EFFECT OF SUPPLEMENTAL INORGANIC PHOSPHORUS ON CONTENT OF ORGANIC PHOSPHORUS IN DAIRY FECES

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Abstract

High phosphorus (P) concentrations in dairy manure have the potential to degrade surface water quality. Dairy feed rations include supplemental orthophosphate salts to increase the P content of the feed to optimize the nutritional needs of dairy cows. Our research shows that excess supplemental P fed to dairy cows increases the amount of natural organic P from grains that pass through the rumen unused, and which ends up in the feces.

Introduction

In nature, phosphorus exists in two main forms, inorganic phosphate (P_i) and organic phosphorus (P_o). The difference between the two is that P_o is just P_i that is chemically bonded to some form of carbon compound (Figure 1). In soils, P_o comprises from 30 to 70 percent of the total P (Marschner, 1995). In the soil solution, P_o ranges from 20 to 70 percent of the total P (Ron Vaz et al., 1993). In the soil solution near plant roots where the concentration of P_i is depleted by plant uptake, P_o can be 80 to 90 percent of the total P (Helal and Dressler, 1989). Some important compounds of P_o present in soils and plants are DNA, sugar phosphates, and phospholipids, but the most common form of P_o are inositol phosphates also known as phytates or phytic acid. In soils, phytates comprise between 10 to 50 percent of the total P_o (Anderson, 1967). Phytates are also the main chemical compounds plants use to store P in seeds (Taiz and Zeiger, 1998) and they are thus are a major source of P in animal diets. Phytates are relatively stable in soils because they form highly insoluble compounds with many metals (aluminum, iron, calcium, etc) commonly found in soils and plants. Phytates thus tend to accumulate in soils even when the seeds decay and are converted to soil organic matter.

In order for plants, microbes, and animals to take up P, it must be in the inorganic form (P_i). Therefore, conversion of P_o to P_i is an important process. The conversion of P_o to P_i involves breaking, technically known as *hydrolyzing*, the chemical bond between the orthophostate group and the carbon compound. This bond is called an *ester* bond (Figure 2). Two main types of enzymes hydrolyze this ester bond. Phosphatase enzymes hydrolyze many different types of phosphate ester bonds but phytate can only be hydrolyzed by phytase enzymes. Microorganisms in the stomach of ruminants as well as those in soils secrete both phosphatases and phytases to help them acquire P in the inorganic form. The roots of some plants also secrete these enzymes. Manufacturing enzymes requires energy so the loss of these enzymes to the soil or rumen environment is an energy loss for the plants or microbes. Therefore, plants and microbes will preferentially use P_i if presented with both P_i and P_o.

In soils and plants, P is bound to metals to maintain charge neutrality. Both the metal species and the form of P affect its solubility, and therefore, the availability of P for uptake by plants and microbes. Some plant species have evolved mechanisms to increase their uptake of

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P by utilizing organic forms of P. Specifically, white lupin has been shown to excrete citric acid and enzymes in P deficient soils to meet their P needs (Gardner et al., 1982b; Braum and Helmke, 1995; He, 1998). Possible mechanisms for this process include citric acid displacing P_i from mineral surfaces, citric acid increasing P_i solubility by acidifying the soil, and citric acid increasing P_o availability to phosphatase enzymes by complexing metals that tend to make organic forms of P insoluble.

As part of our overall research program in this area of phosphorus chemistry, we designed this research to study the effects of excess inorganic phosphate supplements on the content of hydrolysable organic phosphorus in dairy feces.

Materials and Methods

Eight composite dairy feces samples were collected from feeding trails using four separate feed rations. The feces samples were treated with different concentrations of EDTA followed by dialysis to remove P_i and complexed metals. After dialysis, the samples were incubated with phosphatase, phytase, or no enzyme as a control. P_i was measured in all the samples to assess the effect of increasing EDTA concentration on the ability of the enzymes to hydrolyze P_o.

Results and Discussion

Figure 3 shows the results of increasing EDTA concentration on the ability of phytase and phosphatase to hydrolyze P_o in one of the dairy samples. The amount of P_o hydrolyzed by phosphatase was not affected by increasing EDTA concentration but remained essentially constant. With no EDTA added, phytase did not hydrolyze any P_o. As the EDTA concentration was increased, the amount of P_o hydrolyzed by phytase increased up to a maximum at 5 mM EDTA. These results show that removal of metals from the organic forms of phosphorus in feces enhances their hydrolysis by enzymes, similar to the trends found in soil systems.

The concentration P in the diet as percent of dry matter (DM), the amount of supplemental inorganic P, and the total P in the feces are given in the three columns shown in Figure 4. The concentrations of hydrolysable organic phosphorus in the feces are shown in the horizontal bar graphs of Figure 4. The maximum amount of phytase hydrolyzable P_o ranged from 230 to 1180 $\mu g\ g^{-1}$ dry feces in the eight samples that were tested (Figure 4). For ration 3, the feces sample with a high content of total fecal P also had a high content of Ca in the diet, which reduced the uptake of P by the cows. For a given ration, the amount of P_o that was hydrolyzed by phytase increased as the amount of supplemental P_i in the feed ration increased.

Summary

- The amount of supplemental P_i added to dairy feed rations directly affects the amount of P_o that passes through the rumen unutilized.
- Metal complexation by EDTA enhances the ability of phytase enzymes to hydrolyze P_o in dairy feces.

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