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Calcium digestion – Ca^{++} Availability

In the August 22nd issue of **Feedstuffs** appeared an interesting article titled *Calcium concentration not critical to ATTD* (apparent total tract digestibility) authored by John Goihl – president of Agri-Nutrition Services, Inc. in Shakopee, MN. John is a frequent contributor in Feedstuffs. We recommend your referencing this article and absorbing its content. The article discusses the roles calcium (Ca) and phosphorus (P) play in the development and maintenance of the skeletal system as well as other physiological functions. The article focuses on the dietary ratios and concentrations of Ca and P for optimizing efficient utilization of both. The exposé revealed that concentrations of one (Ca) may not only influence the digestibility of the other (P) but may also affect its own (Ca) digestibility. A composite study from The North Central Coordinating Committee on Swine Nutrition (NCCC-42) was cited as central to the insights revealed regarding this issue.

Six participating universities fed 50 pound pigs common growing diets calculated to contain 0.46% total P and varying concentrations of 0.33, 0.46, 0.51, 0.67, 0.92, & 1.04% Ca. The experimental diets ranged between 55 and 173% of the Ca requirement (NRC, 1998). The only difference among the six diets was that the concentration of $CaCO_3$ varied to create diets that contained the graded amounts of dietary Ca. Calcium carbonate was furnished by ILC Resources and contained 38.83% Ca with average particle sizes of 550 µm (*microns*). FreFlo from Alden, IA plant was the supplemental product in this trial. In the present experiment, no attempt was made to distinguish Ca absorption mechanisms, either as downregulated by hormonal influence (PTH) or by a passive mechanism. Their findings indicated that ATTD of Ca in $CaCO_3$ is not affected by dietary Ca concentration varying between as low as 55% and as much as 173% of NRC requirements in this experiment. Retention of Ca increased while retention of P decreased as dietary Ca increased. It was concluded that dietary concentration of Ca does not affect ATTD of Ca in $CaCO_3$ but increased dietary Ca may decrease the ATTD of P in the diet. Mechanisms of explanation were left unsolved and questions certainly linger.

For further particulars on these findings, please refer directly to

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the Feedstuffs review or to the study itself in *Journal of Animal Science 2011, 89:2139-2144.* Either is available upon request.

The bottom line of the Feedstuffs' review "…indicated that calcium digestibility in calcium carbonate is much less than 100% …" Further, concluded "More research is needed on calcium digestibility of ingredients to accurately formulate diets on a digestible calcium and phosphorus basis."

We share the author's opinion that "more research is needed on calcium digestibility…" Our article here will focus on the supplemental $CaCO_3$ used in the study demonstrating its ability to allow for consistency of this trial's performance even in the midst of resultant mysteries. Just how Ca was absorbed wasn't examined as stated above, but how Ca is made available for absorption begins with the actual digestion process of dietary $CaCO_3$.

To understand this aspect, let's take a look at the fundamental definition of the biological process of digestion.

Digestion defined as**:**

1. **(noun) digestion**

…the process in the alimentary canal by which food is broken up *physically*, as by the action of the teeth, and *chemically*, as by the action of enzymes, and converted into a substance suitable for absorption and assimilation into the body. … *and*

2. **(noun) digestion**

…the conversion of food, in the stomach and intestines, into *soluble* and diffusible products, capable of being absorbed by the blood.

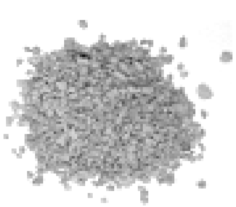
According to these definitions, the particular chemical digestion of $CaCO_3$ involves the following reaction yielding ionized free calcium (Ca^{++}):

$$CaCO_3 + HCl \rightarrow \mathbf{Ca}^{++} + CO_2 + H_2O + Cl^-$$

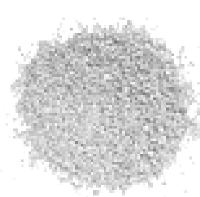
Actual calcium digestion occurs when ingested particles of $CaCO_3$ come in contact with the hydrochloric acid in the stomach. The rate of chemical reaction depends mostly on surface area exposure of $CaCO_3$ in presence of the stomach acid, not just chemical configuration alone.

