Defining the Phosphorus Requirements of Cattle

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Introduction

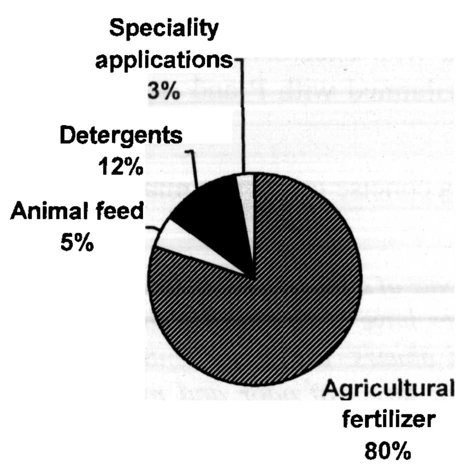
Why has there been such a renewed interest in further defining the phosphorus (P) requirements of livestock in the United States? Haven't we known how much P to supplement since the 1890's (Morrison's Feeds and Feeding) and more precisely since the 1970's after publications by Call and others from Utah State University and Ternouth and colleagues from Australia? Why haven't we been concerned when we supplied P in excess of requirements; especially on ranches in the Northern Great Plains?

What is changing is that P has now become an environmental issue. For example, N and P contamination of ground and surface water are the leading environmental issues facing livestock farmers in Virginia, Maryland, and Pennsylvania. The increasing concentration of poultry, swine and cattle has led to nutrient imbalances on farms and across watersheds. When total P inputs to a farm or watershed have exceeded exports, P accumulated in soil, and if there is runoff, will contaminate water resources (Knowlton and Kohn, 1999). However, in the past there has been little pressure to decrease excretion of P and livestock and poultry producers have typically over fed P in excess of requirements (Klopfenstein et al., 2002). The purpose of this presentation is to provide a general overview of several of these issues.

Specifically, what are the environmental concerns with phosphorus?

The following figure (Figure 1) presents worldwide usage of phosphates. The greatest consumption of phosphate has been for agricultural fertilizers (80%) followed by detergents (12%), animal feed (5%) and finally specialty applications (3%).

Figure 1. Worldwide usage of phosphate
(from Phosphate Recovery, National History Muesum at http://www.nhm.ac.uk)



China and the U.S. were the two largest consumers of P during the 1990's (Figure 2). Total N and P usage in the U.S. since 1960 is presented in Figure 3. While N usage for fertilizers has continued to increase, P consumption has remained relatively stable since the 1980's (The Fertilizer Institute).

Figure 2. Comparison of phosphate consumption; China vs U.S. (Fertilizer Institute, www.tfi.org)

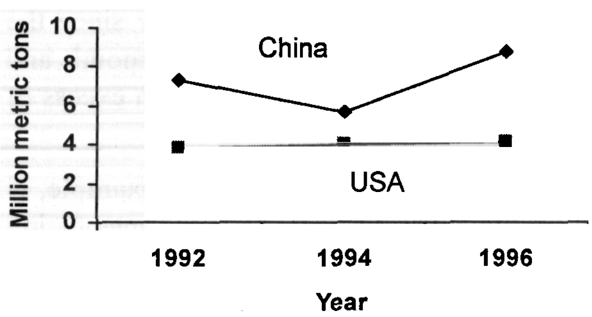
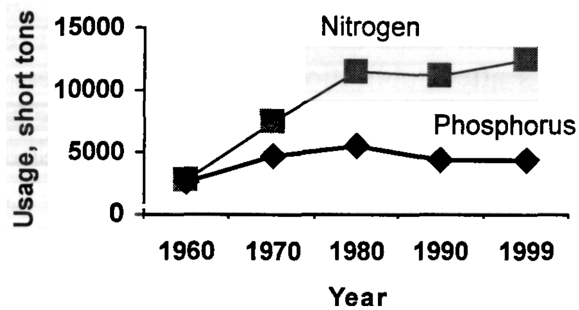


