Understanding Stress and Its Effect on Dairy Cattle

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Stress Regulation

The term "stress" was first introduced to the field of biology by Walter Cannon in 1915 as an animal's emergency reaction, fight or flight response, to a perceived harmful event, attack or threat to survival (Cannon, 1915). While his pioneering work into the physiological processes of the body in response to stressful stimuli was revolutionary, today we know that the stress response is a much more sophisticated and intricate series of biological events. Due to the complexity and multifaceted nature of the body's reaction to stress, the stress response may be more accurately described as "A choreographed series of biological reactions to a real and/or perceived psychological or somatic threat(s) regulated by neuroendocrine and endocrine processes to preserve life" that is precisely regulated by through activation of the hypothalamic-pituitary-adrenal (HPA) axis and activation of the sympathetic nervous system (SNS; Elenkov et al., 2000).

While the hormone cortisol is thought to be a primary indicator of the stress response, it also plays an important role in **gluconeogenesis,** the generation of glucose from other organic molecules like pyruvate, lactate, glycerol, and amino acids, during the "flight or fight" response. Cortisol increases blood glucose concentrations by stimulating the liver to convert fat and protein to these intermediate metabolites that are ultimately converted to glucose for energy. However, chronic exposure to high concentrations of cortisol can cause severe physiological and psychological problems such as excessive protein catabolism, hyperglycemia, immunosuppression, and depression. In domestic livestock, excessive concentrations of cortisol have been linked to reduced rates of reproduction, suboptimal growth, suppressed milk production, and suppression of immune function that could increase susceptibility to disease (Ono et al., 1984; Friend, 1991).

Stress in Dairy Cattle

Dairy cattle experience numerous environmental, managerial, and nutritional stressors throughout the production cycle that could potentially inhibit overall productivity and well-being due to neuroendocrine disruption and stress-induced immunosuppression. Generally, in the case of dairy cattle, stressors can be grouped into the following five broad categories: 1) Physical/Environmental; 2) Social; 3) Nutritional; 4) Psychological; and 5) Immunological. Examples of physical/environmental stressors would include injury, heat stress, cold stress, muddy conditions, and lameness/soreness. Social stress is typically encountered either by mixing unfamiliar animals together, isolating herd animals, or changes in the herd hierarchy. Nutritional stress can occur when animals are fed inadequate diets, contaminated diets, or feeding patterns are disrupted due to weather events or labor issues. Psychological stressors can be more difficult to discern and may be as subtle as moving cattle to a new pen, paddock, or pasture. Unfamiliar inanimate objects within the environment or the proximity of barking dogs, trains or vehicles can impose a psychological stress on cattle that may impact productivity and well-being.

Heat stress is dairy cattle costs producers millions of dollars each year just in milk production losses alone. However, the economic impact of heat stress in the dairy industry is not limited to losses in milk production, but also includes losses associated with acute health problems, rumen acidosis, reduced pregnancy rates, increased abortion rates, increased medicine costs, and increased mortality. While all of the biological pathways by which heat stress may reduce fertility and conception rates may not be fully elucidated, there is evidence of both direct and indirect effects of heat stress. Indirectly, heat stress could reduce fertility due to reduced feed intake observed in heat stressed cattle. Reduced feed intake can lead to a negative energy balance which in turn would result in decreased release of reproductive hormones causing reduced estrus expression and poor-quality oocytes (De Rensis and Scaramuzzi, 2003). In cultured cells obtained from dominant follicles collected at day 6 of the estrus cycle, Wolfenson and Roth (2019) reported significantly lesser concentrations of progesterone from cells collected during summer months compared to winter months. These authors also reported consistently lower first AI conception rates during the summer months as compared to winter months over a span of 18 years, with conception rates dropping more than 20% in years when the mean maximal August temperature exceeded 89.6 °F. Another indirect pathway by which heat stress could impact fertility is through the increased release of the stress hormone cortisol. Increased concentrations of cortisol have long been known to inhibit several aspects of the reproductive process. The direct effects of heat stress on fertility and reproductive performance are associated with alterations in the uterine environment. Changes in uterine pH and blood flow associated with heat stress would create a uterine environment that is not conducive to maintaining embryo development.

