**Feeding During Stress and the Interaction between Nutrition and Immunity**

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**Abstract:**

Stress, a multifaceted challenge in the realm of animal husbandry, significantly impacts cattle health, behavior, and productivity. This abstract encapsulates the intricate relationship between stress and cattle, encompassing various forms of stressors and their effects. Cattle experience distinct types of stress: psychological stress arising from fear and unfamiliarity, physiologic stress resulting from endocrine disruptions, and physical stress stemming from external challenges like injuries, thermal extremes, and disease. These stressors have far-reaching consequences on animal well-being. The abstract highlights the significance of managing psychological stress through sensitive handling, gradual acclimatization, and novel practices to minimize distress during events such as commingling. Addressing physiologic stress underscores the importance of tailored nutrition to stabilize endocrine functions and support overall health. The realm of physical stress necessitates prompt intervention, strategic shelter provision, and careful resource management to mitigate adversities such as injuries, hunger, thirst, fatigue, and disease. Notably, thermal stress, a formidable adversary, poses unique challenges due to climatic conditions. Innovative strategies like cooling mechanisms, shading, and timed feeding become vital in reducing the economic impact of climatic stressors. Ultimately, the abstract emphasizes the collective effort required to navigate the complex landscape of stress in cattle. By understanding stressors and their implications, the cattle industry can evolve with improved management practices, nutritional interventions, and innovative solutions that prioritize animal comfort, health, and performance.

***Keywords:*** *stress, cattle, psychological stress, physiologic stress, physical stress, animal welfare, performance*

**Introduction**

The relationship between nutrition and the immune system is intricate and interconnected, with profound implications for an organism's ability to ward off disease and combat stress. While the immune system typically represents a relatively small fraction of an animal's nutritional needs under normal circumstances, its activation in response to immune challenges significantly alters nutritional requirements. Deficiencies in essential nutrients not only heighten susceptibility to various infectious diseases – bacterial, viral, and parasitic – but also exacerbate disease severity and the risk of secondary infections. Even in adequately fed animals with sufficient energy and protein intake, deficiencies in vitamins and trace minerals can substantially suppress immune function and stress resistance.

Nutritional insufficiencies can tip the balance between health and illness. An organism lacking crucial nutrients becomes more susceptible to infections, rendering the immune system less effective in mounting an effective defense. This vulnerability extends beyond initial infection to the potential for more severe diseases and complications.

Stress is a powerful disruptor of nutritional equilibrium. Animals facing stress – be it transportation, environmental shifts, or other factors – experience heightened nutritional demands to sustain immune function. The resulting short-term deficiencies can have a cascading effect on overall health. In scenarios such as shipping-stressed cattle, where nutrient deficiencies become prevalent, the critical period is in the first month after arriving at the feedlot. During this time, immune suppression is pronounced, significantly contributing to the elevated incidence of respiratory diseases in the initial 45 days of feeding. To counteract this, certain nutrients like vitamin E can be strategically administered at levels surpassing regular requirements to invigorate immunity in immunosuppressed animals.

Heat stress exerts far-reaching consequences on animals, impacting milk production, reproductive performance, and immune function. Both environmental temperature and humidity levels play pivotal roles in determining the degree of heat stress experienced by dairy cows. Under these conditions, the immune system's efficacy is compromised, exacerbating the challenges already posed by high temperatures.

Understanding the dynamic interplay between nutrition, immunity, and stress is pivotal in safeguarding animal health and well-being. By acknowledging the profound effects of nutritional deficiencies during immune challenges and stress, we can develop targeted interventions to support immune function and mitigate the negative impacts of stressors. This holistic approach to animal care holds the promise of enhancing disease resistance, overall health, and productivity.

**Understanding Immunity to Infection**

The protection against infection in animals involves a dual defense mechanism, encompassing both nonspecific or innate immunity and targeted acquired immunity. However, the effectiveness of these immune mechanisms is significantly compromised in stressed animals.

**Innate Immunity: The First Line of Defense**

1. **Epithelial Barrier:** The body's surfaces, such as skin, hooves, and mucous membranes, act as physical barriers to prevent infectious agents from infiltrating. However, damage to these barriers due to physical trauma or deficiencies in nutrients like vitamin A and zinc can create entry points for pathogens.
2. **Secretions and Antimicrobial Compounds:** Mucus, saliva, tears, and other bodily secretions serve to block and wash out infectious agents. These secretions also contain antimicrobial compounds that help neutralize invaders. Stress often disrupts the effectiveness of these protective mechanisms.
3. **Phagocytes:** Phagocytes, including macrophages, monocytes, and neutrophils, are specialized cells that patrol the blood and tissues, engulfing, killing, and digesting harmful microorganisms. This vital immune response is hampered by stress, rendering the body less capable of warding off pathogens.
4. **Normal Microbial Flora:** The naturally occurring microorganisms within the body can compete with disease-causing agents, limiting their growth. However, the protective role of these flora is diminished in stressed animals.