Figure 3. Changes in N and P fertilizer usage in the U.S. since 1960 (Fertilizer Institute)



The environmental concerns with P are primarily associated with pollution of surface water. Excess P in water, like excess N, causes algae populations to grow rapidly, or to "bloom". The subsequent decomposition of the algae consumes dissolved oxygen in the water. This lack of dissolved oxygen is the major factor affecting the growth and reproduction of fish, clams, crabs, oysters, and other aquatic animal life. An algae bloom and subsequent decrease in dissolved oxygen is known as eutrophication, and may be caused by runoff or leaching of P or N from soil (Knowlton and Kohn, 1999).

It has been well known that excess application of N, either through manure or chemical fertilizer, can result in loss of N to surface water. In contrast, P was originally thought to be fixed in the soil in a relatively stable form, and the conventional wisdom was that excess P would accumulate in soils and runoff only if there were erosion. Management of P on farms was a matter of preventing erosion using favorable tillage and cropping strategies. Now, it has been discovered that with excessive application of P to soils over a period of several years, the soils become saturated with P and runoff can occur even when erosion is controlled (Sharpley, 1996).

Satter and Wu (2002) did a concise job in summarizing the concerns of N and P feeding on livestock operations;

"Public scrutiny of the impact of agricultural practices on the environment is growing. The livestock and poultry industries have been targeted for attention because of their visibility, and for real as well as perceived abuses. Large concentrations of animals in relatively small areas create difficult challenges in terms of odor and nutrient management, but problems of nutrient management can plague small as well as large animal operations. One of the fundamental challenges facing the livestock/feed industries is to recycle the flow of feed nutrients, particularly phosphorus and nitrogen, from animal operations back to cropland where they can again be used for crop production. Anything short of this is not sustainable, and will ultimately be unacceptable to the broader public."

Examples of research which led to supplementing phosphorus to beef cattle.

Herd (1997) from Texas A&M reviewed the field research responses of P supplementation on the King Ranch from the 1930's and 1940's. The results of two experiments showed that when P was supplemented, the percent calf crop weaned increased 40 and 41 percent, weaning weights increased 69 and 49 pounds, and calf weight weaned per cow exposed increased 156 and 165 pounds, respectively. Later work by Bohman et al. (1961) from the University of Nevada showed similar improvements in productivity when P was combined with a protein supplement for range cattle.

As a result of studies like these, it became a goal of many cattlemen to supplement approximately 6.0 pounds of actual P per cow per year. According to Herd (1997) this level of supplemental P intake/cow/year is probably still a reasonable goal for cows grazing on native, unfertilized pastures with little or no protein or energy supplementation. But, this recommendation is probably not appropriate when cattle graze P-fertilized, cool-season grass pastures.

The primary reason for feeding supplemental P was to enhance reproductive performance. However, research data to support this in confined cattle was tenuous even though many of the early studies reported depressed reproduction when dietary P levels were <0.2%. For example, the most common mineral deficiency in cattle in Queensland, Australia is P and a deficiency on acutely deficient soils can reduce growth rates by up to 20% and calving rates by up to 40% (Meat and Livestock, Australia). In their attempt to use soil P levels as an indicator of animal P status, the following recommendations were developed (Table 1; Tyler, Queensland Beef Industry Institute, 2000).

Table 1. Relationship between soil P and expected P deficiency symptoms in Queensland Australia (from Tyler, 2000)

