Updating Phosphorus Supplementation in Ruminants to Meet the Animal's Requirement, Reduce Excess Cost, and Reduce Environmental Concerns

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Phosphorus has been called the "master mineral" because it is involved in most metabolic pathways, is a key component of Adenosine 5'-triphosphate (ATP) which transports chemical energy within cells for energy metabolism, and it is a component of deoxyribonucleic acid (DNA). "Next to calcium, phosphorus is the most abundant mineral in the body. Approximately 85% of phosphorus in the body can be found in bones and teeth, and roughly 10% circulates in the bloodstream. The remaining phosphorous can be found in cells and tissues throughout the body. Phosphorus helps filter out waste in the kidneys and contributes to energy production in the body by participating in the breakdown of carbohydrates, protein, and fats" (http://www.umm.edu/altmed/articles/phosphorus-000319.htm).

In the past, phosphorus has often been over-supplemented due to its once cheap cost and at the advice of many nutritionists and veterinarians. However, as more emphasis is being placed on meeting, not exceeding, mineral requirements to be both economically and environmentally responsible, things are changing. Recently, dietary Calcium (Ca):Phosphorus (P) ratios of between 1:1 to 7:1 have been shown to result in similar animal performance, provided the phosphorus adequately meets requirements. However, it is recommended not to allow total daily P intake to exceed daily calcium intake for young beef animals, to avoid urinary calculi (http://ianrpubs.unl.edu/beef/ec277.htm). Urinary calculi, or water belly, is a common disease of male sheep, and less frequently bulls or steers being fed grain-based diets, and is caused by the formation of small stones, called calculi, in the urinary tract that cause retention of urine and rupture of the urinary bladder or urethra. Treatment is normally not effective, and the best preventative is to keep a Ca:P ratio in the range of 2:1.

Phosphorus losses from livestock farms are primarily in the feces, and are a major environmental concern. Increasing dietary P levels above the animal's requirement not only leads to greater concentrations of total fecal P, but more importantly, increases the amount of water-soluble P, which is most susceptible to loss into the environment when the manure is land applied (Dou et al., 2002, 2003). Fecal P increases as dietary P supplementation increases (Wu et al., 2000; Dou et al., 2002, 2003;Odongo et al., 2007) and can account for significant P loading to bodies of surface water, resulting in excessive plant growth and decay, which result in further impacts including a lack of oxygen, severe reductions in water quality, and reductions in fish and other aquatic animal populations. The inorganic forms of P contained in supplements are a major concern environmentally, because they are more polluting than organic sources due to their water-soluble nature which results in leaching and runoff. However, the impacts of lowering the dietary P concentration also must be examined from the standpoint of performance and economics.

In feedlot cattle, Erickson et al., (1999) reported no decrease in performance of steers receiving grain-based diets containing .14 or .19% P compared with those containing .34% P and concluded “plasma P, performance, and bone characteristics indicate that P requirements are less than 0.16% of diet DM. Erickson et al., (2002) reported similar results in steers with grain-based diets containing .16% P (non-supplemented), .22, .28, .34, or .40% P, and suggested that the P requirement for finishing cattle was less than .16% of the diet dry matter, and that typical grain-based diets do not require supplementation of inorganic mineral P to meet requirements, concluding that supplementation of P in finishing diets is unnecessary from both economic and environmental standpoints and should be discontinued. This is supported by the conclusion that P excretion can be reduced 20 to 30% by not adding supplemental P to the diet of cattle being fed grain-based diets (FASS, 2001).

The impact of reducing the dietary P level in dairy diets has received considerable attention in recent years. Recently, Odongo et al. (2008, as reported by Kebreab et al., 2008) suggested that the current forages grown in Ontario contain adequate amounts of P to sustain milk production in mature dairy cows without mineral P supplementation or without affecting animal productivity. From an environmental point of view, an efficient use of dietary P by dairy cows is important to minimize fecal P output and, as a result, P losses to the environment. Kebreab et al. (2008) reported that reducing P levels from 0.41% of diet dry matter to 0.35% P, in dairy diets in Ontario, could save producers CAN $20/cow per year and the environment 1.3 kilotons of P per year without impairing cow health or productivity, with the majority of the reduction coming from inorganic P sources added to the feed through supplementation. This would be in agreement with the findings of Dou et al. (2003) who reported in a survey of 612 dairy operations in New York, Pennsylvania, Delaware, Maryland, and Virginia that, on average, the P levels being fed to lactating dairy cows averaged 34% above the NRC (2001) recommendations, averaging 4.4 grams of P per kilogram (.44%) of diet dry matter, and that the higher P concentrations were not associated with higher milk yields. Similarly, Knowlton et al. (2004) reported that P is commonly fed from 20 to 40% above published requirements.