**Specific or Acquired Immunity: Tailored Defenses**

Exposure to foreign substances, known as antigens, triggers the development of immune cells and antibodies specific to that particular antigen. This form of immunity takes time to mature and is effective only when the animal has encountered the antigen before. Specific immunity plays a critical role in preventing future infections and aiding in recovery from existing ones.

Antigens can be live viruses, bacteria, weakened strains, or even fragments of pathogens. Vaccines, containing attenuated or inactivated agents, can induce immunity without causing full-blown disease. Upon antigen exposure, two distinct types of blood cells develop to combat the antigen:

* **T-Cells:** Responsible for cell-mediated immunity, T-cells coordinate immune responses against infected cells, aiding in their elimination.
* **B-Cells:** These cells are responsible for humoral immunity, producing antibodies that neutralize harmful substances, including antigens. Antibodies mark pathogens for destruction by other immune cells.

The immune system's ability to protect against infections relies on a harmonious interplay between innate and acquired defenses. Stress profoundly impacts both these facets of immunity, weakening the body's ability to defend against pathogens. Recognizing the delicate balance between these immune mechanisms and understanding their vulnerabilities under stress is essential in devising strategies to bolster overall immune health and mitigate the negative impacts of stressors on animal well-being.

**Stress in Cattle**

Stress in cattle is a complex phenomenon resulting from exposure to abnormal situations or environments. It is particularly evident during handling and transportation. Throughout the various stages of the production cycle, cattle are subjected to environmental, managerial, and nutritional stressors. These stressors can disrupt neuroendocrine functions and induce immunosuppression, potentially compromising both productivity and well-being.

**Recognizing Stress Symptoms**

Stressed cattle often exhibit observable behaviors that indicate their discomfort. These behaviors encompass:

* **Vocalization:** Increased noise-making as a response to stress.
* **Escape Attempts:** Cattle may try to run away from perceived stressors.
* **Appetite Suppression:** A decrease or complete loss of appetite.
* **Isolation:** Seeking solitude as a coping mechanism.
* **Elevated Respiratory Rate:** Stress can lead to an increased breathing rate.
* **Dehydration:** Stress can contribute to reduced water intake.
* **Increased Heart Rate:** Stress triggers an elevated heart rate.

**Categorizing Stressors**

Stressors can be classified into three main categories:

1. **Psychologic Stress:** Fear-induced stress arises from situations like social mixing, exposure to new environments, loud noises, and restraint.
2. **Physiologic Stress:** This type of stress stems from disruptions in normal endocrine or neuroendocrine functions due to factors such as nutrient deficiencies, glandular disorders, and other endocrine disturbances.
3. **Physical Stress:** Associated with injuries, thermal stress (both heat and cold stress), hunger, thirst, fatigue, and disease.

**Heat Stress and its Ramifications**

Elevated climatic temperatures expose cattle to heat stress, resulting in negative impacts on performance and comfort. The consequences of acute heat stress include heightened respiratory rates, reduced feed intake, increased water consumption, and imbalances in blood gases and plasma electrolytes.

During the summer, feedlot cattle can suffer from heat stress due to high ambient temperatures, humidity, solar radiation, and low wind speed. To mitigate the effects of heat stress, cattle employ a coping mechanism of reducing metabolic heat production through decreased dry matter intake. This strategy, however, adversely affects overall performance.

**Managing Stress in Cattle**

Managing stressors in cattle is pivotal for their well-being and optimal performance. Strategies include:

* **Alternative Management Practices:** Implementing methods that minimize stressors, such as reducing commingling, using gradual transitions to new environments, and minimizing exposure to loud noises.
* **Nutritional Strategies:** Providing proper nutrition, including essential nutrients, can help counteract the physiological effects of stress.
* **Thermal Stress Management:** Creating shaded areas, providing access to cooling mechanisms like fans and misters, and adjusting feeding times to cooler periods can alleviate heat stress.
* **Health Monitoring:** Regular health checks and prompt treatment of diseases can reduce physical stress.

Stress has far-reaching consequences for cattle, affecting their health, behavior, and performance. Recognizing stress symptoms and employing effective management strategies are essential for maintaining animal well-being, productivity, and the sustainability of the cattle industry.