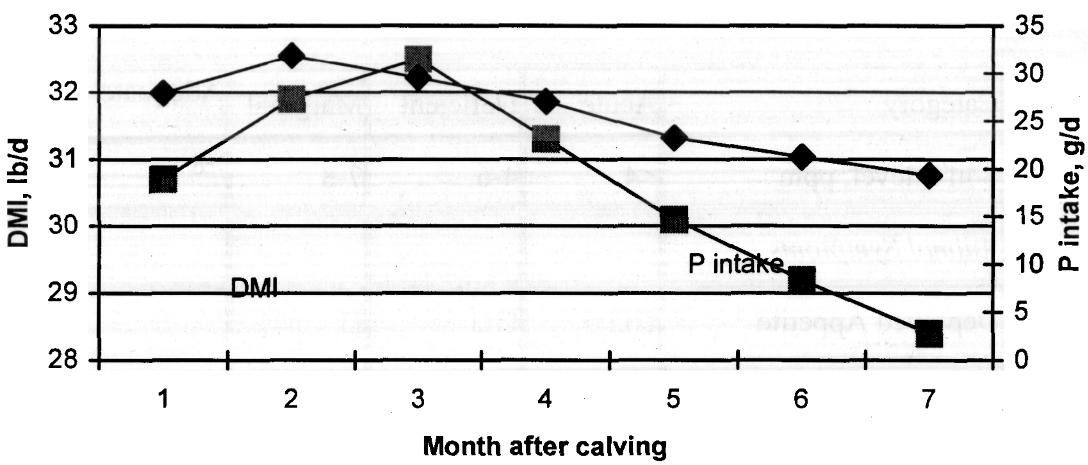
Category	Acute	Deficient	Marginal	Adequate
Soil P level, ppm	<4	4-6	7-8	>8
Animal Symptoms				
Depraved Appetite	□□□	□□	□	
Peg Leg	□□	□	□	
Poor growth rates	□□□	□□	□	
Low Reproductive Rates	□□□	□□	□	
Coat and condition	□□□	□□□	□	

When in acute deficiency, animals have exhibited stiffness in the front quarters resulting in a characteristic lameness referred to as "pegleg" in Australia, "creeps" in Texas, and "styfsiekte" in South Africa (Karn, 2001). The other symptoms most often associated with a P deficiency have been weak and broken bones, reduced feed intake and/or growth, impaired reproductive rates, lowered milk production and reduced calf weaning weights (Karn, 2001). McDowell et al. (1983; also cited by Karn, 2001) reported animals often died from botulism contracted from eating bones from old carcasses contaminated with Clostridium botulinum. Phosphorus depleted cows preferred to eat bones that were weathered and at least 1.5 years old compared to fresh bones (Blair-West et al., 1992, both articles cited by Karn, 2001). Brouwer et al., (2000) cited interesting work which showed that P supplementation actually increased weight loss when cattle were fed at levels below maintenance and this appeared to be a result of when protein and energy requirements were not balanced by the supplement. It is also important to note from the Brouwer et al. work that responses to P supplementation varied substantially from one area to the next. Supplementation might be essential in one area and unnecessary in another area within the same region and therefore extrapolation of results should be done cautiously.

Field observations from one ranch in MT suggested that reproduction might be negatively influenced by unusually high levels of Al in the soil. Research from FL showed that the addition of Al or Fe to diets had the effect of depressing P absorption by chelating to the P (Rosa et al., 1982).

Meeting P requirements

Figure 4 . Expected DM intake and P requirements (g/d) for a 1400 lb mature cow with 25 lbs of milk at peak lactation (NRC, 1996)



Utilizing the information provided by the 1996 NRC, the following figure was developed to show the P requirements of a 1400 lb mature beef cow with a peak milk production of 25 lbs/day. This graph assumes a DMI between 28 and 32 lbs/day and a P intake between 19 and 32 g/day. Using these changing requirements, Table 2 demonstrates combining the NRC recommendations with average forage P analyses from Alberta (Alberta Beef Herd Management Binder). If at peak milk production, the requirement is for 32 g of P/d, then only alfalfa hay would come close to meeting the cow's requirement. However, by weaning, the P requirement has declined to approximately 20 g/day and all feedstuffs would meet requirements.