One of the major factors affecting bioavailability of calcium from supplemental $CaCO_3$ is actually two-fold. First is the duality of both particle size and corresponding rate of solublization in stomach acid. And second is the inherent hardness of calcitic limestone rock source. Acid solubility rates are therefore determined by both surface area exposure and hardness of the particles being dissolved. Like particle sized products from different calcitic limestone deposits differ in solubility, which is most likely due to this hardness factor.

An additional influence to nutrient bioavailability is the rate of digesta passage through the GI tract. On one extreme, if particles of $CaCO_3$ are too large regardless of rate of passage, very little *digestion* will take place releasing ionized Ca^{++} for absorption irrespective of accessibility and/or concentration of vitamin D_3 for active transport. On the other extreme, if particles of $CaCO_3$ are too small (finely ground powder), rapidly solublized Ca^{++} may pass through the GI tract and be eliminated before adequate absorption occurs – whether by active transport with proper Vitamin D (form & levels) or passively by overwhelming concentrations. Thus, eliminated as intact $CaCO_3$ particles or free ionized Ca^{++}, the results are the same regarding *availability* of calcium to the animal. As an example, two extremes demonstrating this point would be feeding a coarse particulate product, such as Unical-F (2300 µm average diameter) versus finely ground powder, such as Unical-P (10 µm average diameter) to a typical

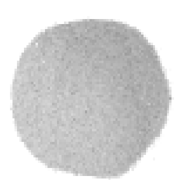


Unical-F

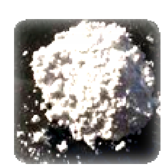


Unical-L

FreFlo



Unical-S



Unical-P

monogastric during the growing period.

First, in order to understand availability of Ca in an animal during digestion, a laboratory protocol measuring *in vitro* acid solubility of different particle sized $CaCO_3$ is used which mimics *in vivo* conditions. In its simplicity, *a measured amount of sample of specified particle sized $CaCO_3$ is introduced into an acid bath of HCl for an exact time period (ten minutes), after which the resultant pH change is measured that correlates directly to concentration of $CaCO_3$ dissolved (or solublized into free Ca^{++}).* No direct correlations can be used to quantify *in vivo* use, but relative interpretive comparisons can be made among various particle size $CaCO_3$ products in the laboratory.

Using the two product profiles above, the coarse diameter material ranges in neighborhood of high 30s to low 40s percentile acid solubility. The powdered product is much more predictably reactive, of course, and ranges in the mid 70s percentile acid solubility. These percentages are best extrapolated quadratically rather than linearly. Large particles dissolve visibly quite slowly, while the powder disappears fairly rapidly.

Both of these products would be poor considerations in most monogastric diets – whether swine or poultry – under growing-finishing production. What type of particle sized $CaCO_3$ may be better suited for dietary formulation use in optimizing the digestion of $CaCO_3$ to make Ca^{++} available for absorption in terms of both timing and amounts? No exact science has been developed to the point of accurately answering that question. However, ILC Resources' in-house product testing and data monitoring along with outside research does provide useful guidance. Layer poultry industry has long used coarse particulate $CaCO_3$ for slow release of Ca^{++} after deposition in the gizzard to make proper eggshell daily throughout the hen's laying cycle. Thus, coarse particulate $CaCO_3$ of low acid solubility is used. On the other end of the particle size spectrum, finely ground powdered $CaCO_3$ of high acid solubility is used in such production as milk replacers where very available sources of nutrients are needed to nourish neonatal animals. Both materials are from the same source of calcitic limestone processed into specific particle sized $CaCO_3$ products. Basically, the key element for consideration is the component rate of dissolution in stomach acid releasing ionized Ca^{++} for proper absorption and utilization to meet varying physiological requirements.