Typically, stress associated with fear, such as that experienced during commingling or social mixing, exposure to novel environments and loud or unusual noises, and restraint, is considered psychological stress. Physiologic stress can result from deviations in normal endocrine or neuroendocrine function caused by various conditions, such as nutrient restriction or deficiencies, glandular disorders, and other endocrine disruptors. Physical stress represents stress associated with injury, thermal stress, hunger and thirst, fatigue, and disease (Hahn GL, 1994). Some stressors can be prevented or overcome through alternative management practices and various nutritional strategies; however, some stressors, such as thermal stress (heat and cold stress), are often difficult to prevent, and impose significant economic burdens on the cattle industry.

Because of elevated climatic temperatures, cattle may experience periods of heat stress, resulting in decreased performance, increased discomfort, and even death (Lefcourt AM And Adams WR, 1996 & Mader TL, 1999). The physiologic consequences associated with acute heat stress include increased respiratory rates, decreased feed intake, increased water intake, and imbalances in blood gases and plasma electrolytes (Sanchez *et al.,* 1994).

In the summer months, finishing feedlot cattle often experience heat stress because of hot climatic conditions resulting from above-normal ambient temperatures, high relative humidity, high solar radiation, and low wind speed (Hubbard *et al.,* 1999). As a coping strategy, cattle attempt to reduce core body temperature by decreasing metabolic heat production through reduced dry matter intake, which ultimately reduces overall performance (NRC, 1981).

**Effect of Nutritional Status on Resistance to Infection**

Good nutrition improves disease resistance of stressed cattle, by helping to counteract the suppression of the immune system caused by stress hormones and by providing nutrients essential for maintaining and activating theimmune system as required.

***Energy –***

Stressed calves seem to have an altered eating pattern—unlike normal calves, they won’t eat more of a lower energy diet, and given a choice, they select a diet with about 72% grain during the first week after arrival at the feedlot. Consequently, performance of lightweight stressed calves is increased with high-concentrate receiving diets (>60% grain), although morbidity rate may increase as well (Galyean *et al.,* 1999).

Generally, the percentage of calves treated for BRD (morbidity), and/or the severity of illness (days of medical treatment per calf) increase as the proportion of grain in the starter diet increases. Glen Lofgreen, a pioneer in receiving calf nutrition, found in his work that any additional pounds of gain put on in the first 28 days was maintained or enlarged over 253 days feeding period. On the other hand, feeding good quality hay plus a protein supplement may work well in some cases, but calves may not fully compensate for lower gains in the receiving period. The optimum concentration of grain in the receiving diet depends on the age and weight of animal, previous management, stress level, and other factors; cattle with lower intakes (calves) can safely consume diets with a higher proportion of grain than can cattle with higher intakes.

***Protein –***

A large number of studies have been conducted comparing protein levels and sources for receiving diets. In general, diets that contain relatively low or high levels of dietary proteins adversely affect immunity to infection compared to diets with moderate protein levels. Averaged for 15 studies, the trial-indexed morbidity rate was lowest for diets containing 12 to 14% protein, and increased as protein increased to 22% of DM. However, the best performance is usually achieved at higher levels of dietary protein (16 to 20%).

Similarly, performance was usually best for diets using soymeal, which has a low rumen bypass value, whereas morbidity was better when less soluble, higher bypass proteins were fed (distillers dried grains, blood meal). Nissen *et al.* reported that gain and feed efficiency improved as metabolizable protein concentration increased, serum cortisol increased linearly, and the proportion of calves responding to the IBR vaccine decreasedlinearly.

*Vitamins A and D* within the ranges that are normally fed, are important in regulating immunity. Vitamin A deficiency reduces resistance to all types of disease, including parasites. Vitamin A supplementation is essential for cattle fed grainbased diets. Incoming cattle can be marginally deficient in vitamin A depending on the previous diet, and may not be able to utilize vitamin A efficiently if deficient in trace minerals. Under practical conditions, vitamin D deficiency is unlikely to be a concern even when cattle are not supplemented, unless they also do not have access to sunlight.

Antioxidant nutrients are crucial to the immune response, becoming rapidly depleted during infection. The amount of antioxidant nutrients in the diet determines the antioxidant status of the animal. These key nutrients include dietary antioxidants such as carotenes, vitamin E, and vitamin A, and trace minerals such as selenium, zinc, copper, and manganese used to synthesize antioxidant enzymes. Antioxidants protect immune cells and surrounding tissue from damage caused by the immune response, which otherwise would damage the animal as much or more than the disease organisms. Antioxidants are particularly important for the effectiveness of phagocytes, which are the front line of defence against invading pathogens. If phagocytes are deficient in antioxidants, microbial killing is ineffective. *Vitamin E*is currently the most important antioxidant in feedlot diets.

