ADVANCES IN NUTRITION AND BOVINE DISEASE

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The relationship between nutrition and livestock production has been recognized for centuries. Gradually, more specific disease syndromes were associated with specific feeding practices (eg. grass staggers in early pasture, alkali disease in arid climates). However, only in the last 60 to 70 years has animal agriculture attained an understanding of the nutritional mechanisms that contribute to the pathogenesis of many disease syndromes. In particular, we have recognized the diseases resulting from dietary deficiencies and excesses. Nonetheless, as the need for production efficiency in animal agriculture increases, and the reliance on chemical methods to enhance disease resistance decreases, progress in the understanding of nutritional-disease relationships will need to integrate complex mechanisms of metabolism, pathophysiology, and toxicology. It is the purpose of this paper to outline selected topics that epitomize the complex role of nutrition in bovine metabolic and infectious disease.

I. Nutritional Interactions

Periparturient paresis (milk fever) is an economically important disease among dairy cattle, occurring infrequently in beef cattle. In addition to direct losses, indirect costs can be substantial as cows with periparturient hypocalcemia after calving have higher risk of acquiring other diseases, including mastitis, retained placenta, metritis, and possibly displaced abomasum.[1,2] Milk fever occurs when hypocalcemic-prone cows develop an acute inability to resorb Ca from bone, which results from impairment of osteoclast activity.[3] A higher incidence of this disease occurs among cows fed pre-partum rations high in calcium. Thus, a fundamental means of prevention has been to feed reduced levels of this nutrient (< 50 gm/day) in dry cow rations. However, recent research has indicated that the proportion of anions to cations in dry cow rations will influence periparturient calcium mobilization, and consequently the incidence of periparturient paresis.[4-8] Early studies determined that supplemental dietary NH_4Cl decreased the incidence of milk fever.[6] Dietary NH_4Cl was believed to cause a mild systemic acidosis, resulting in increased bone mobilization, and an increase in the proportion of serum ionized calcium.[6] More recently, Oetzel et al[4] determined that dry cows fed an anionic diet (excess of Cl and S, relative to Na and K) had a lower incidence of periparturient hypocalcemia (7/24 cows) and milk fever (1/24 cows) than cows fed cationic diets (16/24 and 4/24 cows, respectively). At calving, both total and ionized serum Ca was higher in the cows fed the anionic diet than the cows fed the cationic diet. The incidence of hypocalcemia or milk fever did not differ between cows fed diets low (0.6% DM) or high (1.2% DM) in Ca.[4] This suggests that alkogenic (Na,K) content of a ration may influence the incidence of milk fever as much as Ca content.[4] Other reports have supported use of dietary anionic salts (NH_4Cl,$CaCl_2$,$(NH_4)_2SO_4$) to increase serum Ca, and thus reduce the incidence of milk fever.[5-8] Anionic salts also increase urinary Ca, probably in response to excess serum Ca following bone resorption and intestinal absorption.[7]

These studies illustrate the complexity of nutritional interactions, and their role in metabolic disease. The concept of nutritional interactions, especially among minerals is not new. The effect of dietary sulfur and molybdenum on the uptake of copper (Cu) is a classic example of dietary interaction.[9] Numerous other examples of interactions at the level of absorption exist. However, the milk fever studies indicate that dietary interactions alter

distribution and excretion as well. Feeding of total mixed rations, use of alternative feedstuffs such as poultry litter and additives such as BST, and ultimately, increased production efficiency will demand that we understand the complex nature of nutrient interactions at all levels of metabolism.

II. Modification of Rumen Flora Output

Rumen microfloral fermentation and physiology is the basis of ruminant nutrition. Growth, production, and health all rely on the end products of this microbial population. Manipulation of rumen fermentation by managing diet has offered some elegant means to enhance the role of nutrition in cattle disease prevention.

Ionophores are supplemented in cattle rations to enhance rate of gain and feed conversion by selecting for rumen bacteria that produce higher molar ratios of propionate, relative to acetate and n-butyrate. Particularly in cattle fed diets high in soluble carbohydrates, ionophores will suppress the growth of lactic acid producing bacteria (*Lactobacilli, Streptococcus bovis*), while not inhibiting lactate utilizing bacteria.[10-12] This manipulation of ruminal microflora, and their end products helps to maintain a more favorable rumen environment, and thus prevent lactic acidosis in cattle fed high energy rations. The selective suppression of *Lactobacilli* sp. and their end products has other clinical uses. Reports have indicated that the ionophores monensin and lasalocid help to prevent the incidence and severity of acute bovine pulmonary edema and emphysema (ABPE).[11-13] Ionophores supplemented for 4 to 5 days before, and 7 to 10 days after placement of cattle on lush pasture will reduce the incidence of ABPE.[11-13] This occurs because ionophores decrease ruminal conversion of L-tryptophan to 3-methylindole. 3-methylindole is a major mediator in the pathogenesis of ABPE, being converted by pneumonic enzyme systems to a potent pneumotoxin.[11] An ionophore-induced decrease in 3-methylindole production may result from a decrease in *Lactobacillus* sp. activity, and conversion of L-tryptophan to indole rather than 3-methylindole.[14] Poichoiba, et al.[11] recently reported that 3-methylindole production may be most effectively prevented by a combination of ionophore use, sound grazing management, and feeding of forages.