Wu (2005) reported that dietary P at 0.32% of diet dry matter appeared inadequate for dairy cows producing 43 kg/d (95 lb/d) of milk, whereas 0.44% P was excessive, compared with the calculated requirement of 0.37% according to NRC (2001). However, based on the relationship between P intake and fecal P concentration, reducing P in the diet from 0.44 to 0.37% would reduce fecal P excretion by 12%. In contrast, Wu et al. (2003) reported similar milk yields when cows were fed 0.33 or 0.42% P, however, these cows averaged 36 kg/d (79 lb/d), compared with the 43 kg/d in the study by Wu (2005). Therefore, levels less than .40% P meet requirements across a wide range of productivity, and the calculated requirement of the Dairy NRC (2001) seems adequate, so it’s reasonable to question why the over-feeding of dietary P is so common. Knowlton et al. (2004) suggests that one of the main reasons is concern over reduced reproductive performance with low P intakes resulting from the early studies on the impact of P on reproduction, conducted in the 1930’s and 1940’s. However, as suggested by Knowlton et al. (2004), those early studies were conducted primarily with range cattle, and the P concentrations were below .20% of diet dry matter, far below the levels found in today's concentrate feeds and most forages. In fact, Satter and Wu (1999) reported on the outcomes of 13 separate studies comparing low (.32 to .40% P) or high (.39 to 0.61% P) in dairy cattle, and dietary P concentration had no effect on days to 1st estrus, days open, days to 1st AI, services per conception, or pregnancy rate. In fact, Knowlton et al. (2004) stated that "revisiting the literature makes clear that there is no documented benefit to overfeeding P."

In beef cattle grazing forages, variation in grass species, regional soil profiles, fertilization practices, and selectivity by the animal in what they consume has made research more difficult than in those production situations where cattle are being fed a known amount of specific harvested feeds. According to NRC (1996), the P requirement for a 1200 lb mature cow during pregnancy is .15% P, and during lactation when she is producing 20 lbs of milk, the requirement is .19% P. The following are some examples of the P concentrations of commonly used feeds: alfalfa hay, mid-bloom .22%; alfalfa haylage, mid-bloom .20%; Corn silage .20%; Grass hay (Brome, mid-bloom) .28%; Sorghum-Sudan hay .30%. The P concentrations in corn and soybean co-products are higher: corn gluten feed (dry or wet) 1.10%; dry distillers grains .83%; soybean meal .71%. However, for very mature feeds, they are lower: corn stover .09%; grass hay (N. Dakota native, full bloom) .14%; oat straw .10%; wheat straw .09% (Lardy and Poland, 1998).

Regional differences in forage P levels do exist, and P supplementation of cattle in deficient areas must not be ignored. However, Rayburn et al. (2006) reported on the findings of 607 pasture samples taken in West Virginia between 1997 and 2001. The P content of the forages was between .27 and .41%. In 55 hay samples from 17 Wisconsin counties taken in 2003 and 2004, the P content averaged .25% (Lehmkuhler unpublished data as reported by Brokman et al., 2007). Brokman et al. (2007) reported no improvement in ADG with steers grazing a cool season grass/alfalfa pasture supplemented with P, and concluded that in most of the Midwest, P supplementation is not necessary, because forage contains adequate P to meet the requirements of growing cattle. However, Ward and Lardy (2005) report that phosphorus deficiencies are common in native pastures and harvested forages in North Dakota, stating that the phosphorus content of most plants in semiarid regions averages 0.30 percent during the vegetative state, and drops to 0.15 percent as grass matures. They note that a similar pattern in P content occurs in cured hays; the later hay is cut in the season (past boot stage), the more P concentration is reduced. In winter months and during times of drought, when harvested forages are the primary source of feed, P may become deficient.

In conclusion, It's important to remember that forage digestibility determines energy and protein availability from forages, and these are the limiting factors to grazing cattle performance. The P content of most forages, feed grains, and ethanol co-products contain sufficient P to make supplementation unnecessary. However, mature forages may require supplementation. The most economical and environmentally responsible management option is to take a feed test rather than over-supplement phosphorus.

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