MINI REVIEW

Organic acids as enhancers of phytase activity: A brief discussion based on the available literature and personal research

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The objective of this study was to briefly review the current knowledge regarding the combination of phytases and organic acids in animal and human nutrition. Based on this, and supported by some personal research data, we concluded that some organic acids, such as citric acid, enhances phytase activity and promotes better growth performance and bone mineralization in phosphorus-restricted broilers. Further research is needed to better understand the rule of these additives in other species, including humans.

Key Words: *Phytate; Phosphorus; Food additive; Enzyme; Acid*

Exogenous enzymes and organic acids have long been used in animal nutrition. Acting in different ways in the organism, both additives interfere with gastrointestinal homeostasis, leading to better feed digestibility and local microbiota modulation (1,2). These responses result in improvement of animal's feed efficiency (i.e., conversion of feed into meat, eggs or other products) and reduction of intestinal inflammation, thereby decreasing the production costs. Also, enzymes and organic acids are largely adopted in human nutrition, most frequently during food processing, in order to preserve flavor, enhance taste and appearance, or perform a specific technological purpose, such as preservation or chemical modification (3).

Phytase is the most common enzyme used in animal nutrition. Usually, suppliers provide a static matrix which accounts for its contribution in phosphorus (P), amino acids, energy and other nutrients to the formulation. However, many factors could change this matrix (4,5). Evidence exists that organic acids and phytase have additive and/or synergic effect on the availability of P in poultry diets (6). In addition, the combination of these additives had already proved its value in the improvement of phytase activity in whole-grain bread dough (7). Regardless of these positive results, little attention has been driven to the application of this knowledge in animal or human nutrition.

Therefore, the objective of this study was to briefly discuss the current status of this subject in the literature and provide some personal research data that support the combined use of phytase and citric acid in poultry nutrition.

PHYTASES AND THEIR SUBSTRATE

Phytases are phosphatases that have phytic acid as substrate, a phosphate-rich molecule synthesized by plant organisms as P storage (5). Monogastric animals, including humans, do not produce endogenous enzymes at significant levels to digest phytic acid and, in this sense, most of the P present in phytic acid is virtually unavailable for these species. Moreover, phytic acid is highly reactive and chelates a number of dietary nutrients, generating insoluble phytates that significantly reduce the uptake of these nutrients (8).

Thus, phytase is included in the diet in order to make phytate P available and also to alleviate the antinutritional effect of phytic acid on the digestibility of proteins, carbohydrates and minerals. Unfortunately, phytases are not 100% efficient in their task and, accordingly, a significant amount of phytate P (and phytates) remains intact in the diet even after the enzyme supplementation (6).

IMPROVING PHYTASE ACTIVITY BY USING ORGANIC ACIDS

Several commercial products and molecules are currently available for use as acidifiers in animal and human nutrition. Their mode of action and effects have been extensively reviewed (3,9). Recent investigations have focused their efforts in elucidating the effects of organic acids on the solubility and digestibility of minerals, findings that are aligned with the objectives of dietary phytase supplementation.

Boling et al. (10), for instance, proposed that by lowering the gastrointestinal pH, citric acid inhibit the chemical bond between calcium and phytic acid, thereby increasing dietary P availability. This happens because the conjugated form of phytic acid (phytate) is highly insoluble and has much less affinity to phytase than the non-conjugated form. In this sense, any of the organic acids could potentially improve the availability of phytate P in phytase-supplemented diets. Working with broilers, however, Liem et al. (11) concluded that among a series of organic acids evaluated, citric acid is the most efficient in improving phytate P utilization, followed by malic and fumaric acids. Porres et al. (7) also demonstrated the ability of the combination of phytase and citric acid in reducing the amount of phytate in whole-wheat bread and improving iron dialyzability from this meal.

Another mechanism by which organic acids could potentially enhance phytase activity is by chelating divalent cations such as Ca^{2+}, Zn^{2+}, Fe^{2+} and others, thereby reducing the formation of insoluble mineral-phytate complexes. Maenz et al. (12) have already demonstrated this ability, *in vitro*, in EDTA, citric acid and phtalic acid.

As some inconsistency in these responses is still found in the literature, our research group developed a meta-analytical study to critically determine based on the available literature data, whether citric acid improves growth performance and bone mineralization of P-restricted broilers when added into the feed in combination with phytase (13). Because of the direct rule of dietary P on bone development and body growth, the measure of these variables is traditionally adopted as an indirect way to evaluate the availability of P in the diets.

The results of this study proved that there is positive effect of the combination of phytase and citric acid on weight gain and bone mineralization of broilers. On average, birds that consumed the combination of phytase and citric acid gained 2.46 g/day more (p=0.005) and had 3.27% more (p=0.002) mineral content in the tibia when compared to the ones supplemented exclusively with phytase. Besides, we also demonstrated that part of the difficult in detecting positive results of the combination of these feed additives might be associated with the extension of the P-restriction period provided to animals, as well as to the concentrations of phytase, citric acid and phytate P in the experimental diets.

CONCLUSION

The combination of phytase and citric acid is a remarkable tool to improve the efficacy of phytase in making phytate P available to monogastric animals.

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Probably, the intensity of the anti-nutritional effects associated with phytic acid is also decreased by applying this protocol. These results open an interesting opportunity to evaluate the effects of these additives in the diet of a range of other animals, including humans. Moreover, considering that the access to an adequate nutrition is not guaranteed in many parts of the globe, taking full advantage of the available technologies might be a solution for balancing human nutritional needs with the economical and environmental aspects involved with this question.

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