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MINERAL Writes

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Calcium Thoughts...

Two recent articles from different publications give cause to think about the complexity of calcium as a vital nutrient in livestock feeding. The old adage of "if a little is good, even more would be better" is not wise advice in nutritional considerations. Fine tuning of nutrients in formulating diets is increasingly important, not only for efficiency of performance but for economical efficiency too. Another point of contemplation suggests we feed livestock for more than meeting the animal's needs alone. One thought comes from swine nutrition, the other from dairy research.

Swine Nutrition

First, from **PIG*PROGRESS*.NET** on **September 30, 2009**, one comment was made regarding mineral nutrition in young growing pigs. This quote came from Dr. I. Mavromichalis in Madrid, Spain.

> "Calcium is the least expensive nutrient in a pig diet because its main source, calcium carbonate, can be provided inexpensively from limestone. Thus, many low-cost formulas tend to be over-fortified with calcium, with some containing over 1% Ca. Calcium carbonate, however, has such a strong buffering activity that can significantly lower the acidity of gastrointestinal contents and, thus, interfere with protein digestion. It is strongly recommended, therefore, that dietary calcium specifications do not exceed actual requirements and the calcium to phosphorus ratio be no more than 1.2:1."

This is hardly a revolutionary concept. One would imagine most readers responding by simply saying, "Well, of course!" We should maybe pause a little longer, however. From an even broader perspective, in today's nutritional formulations, we can ill afford neither excesses nor shortages of nutrients. For many years, we have been very familiar with the

(Continued on back page)

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(Continued from front page1)

concept of "balanced diets." But that has probably been also a matter of subjective evaluation. For example, much nutritional formulation of minerals used to incorporate a comfortable overage (~ 10-15%) just to ensure nutritional adequacy allowing for both individual animal consumption variances as well as handling/ mixing errors. Today's economics no longer make that acceptable. Along with this, as we understand more fully both synergistic and antagonistic relationships among minerals, nutritionally we need to formulate diets as close to being fully balanced as is reasonably possible. The noted comment above clearly points to interferences among nutrient classes and not simply nutrient relationships within a given class. Reacting calcium carbonate ($CaCO_3$) in the stomach's hydrochloric acid (HCl) gives off water (H_2O) and carbon dioxide (CO_2) and ionized calcium (Ca^{++}). That's how Ca is released for absorption and subsequent utilization, but in the process the hydrochloric acid is neutralized.

$$CaCO_3 + 2H^+ \text{(acid)} \rightarrow Ca^{++} + CO_2 + H_2O$$

Hydrochloric acid is essential for initial digestion of protein by cleaving the polypeptide bonds. All seems so very simple and basic. It is, but we must also keep these basics in mind as diets are formulated and ingredients are milled into well-balanced feed targeting optimal performance when consumed. Just one thought....

Dairy Research

Second, another calcium thought came from an article in the **October 2009** issue of the **Journal of Dairy Science**. Researchers at the Ohio State University Ag Research Center in Wooster, OH, looked at the *ionized calcium requirement of rumen cellulolytic bacteria.* Cellulolytic bacteria present in the rumen are necessary for digesting fiber in the diets of ruminants – predominantly beef and dairy. This is *Basic Ruminant Nutrition 101*. The chemical bonds in dietary fiber are not able to be broken down by animal enzymatic action. It takes the symbiotic relationship between the host animal (ruminant) and fiber digesting bacteria (populating the animal's rumen *fermentation vat*) to digest the cellulose in fiber containing forages. The bacteria break down these fibrous bonds and convert components into usable energy compounds for the ruminant animal. However, bacteria need more nutrients than just the fiber substrate provided in the diet. Three predominant species of rumen cellulolytic bacteria are *Fibrobacter succinogenes* (FS), *Ruminococcus flavefaciens* (RF), and *Runinococcus albus* (RA). The Ohio researchers examined the apparent requirement for ionized calcium (Ca^{++}) of these three species. The function of Ca^{++} in cellulose degradation is unknown, but may be related to the secretion or activation of their cellulolytic enzymes. In today's cattle feeding systems, calcium is supplemented to meet the requirements of the animal without consideration for requirements of the ruminal microorganisms. Unfortunately, common supplements such as $CaCO_3$ and dicalcium phosphate have low ruminal reactivity. Also, Ca in alfalfa has variable availability because much is in the form of insoluble Ca oxalate. Previous authors have shown that Ca^{++} of ruminal contents was influenced by the form (insoluble or soluble) of Ca supplemented and by ruminal pH. Higher ruminal pH (less acidic) conditions as evidenced on high fiber lower carbohydrate diets are less reactive to the above supplements for their contribution of Ca^{++}. The researchers were led to hypothesize that availability of Ca^{++} may play an important role in the interactions of cellulolytic ruminal microorganisms with their substrate. To test this hypothesis, the Ohio research team performed an elaborate, detailed *in vitro* study of each of these bacterial species with several strains within species included to test growth and proliferation in absence of Ca^{++} on inoculated test medium or presence of ionized calcium. For a closer examination of this study's details we refer the reader to the actual report. We offer some generalized findings here.