The University of Arkansas conducted a research study in 2006 looking at *"The effect of calcium carbonate particle size on the utilization of phosphorus from phytase for broilers."* (Refer to Third Quarter 2006 *Mineral Writes*). Particle sized $CaCO_3$ used in the diets ranged from coarse particulates (Unical-F, as mentioned above) down to finely ground powder (Unical-P, as mentioned above) along with three other particle size gradations. These additional three were Unical-L (large granular product), Unical-S (small granular product), and FreFlo (blend of large to small granular product). Refer to Table 1.

This study examined the effects which different dietary particle sized $CaCO_3$ had on utilization

Table 1. ILC Resources' $CaCO_3$ Products

Product	Description	Ave diam microns*	% Acid Solubility
Unical-F	**large particulate**	**2300**	**38-42**
Unical-L	**large granule**	**1100**	**44-46**
FreFlo	**blend lg/sm granule**	**550**	**53-54**
Unical-S	**small granule**	**200**	**55-57**
Unical-P	**fine ground powder**	**10**	**74-76**

*Microns (µm) = 1/1000 of a millimeter

of phosphorus in broiler diets containing phytase enzyme. One of the suppositions made was that very fine particles of $CaCO_3$ could release Ca^{++} rapidly enough to rebind the phytate molecule, thus negating the effects of phytase and resulting in reducing phosphorus availability for utilization.

The ARK study revealed that live growth performance was affected by feeding different particle sized $CaCO_3$. The best performance for weight gain and feed consumption was obtained in chicks fed FreFlo (a blend of large to small granular particles). Comparable response was obtained in chicks fed Unical-S (small granular particles alone). These two products have particle size profiles ranging between 200 and 500 microns, with over half their particles dissolving *in vitro* within ten minutes. Poorest performance and highest mortality were observed in chicks fed Unical-F averaging over 2300 microns and dissolving quite slowly. Predictably, coarse particles were simply too large to allow enough ionized Ca^{++} to meet the birds' *calcium* requirements. On the other end, Unical-P, ranging around 10 microns, solublized Ca^{++} ions too rapidly and presumably rebound the phytate molecule and/or were carried through the GI tract too rapidly to meet the birds' nutrient requirements for *calcium*. Interpretation of this broiler study suggests a similar condition in other monogastrics. Tying the Arkansas study in with the NCCC-42 study reported in Feedstuffs suggests further validity to feeding a blend of large to small granular particle $CaCO_3$ product to growing monogastrics.

We agree with Goihl's conclusion that "More research is needed on calcium digestibility of ingredients (*$CaCO_3$*) to accurately formulate diets on a digestible calcium and phosphorus basis." In particular from this NCCC-42 study, we've learned that as dietary Ca increased beyond requirements, retention of Ca also continued to increase but correspondingly retention of P decreased. Admittedly, dietary P concentrations remained constant and one intuitively wouldn't necessary expect increased retention, but why would there be decreased retention in the presence of increasing Ca retention?

Much of the puzzle needs further clarification before all is understood, but we do have more pieces to this puzzle available than are universally recognized. The picture seems a little clearer when we return to the basic definitions of *digestion* referenced at the beginning of this article. Indeed, however, much about the overall Ca/P dynamics remains yet to be researched fully and properly. From the NCCC-42 research study, the physiological dynamics of Ca/P interactions within the body continue to confound our understanding. But, choosing an appropriate supplemental $CaCO_3$ product optimizing free Ca^{++} available for absorption for a given feeding application will also target optimal performance.

A substantial amount of research reported today seems to focus on exotic and minute details. We purport no condemnation of this trend as such, but we strongly believe a return to researching basic nutrition will reveal information of paramount interest as well as for practical application.

Regarding calcium nutrition, simply not enough is yet known about this element. It is the most abundant mineral in the body, mostly located in bones. Secondary to Ca is P, also chiefly located in bones. Proper skeletal development and maintenance is critical for optimum growth and efficiency of production, regardless of species.

We conclude by reiterating that a very important component of understanding digestibility of dietary $CaCO_3$ lies within both its particle size gradation and its corresponding solubility in the dilute hydrochloric acid of the stomach. Both features are crucial in releasing ionized Ca^{++} thus, optimizing availability for subsequent absorption and utilization as Ca interacts with other nutrients, principally with phosphorus.

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