supplementation of high-quality protein sources, incorporation of rumen undegradable protein (RUP), and proper balancing of essential amino acids are important nutritional strategies during thermal stress. These approaches enhance amino acid availability for intestinal absorption, improve milk protein synthesis and nutrient utilization efficiency, and reduce excess nitrogen excretion, thereby supporting productivity and metabolic health under heat stress conditions.
3. **Electrolyte Balance and Mineral Supplementation :-** Heat stress increases the loss of essential minerals through sweating, salivation, and urination, leading to electrolyte imbalance and impaired physiological functions in dairy animals. Supplementation of key electrolytes such as sodium (Na), potassium (K), chloride (Cl), and magnesium (Mg) is therefore essential during summer conditions. Maintaining an optimum dietary electrolyte balance (DEB) helps regulate acid-base homeostasis, prevents dehydration, enhances feed intake, and supports milk production and overall animal performance under thermal stress conditions.

Vitamins and Minerals: - Heat stress increases the production of reactive oxygen species (ROS), leading to oxidative damage and a decline in the antioxidant status of animals. Supplementation with specific vitamins such as vitamin A, E, C Niacin and minerals like selenium, zinc, copper and chromium can help mitigate the adverse effects of heat stress by enhancing antioxidant capacity, improving immune function, reducing cellular damage and improves overall health and productivity of animal.

Feed Additives

Feed additives play an important role in improving the tolerance of animals to heat stress and maintaining productivity. Commonly used additives include yeast cultures, probiotics, buffers, betaine, monensin, and capsicum oleoresin. These additives help stabilize



the rumen environment, enhance nutrient digestibility and utilization, and improve thermotolerance. Consequently, they contribute to better animal performance, health, and production efficiency under hot environmental conditions.

Conclusion

Heat stress significantly impairs the productivity and health of dairy animals by reducing feed intake, altering metabolism, and increasing oxidative stress. Nutritional management is an effective strategy to mitigate the adverse effects of heat stress. Feeding energy-dense and balanced diets, maintaining electrolyte and antioxidant balance, ensuring adequate water intake, and adopting proper feeding practices can substantially improve animal comfort, milk production, reproductive efficiency and overall performance during hot climatic conditions. An integrated nutritional and environmental management approach is essential for sustainable dairy production under heat stress conditions.

