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A Potential Phosphate Crisis

Philip H. Abelson

Phosphate is a crucial component of DNA, RNA, ATP, and other biologically active compounds. Microbes, plants, and animals—including humans—cannot exist without it. Rocks containing phosphate have been discovered and are being mined at minimal cost. But resources are limited, and phosphate is being dissipated. Future generations ultimately will face problems in obtaining enough to exist.

The current major use of phosphate is in fertilizers. Growing crops remove it and other nutrients from the soil. Long-term research at the Morrow agricultural plots of the University of Illinois at Urbana-Champaign has corroborated the fact that even the best land loses fertility unless nutrients are replenished. At the Morrow plots, there is a threefold or greater difference in yields of corn between fertilized areas and untreated ones. Most of the world's farms do not have or do not receive adequate amounts of phosphate. Feeding the world's increasing population will accelerate the rate of depletion of phosphate reserves.

Research has resulted in ways to diminish the loss of phosphate.

Corn seeds, which are a major source of food for cattle, swine, and poultry, contain substantial amounts of phosphate. About 75% of it is in the form of phytate, a water-insoluble compound. When the seeds sprout, enzymes are created that release phosphate from the phytate, making it available for biological activities. When seeds are fed to ruminants, bacteria in the rumen degrade some of the phytate, providing phosphate for use by the animals. But nonruminants such as poultry, swine, and people do not have an efficient system for making phosphate available from phytate. They excrete most of it. Ultimately, some of the phosphate excreted contributes to water pollution and eutrophication and becomes unavailable for further use.

Recent scientific research has resulted in ways to diminish the loss of phosphate. One of the methods was described at the recent AAAS annual meeting in Anaheim, California. Adolphus van Loon of Hoffman–La Roche, Basel, Switzerland, reported on research results that facilitate the release of phosphate from feed prepared for chickens and hogs. One of his colleagues conducted many successful experiments to improve the stability of phytase enzymes, which catalyze the breakup of phytate. The DNA coding for phytase that is present in thermophilic bacteria was altered to produce more highly thermostable enzymes. These are incorporated in feed when it is initially being cooked. Experiments have demonstrated that as much as one-third of the phytate phosphate is made available when monogastric animals are fed the improved feed. Van Loon estimated that annual sales will total as much as $500 million.

Another approach to the phytate problem has been attempts to reduce the amount of phytate in seeds. However, studies using this approach usually found that when the phytate content was decreased substantially, the seeds did not germinate, or if they did, they did not give rise to healthy plants. A breakthrough was achieved when Victor Raboy and his colleagues at the U.S. Department of Agriculture Agricultural Research Service in Aberdeen, Idaho, obtained useful mutants of corn seeds. Although the seeds contain relatively little phytate, they give rise to productive plants. Phosphate needed by the seed is stored safely by a mechanism not yet determined.

Growing and feeding experiments are currently being conducted. In one study, University of Missouri scientists conducted experiments involving analysis of waste from pigs fed either unmodified or low-phytate corn. Pigs who were fed the low-phytate corn showed, on average, a 37% reduction in phosphorus excreted. In growing pigs, 64% of the phosphorus in low-phytate corn was available, as compared with 10% from genetically similar corn with normal phytate levels.

The rate at which U.S. farmers will adopt low-phytate varieties of corn will depend on whether seeds also provide a combination of traits that include higher yield, increased energy for feed, and resistance to pests and herbicides. Ultimately this objective will be achieved.

Accomplishments such as these that lead to the conservation of phosphorus will avert a crisis in phosphate availability in the short term, but further research is needed to avert problems in the long term.