Table 2. Average phosphorus analyses of selected Alberta grown feedstuffs[a] and expected P consumption (14.5 kg DMI/d) for a 1400 lb beef cow in peak milk production

Item	Avg. P,%	Calculated P intake, g/day[b]	Deficient?
Alfalfa Hay	0.21	29.6	Y
Grass Legume Hay	0.19	27.7	Y
Grass Hay	0.17	24.7	Y
Oat Hay	0.20	29.0	Y
Barley Grain	0.38	---	

[a]Alberta Agriculture Beef Herd Management Reference Binder and Study Guide – 301 at: http://www.agric.gov.ab.ca/livestock/beef/mineral1.html

[b]The NRC (1996) requirement for P is estimated to be approximately 32 g/d (.22%) at peak milk production.

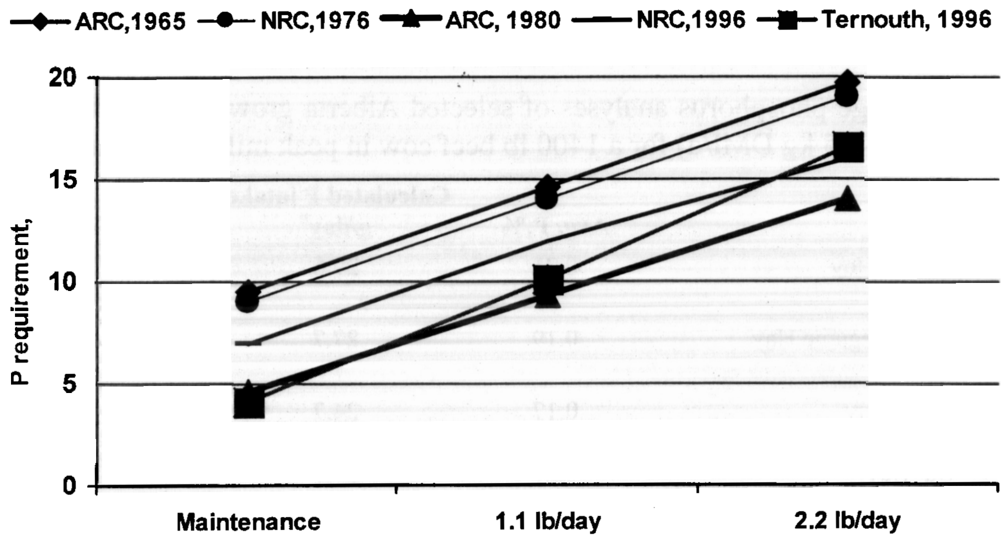
In general, native forages in the Northern Great Plains tend to be marginal or deficient in P; especially for replacement heifers. But, results of two ND experiments conducted during the 1980's showed only small and variable responses to P supplementation (Karn, 1995).

Call et al. (1986) from Utah State University maintained a herd of Hereford cows for a number of years on diets which were considered to be quite P deficient. After several years and lactations it was determined that providing 8-10 g P/day was adequate for reproductive efficiency, but 5-6 g was insufficient. However, the most deficient cows rapidly recovered condition and reproductive function when fed approximately 12 g P/day. The 8-10 g P/day would be approximately 33-50% of current NRC (1996) recommendations for a 1400 lb cow. In earlier work, Call et al. (1978) fed developing heifers 66 or 174% of NRC requirements for P and found no differences in gain, body weight or reproductive efficiency over a 2-year period.

Are the current recommendations defendable?

Based on results of experiments conducted during the past 15 years, the NRC recommendations may still be too conservative. The following figure (Figure 5) shows how variable P recommendations have been over the past thirty-five years for a 660 lb steer growing at three different rates of gain.

Figure 5 . P requirements for a 660 lb steer at three different rates of gain (adapted fromTernouth, 2002)



At maintenance, the requirement for P has ranged between 4.1 and 9.5 g/d compared to 14 to 19.7 g/day for animal gaining 2.2 lb/day.

As an example to demonstrate these differences, Erickson et al. (2002) conducted a feedlot experiment to measure rate and efficiency of gain for finishing calves fed increasing levels of dietary P (Table 3).