**Feeding Behavior Modifications with Heat Stress**

**Water intake**: Water intake increases dramatically in dairy cows under heat stress as a means to dissipate heat to the environment. When environmental temperatures increased from 64° to 86°F, water consumption was shown to increase by 29%. Thus, providing plenty of cool, clean water is critical upon return from milking and within their respective housing. Routinely, waterers should be emptied and scrubbed with a brush and chlorine solution. Providing shade for waterers for heifers and dry cows is also critical in maintaining water intake.

**Dry matter intake**: Dry matter intake drops under heat stress with a corresponding drop in milk production. However, only 50% of the drop in milk production can be explained by decreases seen in dry matter intake. The remaining drop in milk production is associated with changes in metabolism and the responsiveness of various tissues and organs to normally produced hormones. This does not mean that instituting practices to maintain feed intake, they are important and will help maintain or attempt to optimize nutrient intakes at a critical time. Feed should be mixed more often in the summer or an additive (i.e., buffered propionic acid products) incorporated into the TMR mix to extend bunk life and prevent feed from excessively heating in the feed bunk. Dairy cows generally consume more feed over the nighttime hours when environmental temperatures are lower.

**Increased maintenance requirement for energy**: With the increase seen in respiration rates and panting with heat stress, energy needed for maintenance increases by 7% to 25%, or 0.7 to 2.4 Mcal NEL/day. This increase in energy requirement equals the amount of energy needed to produce 2.2 to 7.5 pounds of milk (3.7% butterfat). Thus, helping dairy cows regulate thermally is very important when trying to maintain production.

**Modifying Diets for Heat-Stressed Dairy Cows**

**Maintaining effective fiber intake:**

Adequate effective fiber is necessary for maintaining rumination, buffering the rumen contents, and efficiently digesting forages and grain components of the diet. Heat stress increases the rate of respiration and panting, decreases rumination time, and results in a decrease in the amount of saliva and bicarbonate in the blood. These changes result in a decreased buffering of the rumen and blood. Thus, decreasing the fiber content and increasing the amount of starch in a diet is the last change you want to make in an attempt to increase the energy of the diet because ruminal acidosis could result.

However, feeding excessive amounts of neutral detergent fiber (NDF) to dairy cows under heat stress is detrimental. High NDF forages are generally lower in forage quality and result in more heat of fermentation when digested in the rumen, and thus the dairy cow needs to dissipate more heat compared to consuming diets with adequate amounts of fiber.

**Feeding highly digestible forages:**

Feeding higher-quality forages increases the energy content of the diet, helps maintain adequate rumination, and decreases the heat of fermentation associated with feeding lower-quality forages. Brown midrib forages (i.e., corn silage or forage sorghum) may be more beneficial in diets of heat-stressed dairy cows to improve digestibility of the fiber and, therefore, the amount of energy derived from the consumed diet.

**Adding fat to the diet:**

Adding fat to the diet is expected to decrease heat produced during the digestion of feeds while increasing the amount of energy available. Studies where fats have been fed to heat-stressed cows have shown inconsistent responses in improving milk production; some have improved milk production, and others have shown no response.

**Adding yeast cultures to diets:**

Yeast culture has been shown to improve fiber digestion and stabilize the rumen environment. In heat-stressed dairy cows supplemented with yeast, lower rectal temperatures and respiration rates were observed in several but not all studies. Several studies, but not all, have shown an increase in milk production of heat-stressed cows supplemented with yeast. In 1994, Huber and others summarized 14 lactation comparisons with 823 heat-stressed cows where yeast was or was not added to the diet. Overall, these comparisons showed a 2.2 pound/day increase in milk production with yeast supplementation with six comparisons showing significantly higher milk production with supplementation, three slightly higher, and the remaining five comparisons with no or slightly lower milk production. Two recent studies have shown no improvements in milk production with yeast supplementation, but one indicated improved feed efficiency. Early-lactation cows fed a higher proportion of concentrate may respond more favorably to yeast supplementation than mid- to late-lactation cows.

**Modifying mineral content of the diet:**

Heat-stressed dairy cows sweat, and their sweat contains high amounts of potassium and sodium, thus increasing their need for these minerals in summer rations. To achieve these increased concentrations of potassium and sodium and maintain adequate dietary cation-anion difference (DCAD), additional amounts of sodium bicarbonate, potassium carbonate, or both may need to be added to the diet. In addition, higher amounts of potassium reduce the absorption of magnesium, thus increasing the requirements for magnesium.