Losses in milk production due to heat stress are unfortunately a common occurrence in the dairy industry, and as milk production per cow continues to increase, so does the magnitude of the losses in milk production. In 2009 Rhoads and colleagues reported that in a 9-day controlled heat stress event, milk production was reduced by 10.6 kg/d/cow resulting in an economic loss of $36.96/cow (estimated value of $17.55/cwt) over the 9-day period. However, from 2009 until 2018, milk production per cow has increased 13% (USDA-NASS, 03-12-2019). As milk production increases, the heat increment also increases in the cow (Kadzere et al., 2002), thus increasing the heat load on the cows and making them less tolerant to elevated environmental temperatures. The temperature-humidity index for modern dairy cows has now shifted, and what was once considered the stress-threshold temperature-humidity index (THI) of 72 for dairy cattle has become a mild to moderate heat stress event, and the stress-threshold has decreased to a THI of 65-68.

Milk losses due to heat stress are not solely due to reductions in feed intake. While there is indeed a relationship between feed intake and milk production, prior studies have indicated that only 50% in the reduction in milk yield in heat-stressed dairy cows can be attributed to feed intake (Wheelock et al., 2010; Baumgard et al., 2011). The remaining losses in milk production may be associated with other factors such as increased incidences of acidosis, reduced blood flow to internal organs, slower gastrointestinal tract (GI) activity, shifts in the rumen microbiome, and altered nutrient metabolism. Increases in acidosis may occur due to changes in feeding behavior, reduced salvia production from decreased feed intake and rumination, and reduced salvia production due to panting may all impact the ability to neutralize rumen acid production. During heat stress events, cows also redirect blood flow from internal organs to peripheral tissues in an effort to cool themselves. This redirection of blood flow decreases nutrient uptake by the portal drained viscera. This along with the slower GI tract activity, results in a significant decrease in nutrient uptake. The shifts that occur in the microbial population of the GI tract can also impact digestion and nutrient uptake.

An additional aspect associated with heat stress is the energetic demand that it places on the cow. Prior research (McDowell et al., 1976) has reported that as ambient temperature increases from 68 °F to 104 °F, the maintenance energy requirement of the cow increases by 32% while dry matter intake decreases by 44%. Stress, regardless of the category, increases the energetic and nutrient requirements of the animal. During stressful events, typical biological responses that require energy include increases in heart and respiration rates, increases hormone production, increases in glucose utilization, increases in fat mobilization, and increases in protein degradation. Therefore, continual exposure to stressful events depletes nutrient and energy stores, resulting in periods of negative energy balance which contribute to both short-term and long-term health challenges.

Typical indicators that cattle are experiencing a heat stress include increased respiration rates, increased rectal temperatures, and decreased feed intake. With regard to respiration rate, it is recommended that if more than 2 out of 10 cows have respiration rates exceeding 100 breaths/minute, take immediate action to reduce heat stress (Fidler and Van Devender; http://www.uaex.edu). With regard to rectal temperature, cows with a rectal temperature of 102.2 °F in the afternoon are at risk for reduced milk yield and may experience fertility issues (Zimbelman et al., 2009). Other obvious signs of heat stress included increased standing time, crowding around shaded areas or cooler areas of the barn, crowding around water sources, and increased water intake.

Reducing stress and maintaining health cows requires proactive measures such as managing body condition of the cows, providing adequate housing, and the use of nutritional supplements to help neutralize reactive oxygen species, reduce stress, reduce inflammation and boost immunity. When evaluating body condition of the herd, don't rely on the mean body condition as it can be misleading. Instead, evaluate the number of cows that are outside the acceptable body condition range. Likewise, consider individual animal variations that exist within the herd. A cow's age, physical condition, health status, temperament, and social status can all have a significant impact on the magnitude of stress the cow is experiencing.

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