Further evidence of the relationship between ruminal output and disease incidence has been suggested by Van Saun.[15] Feeding dry cow rations with increased rumen non-degradable protein was found to decrease the incidence of periparturient disease, including ketosis and displaced abomasum.[15] Understanding "optimal" rumen output to meet the production and disease prevention needs of cattle will be a major challenge of future nutrition management.

III. Nutrition, Inflammation and Infection

Historically, the nutritional role in resistance to infectious disease has been well documented with higher rates of morbidity and mortality in malnourished animals and humans. It has become apparent that some diseases, such as coligenic diarrhea in neo-natal calves, can often be successfully managed not by drugs, but by use of supplemental fluids, and often with selective feeding of whole milk alone.[16] Enhancing disease resistance with vitamin and mineral supplementation, especially those with anti-oxidative functions, has received extensive research interest. Dietary Cu and selenium (Se) supplementation enhances bovine phagocytic killing.[17-19]

Gram-negative bacteria are a major cause of clinical mastitis in dairy cattle. In severe cases, a variety of systemic, as well as local inflammatory changes occur, which are mediated by release of endotoxin from the bacterial cell wall.[20] Host mediators, including arachidonic acid metabolites and cytokines, are released that elicit profound changes in the host, including fever, peripheral leukocytosis, release of hepatic-derived acute phase proteins, decreases in serum trace elements, and circulatory shock.[21] Smith et al[22] reported cows supplemented during the dry period with vitamin E and given a single injection of selenium (Se) prior to calving, had a lower incidence of clinical mastitis (37%) and shorter duration of infection (62%) than unsupplemented controls. Further studies with first calf heifers yielded similar results.[23] Studies with experimental *Escherichia coli* intramammary infections found that cows supplemented with Se

(0.14 ppm in diet) had less severe infections than unsupplemented controls (0.04 ppm in diet).[24] Selenium supplementation enhanced mammary resistance, in part, due to enhancing neutrophil function.[24] Selenium, as a component of the enzyme glutathione-peroxidase, protects cytosolic systems from oxidative attack by reducing peroxides to alcohols and water.[24] Thus, the role of glutathione-peroxidase in controlling oxygen radical formation is a critical host regulatory system, particularly in the presence of active phagocytes which initiate oxygen radical synthesis as part of pathogen killing.[19,24] Any impairment of anti-oxidative mechanisms, such as would happen following a dietary Se or vitamin E deficiency, would increase reactive oxygen accumulation, and decrease the ability of host cells and tissues to withstand oxidative peroxidation.[19]

Acute infections, including mastitis, also result in marked decreases in serum trace cations, most notably iron (Fe) and zinc (Zn).[25-27] These elements (especially Fe) are necessary for gram-negative growth, thus host sequestration during infection may suppress bacterial proliferation.[28] Additionally, this mechanism may augment the bacteriostatic effect of chelators such as the protein lactoferrin, which increases in milk during inflammation.[29,30] Iron sequestration may also decrease the rate of Fe-induced oxygen radical formation, an event that regularly occurs during poor tissue perfusion (shock) and inflammation.[31]

Summary

Nutritional management often focuses on production requirements. However, total nutritional management should encompass disease prevention as well, and at times feeding practices that enhance production may antagonize disease prevention (eg. effects of ensiling forages on vitamins E and A content). It is apparent that nutrition plays not just a preventive, but a dynamic role in metabolic and infectious disease. Advances in dietary management must utilize nutritional physiology as a means to integrate efficient production and disease prevention.

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Zusammenfassung

Obwohl das Ernährungsregime sich häufig nur nach dem Produktionsbedarf richtet, sollte es darüberhinaus auch auf Krankheitsverhütung zielen; manchmal kann eine produktionserhöhende Fütterungspraxis der Krankheitsverhütung entgegenwirken (z.B., die Wirkung der Einsilierung auf den Gehalt von Vitamin E und A im Futter). Offensichtlich spielt die Ernährung nicht nur eine Verhütungsrolle, sondern auch eine dynamische Rolle in Bezug auf metabolische und ansteckende Krankheiten. Fortschritte in dem Ernährungsregime müssen sich der Ernährungsphysiologie bedienen, um wirkungsvolle Produktion und Krankheitsverhütung miteinander zu verbinden.

Résumé

L'alimentation du bétail a comme objectifs la production de lait ou de viande, mais aussi le maintien de la santé du cheptel. Parfois la régime d'alimentation qui produit le meilleur rendement augmente le risque de maladies; par exemple, la diminution des vitamines A et E lors de l'ensilage des fourrages. Puisque la nutrition peut prévenir ou contribuer aux maladies métaboliques et infectieuses du bétail. La conaissance de la physiologie de l'alimentation est donc indispensable au progrés en matière de nutrition du bétail, autant pour augmenter la production que pour prévenir les maladies.