Ohio researchers asked the question, "Is Ca required for cellulose degradation?" Their initial response to answering the question was to note previous findings. Attachment of bacteria to substrate (e.g. fiber in roughages) is essential for cellulose degradation, and many authors have studied this process with different experimental approaches. In the late 1980s, it was reported that increasing ionic strength probably improved bacterial adhesion, rather than any specific effect of the cations (positively charged ions including Ca^{++}). Depending on the bacterial species, reduced adhesion of cellulose to bacteria was observed when cations were absent. Their findings showed an absence of a relationship between the presence of Ca or Mg (magnesium) and adhesion of *Fibrobacter succinogenes* to cellulose. They concluded that Ca^{++} does not have a direct effect on binding cellulose by FS at the adhesion step of cellulose degradation. However, the effect of Ca^{++} on cellulose degradation could be related to the secretion of enzymes from the bacterial cell; thus, it may function as an intermediate in the attachment of enzyme(s) to cellulose, or it may moderate the amount and activity of the enzymes. There is a Ca^{++} requirement by FS for cellulose degradation because strains of FS did not degrade cellulose in the absence of Ca^{++}. When growth was excluded from the process by deleting nitrogen (N) from the medium, results confirmed the specific requirement of Ca^{++} for cellulose degradation. Further, cellulose degradation by RF increased with increased Ca^{++} concentrations. *Ruminococcus albus* (RA) did not respond to Ca^{++}. Evidence has reported that Ca^{++} binding improves the stability of structures (cellulose) involved or improves enzymatic activity.

No clear results were gained, but these studies do support roles for Ca^{++} in cellulolytic microbial functions that have not yet been explored adequately. Further investigation may well reveal other regulatory aspects to Ca^{++} for cellulolytic function in the ruminal environment. However, *ionized calcium* definitely plays some important role.

Editorial comment:

This latter study stimulates additional ideas concerning calcium nutrition in the ruminant animal. A recent report given at this year's AFIA Liquid Feed Symposium in Nashville, TN, in September reviewed beef requirements for the different macrominerals of which calcium was one. Essentially, today's calcium requirements for cattle were established by historical trial work in the late 1940s.

Quoting from that report, "Calcium and phosphorus content of gain was calculated from slaughter data published by Ellenberger et al in 1950. This may represent a source of error in calculation of calcium and phosphorus needs for growth, as these data were collected in dairy cattle and cattle today are very different genetically than those in the 1940s."

That almost seems beyond believable acceptance. They were conducted on cattle of that era under feeding conditions and feedstuffs readily available also during that era. Measurements were based on growth performance observations regarding weight gains and efficiencies of gain. In general, those

(Continued from front page3)

recommended levels for diet formulations still set the standards today for formulating diets. Several questions certainly arise due to this realization. What has changed in the past 60 years? Certainly genetics have improved, and thus both growth and feed efficiency of growth have accelerated. Basic beef diets were made up of forages such as alfalfa and corn silage and grain of mostly corn with protein supplementation centered on soybean meal. Dairy rations mirrored these basic feedstuffs as well.

Perhaps these standards established from those long ago decades may still be relatively applicable. But one cannot refrain from questioning the overall validity of such standards with the many changes that have taken place. Not only has genetics changed dramatically with many newer breeds contributing to modern cattle feeding's DNA pool, but feedstuffs in general have evolved perhaps even more. The above mentioned forages and grains plus soybean meal continue to be part of many feeding regimens, but many more and greater variations are fed today, especially in the area of by-products from other processing. Distillers' grains, either wet or dry, along with such ingredients as soybean hulls, wheat middlings, and whole cottonseeds along with various oils and glycerol are just a few that were not prevalent in the feeding of cattle six decades ago. To begin with, the use of these newer products has forced levels of additional nutrient contributions in diets that should also call for further considerations in diet formulations than just with their basic components. Perhaps one prime example is the use of ethanol byproducts, predominantly from corn. Removing starch certainly concentrates the remaining components of protein, energy from oil, and fiber, but also minerals especially phosphorus (P). Therefore, diets containing high levels of distillers' grains furnish both energy and protein while also providing high levels of P. Phosphorus' relationship to other minerals should be scrutinized. In ruminants, maintaining a 2:1 relationship between Ca and P has been the accepted standard. How does the ratio change with excess P if adjustment in Ca levels is not accounted for also? Diets may reach adequacy in standard mineral nutrient contributions, but ensuring proper ratios among those minerals is equally important. This may be to prevent antagonisms or ensure proper synergies. To accomplish such, additional supplementations may be necessary. Calcium standards set in the early 1950s should be looked at again. Others may well follow too.

The complexity of today's research reported by the scientific community indicates movement well away from basic mineral considerations. There is no question that current research studies are helpful with more in-depth informational understanding. In monogastrics, for instance, there is much research elucidating the dynamics of amino acid relationships. The same can be said for dietary energy relationships as well. In no way does this imply an indictment of current scientific study. However, perhaps research revisiting some fundamental mineral requirements and their interrelationships seems warranted. Minerals in general fulfill both a structural and regulatory role supporting growth rate and efficiency of growth along with many other metabolic functions. In light of much rapid change in the dynamics of livestock feeding regarding genetics and a wide array of feed ingredients available today, confirming and/or revising formulation standards in minerals seems wise to consider. Contrary to what some believe, we simply do not know all there is to know about Ca and other macrominerals.