Heat-stressed dairy cows should be fed adequate amounts of trace minerals and vitamins, particularly antioxidant nutrients. At this time, research trials where additional trace minerals or vitamins have been added to diets of cows under heat stress have not consistently shown a benefit. More research is needed before additional amounts and sources of trace minerals are recommended to be added to diets of heat-stressed dairy cows.

Rations for dairy cows should be formulated for dairy cows before heat stress occurs and should contain:

* 1.4% to 1.6% potassium
* 0.35% to 0.45% sodium
* 0.22% to 0.35% magnesium (readily available source)
* +25 to 30 or greater DCAD balance

Environmental and dietary modifications can help mitigate the effects of heat stress on dairy cows and should be implemented before the effects of heat stress are noticed. These modifications are needed not only for the milking herd but just as importantly for the far-off and close-up dry cows. When making these modifications, one must realize that changes in the environmental temperature are the most important, with dietary modifications serving a supportive role. By helping dairy cows dissipate the extra heat load, milk production, reproduction, and health can be maintained or at least the negative effects minimized and potential profitability realized during the spring, summer, and early fall months.

**Factors that Help Prevent Stress**

**Heat**

Provide shade and use bedding that does not hold heat, rinse down the environment, provide fresh water daily and utilize window or fans when temperature is over 24°C.

**Ventilation**

Ensure there is adequate ventilation and provide an outside area for animals when possible during the day.

**Overcrowding**

Make sure there is room for each animal to lie down and have their own water and feed through space. Time should be given to move animals from one place to the other to prevent crowding in pens and chutes. Never move animals in the heat of the day or when it is very windy. Both of these conditions can cause stress.

**Transportation**

Ensure a clean and safe mode of transportation that has room for each animal and adequate ventilation. If the trip is long, provide only a few stops to exercise, feed and water animals. When possible, practice loading and moving animals for shorter distances to get them used to travelling.

**Housing or Facilities**

Provide similar environments to the one the animal was in before and allow the animal time to get used to its environment before working with it.

**Working Equipment**

Chutes, pens and other equipment should reflect the animal’s normal motions and actions without causing any pain.

**Pests**

Provide pest control in the environment and on the animals to stop infestations. Ensure that living spaces are kept clean and well maintained.

**Human Exposure**

Take time and small steps to approach and work with an animal. Be patient and give the animal time to adjust to its environment and the people who will be working with it.

**Important aspects to be practiced for feeding during stress**

* Formulate diets to contain slightly greater NDF and ADF concentrations in order to minimize the risk of ruminal acidosis which is more prone to occur during heat stress.
* Inclusion of fat in higher fiber diets may help maintain energy intake Rectal temperature and milk production can be improved.
* Providing cool, clean water in ad libitum amounts will encourage water intake, feed intake, and milk production.
* Recommended ranges of dietary concentrations of macro-minerals for warm weather feeding include K at 1.5 to 1.6%, Na at 0.45 to 0.60%, and Mg at 0.35 to 0.4% of DM.
* Overfeeding total and degradable protein during times of hot weather have reduced cow performance, possibly due to increased energy costs of N excretion.
* Feeding fungal cultures has improved cow performance in about half of the studies reviewed.
* Feeding in the early morning hours and late evening hours will prevent the rise in body heat from DM intake coinciding with the rise in ambient temperature, thus reducing the maximum heat load on the animal.

**Conclusion**

The intricate interplay between stress and cattle health unveils a multifaceted challenge for producers and caretakers. Understanding the diverse forms of stress – psychological, physiologic, and physical – allows for the development of tailored strategies to preserve animal well-being and productivity. Psychological stress, stemming from fear and unfamiliarity, emphasizes the importance of sensitive handling, gradual exposure, and innovative practices that minimize distress during commingling and novel experiences. Addressing physiologic stress through optimal nutrition becomes paramount in averting disruptions to endocrine functions and supporting overall health. The realm of physical stress encompasses external adversities such as injuries, thermal extremes, hunger, thirst, fatigue, and disease. Timely intervention, strategic shelter provision, and thoughtful resource management contribute to alleviating these challenges.

Thermal stress, a particularly formidable adversary, poses difficulties in its prevention due to climatic conditions. Cattle grappling with heat stress experience a range of physiological disturbances, ultimately affecting performance. Innovative solutions, such as shading, cooling mechanisms, and timing of feeding, become essential components in minimizing the economic burdens incurred by these climatic stressors. By recognizing the signs and sources of stress, the cattle industry can develop comprehensive strategies that prioritize animal comfort, health, and productivity. As we navigate the intricate landscape of stress, it is our duty to harness knowledge and innovation to ensure that cattle thrive, even in the face of diverse stressors.

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