Table 3. Effects of increasing dietary P on finishing performance of calves (Erickson et al. 2002)

		dietary P, %DM				
Item	**.16**	**.22**	**.28**	**.34**	**.40**	**Liner effect, P=**
P intake, g/d	14.2	20.2	23.4	31.7	35.5	.01
DMI, lb/d	19.7	19.8	18.1	20.4	19.5	.92
ADG, lb/d	3.35	3.38	2.95	3.54	3.24	.86
Gain:feed	.17	.17	.16	.17	.17	.65

Results showed that rate and efficiency of gain were not changed by increasing dietary P from .16% to .40% (14.2 to 35.5 g P/day). A similar lack of response was also measured for yearling steers fed finishing diets for 105 days (Erickson et al., 2000). Based on the results of these two studies, lowering dietary P levels to .16% did not appear to alter rate and efficiencies of gain for finishing steers.

Interestingly, survey responses published by Galyean and Gleghorn (2001) from Texas Tech University, suggested that many consulting nutritionists believe that P requirements in the 1996 NRC are still too low (NRC recommendations of .2 to .3% of DMI). The average P content of finishing rations formulated by consultants who responded to this survey were estimated to be .31% with a range between .25 and .35%. Likewise, results of a survey of 33 Virginia dairy herds conducted during the fall of 1998 indicated that Virginia dairy farms overfed P by an average of 45% relative to dairy NRC requirements. This overfeeding increased feed costs by $800 to $2,800 per year. It was believed that most of the overfeeding of P was due to three factors: (a) uncertainty about P content of feeds, (b) lack of awareness of the actual P requirements and (c) a belief that overfeeding P helps milk yield or reproduction (Knowlton, 2002). In a study published by Wu et al. (2001) it was reported that for high-producing dairy cows consuming diets containing 0.31, 0.39, or 0.47% dietary P, the cows excreted 43, 66, and 88 g fecal P/day, respectively. What these results implied was that essentially all of the P fed in excess of the 0.31 % treatment was excreted in the feces.

Some nutritionists may wonder about the availability of the phytase-P provided by the grain or forage fractions of the diet. Current thinking is that almost all phytase-P is available to the animal because of microbial degradation in the rumen (Ternouth, 2002) and the inability to detect phytase-P in the feces of dairy cows (Morse et al., 1992).

Nutritionists will continue to recommend some level of supplemental P for free ranging animals. Wayne Greene from Texas A&M University (Greene, 1998) summarized recent mineral research and provided general recommendations to follow when designing a free-choice mineral supplement containing 15 to 30% salt as the base ingredient.

- For unfertilized grasses, use 12 to 16% Ca, 8 to 12% P, and 2 to 4% Mg as the base supplement.
- For fertilized warm-season forages, use 12 to 16% Ca, 4 to 8% P, and 2 to 4% Mg.
- For cool-season perennial and annual forages, use 12 to 16% Ca, 0 to 4% P, and 6 to 10% Mg as the base supplement.

To identify specific minerals that may be a problem, Greene recommended that forage and water mineral analyses were critical for estimating projected P intakes. If potential intake deficiencies were identified, development of cost-effective supplementation programs that met the needs of individual cow herds could be developed. Remember, a white salt block alone will not contain all of the supplemental minerals needed by most herds of cattle (Herd, 1997).

Summary

The conclusions of the paper recently published by the Council for Agriculture Science and Technology (CAST; authored by Klopfenstein et al., 2002) concerning P utilization by cattle and P in the environment were:

"Beef producers should discontinue supplementation of P in feedlot diets. The beef industry is questioning supplementation strategies that have been commonly accepted in the past. Some nutritionists are adopting new formulation strategies for P for two reasons: they accept the recent research indicating that fortification of P in diets is unnecessary

because requirements may be lower than previously accepted, and they have concerns about the environmental consequences of over-feeding P".

The data presented, I believe, do make a case for lowering the amount of supplemental P fed to beef cattle.

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