MEETING PHOSPHORUS REQUIREMENTS OF RUMINANTS IN AN ENVIRONMENTALLY RESPONSIBLE WAY

Larry D. Satter
U.S. Dairy Forage Research Center, USDA-ARS
and
Dairy Science Department, University of Wisconsin, Madison

INTRODUCTION

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 (P) and nitrogen (N), 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.

To achieve effective nutrient recycling, and to minimize environmental damage, application of manure nutrients must be limited to an amount that crops can utilize. Herein lies the rub. Areas with high livestock densities will have to transport manure nutrients over larger distances to avoid over application of nutrients, or alternatively, relocate animals to where cropland is available for manure application. Full crediting of manure nutrients will be essential, and switching to a phosphorus standard is inevitable. Currently most states permit manure application in amounts that supply the crop need for N. Since the P:N ratio in manure is approximately twice that of the P:N ratio needed by crops, applying manure to meet nitrogen needs results in a build-up of soil P levels.

The Environmental Protection Agency (EPA) is expected to update its definition of and requirements for Concentrated Animal Feeding Operations (CAFO) in December, 2002. Currently, CAFO's are defined as those operations having more than 1000 animal units, with an animal unit equaling 1000 lb of live weight. One thousand beef cows would be equivalent to 700 dairy cows, and an operation with these numbers of animals would be considered a CAFO under current definitions. There has been speculation that EPA may lower the number of animals needed to qualify as a CAFO, but that won't be known until December, 2002. What is expected, however, is that all CAFO's will need to have a nutrient management plan, and that CAFO's located within a priority watershed will be required to limit manure application to crop need for P rather than crop need for N. Many livestock operations in the United States are located in priority watersheds. Switching to a P standard will increase the land area required for manure application, doubling the land area in some cases relative to current requirements. The objective of this paper is to illustrate how eliminating excess P in dairy and beef diets can help producers meet EPA/DNR regulatory requirements, how this can help the environment, and how this can save money.

REDUCING PHOSPHORUS EXCRETION IN DAIRY MANURE

There has been much confusion about the P requirement of lactating cows. This is reflected in large differences between feeding standards used by different countries in Europe and North America (Tamminga, 1992). Some of the standards differ by as much as three fold in their estimate of P maintenance requirements, and nearly two fold in the requirement for milk production. Likewise, large differences exist in estimates of P availability in the gut. It is noteworthy, however, that the standards differ relatively little in their final recommendations for P feeding, as extreme differences in maintenance and lactation requirements tend to cancel each other. The NRC (2001) presents an excellent summary of P utilization by dairy cows, and does much to clarify what has been a murky area in the past.

The literature on P utilization and P requirements of lactating cows has been surprisingly consistent. It is in the interpretation of published reports where much confusion has arisen. This confusion has led to feeding of unrealistically large amounts of P in dairy diets. Several surveys (Sansinena et al., 1999; Bertrand et al., 1999; Satter, unpublished information) in the United States during 1999 indicated that dairy diets were formulated to contain approximately .45-.50% P (DM basis), an amount that is about 20% in excess of the requirement (NRC, 2001). This over supplementation of P was costing the U.S. dairy industry about $100 million annually, as well as increasing risk of environmental damage through eutrophication of lakes and streams. Recent evidence is suggesting that dairy producers have started to reduce dietary levels of P, and that average P concentrations in dairy diets have dropped from about .48% to about .44 or .45%. This is good progress, but it still is about 15% in excess of the lactating cows requirement.

How have we come to this point of excessive P feeding? There are at least three factors which have played a role. Perhaps most significant is the notion that increasing dietary P will improve reproductive performance. Studies in South Africa (Theiler and Green, 1932) demonstrated that supplementing bone meal to beef cows grazing dry season rangeland improved reproductive performance, as well as growth rates and survival rates. A widely cited field study in England (Hignett and Hignett, 1951) involving 802 dairy cows in 39 herds showed improved first service conception rates when P was supplemented to those herds in the study having the lowest dietary P content. In both of these classic studies, dietary P levels were much lower than current NRC (2001) recommendations, and likely provided insufficient P for maximum rumen microbial growth. Durand and Kawashima (1980) suggested the maximum P requirement for ruminal microbes is 4 g P/kg digestible organic matter in the diet. This would be equivalent to less than .30% dietary P. Extremely low dietary P can inhibit microbial growth, leading to reduced protein and energy supply to the host animal. It is well known that energy and protein supply can influence reproductive performance. Modern dairy diets never approach the low dietary P concentrations that can result in impaired microbial growth in the rumen. There is no evidence that feeding P in excess of NRC (2001) requirements will influence reproductive performance. A summary of 13 trials where reproductive performance of dairy cows fed different levels of P was measured indicated no relationship between reproductive performance and dietary P content (Satter and Wu, 2000). A recent study by Lopez et al. (2002) affirms that feeding P in excess of

NRC (2001) recommendations is without effect on reproductive performance in lactating cows. In this study a total of 267 Holstein cows were randomly assigned at calving to a control diet containing .37% P (dry basis) or to a treatment diet containing .57% P. Cows were fitted with a radiotelemetric transmitter (Heatwatch DDx®) and were bred to natural estrous from day 50 to day 100 and to synchronized estrous after day 100. Weekly ultrasonography was performed from day 50 until pregnancy. Weekly blood samples were analyzed for progesterone (P_4) concentrations. Dietary P had no effect on any of the reproductive measures made, and no effect on milk production or milk composition. Tables 1 and 2 contain a sampling of reproductive measurements from this study.

Table 1. Characteristics of estrous behavior for lactating cows fed diets containing .37% or .57%P (Lopez et al., 2002).

Characteristic[1]	.37%P (n=159)	.57%P (n=174)	*P*
Duration of estrus, h[2]	8.7 ± 0.5	8.7 ± 0.6	0.99
Total mounts	7.5 ± 0.5	7.8 ± 0.5	0.68
Total mounting time, sec	25.8 ± 1.8	24.5 ± 1.5	0.59
Average duration of standing events, sec	3.4 ± 0.2	3.4 ± 0.2	0.76

[1]Estruses consisting of only one standing event were removed from the analysis.
[2]Number of hours between the first and the last recorded mount of an estrous period.

Another factor contributing to the overfeeding of P to dairy cows has been the absence of lactation trials showing the absolute minimum of P required to support moderate to high levels of milk production. Without knowing the bare minimum of P needed to support milk production, arriving at a reasonable margin of safety in formulating diets becomes problematic. This uncertainty has led to overly large margins of safety and excessive P in the dairy diet. Information is now available to show that moderate to high producing dairy cows (17,000-28,600 lb milk/lactation) are likely to exhibit beginning signs of P deficiency following long term feeding (1-3 lactations) of diets containing about .3% P (Brintrup et al., 1993; Valk and Ebek, 1999; Wu et al., 2000; Wu et al., 2001).

A third factor contributing to overfeeding of P has been aggressive marketing of P supplements. This has probably been less important than the first two factors mentioned.

Figure 1 is a summary of the status of P nutrition of lactating dairy cows producing > 20,000 lb/305 d lactation (modified from Wu et al., 2001). The bare minimum of dietary P consistent with normal or near normal animal performance is .30%. At this dietary concentration, symptoms of P deficiency may begin to occur. At the other extreme of the continuum in figure 1 is what most dairy producers in the United States are actually feeding.

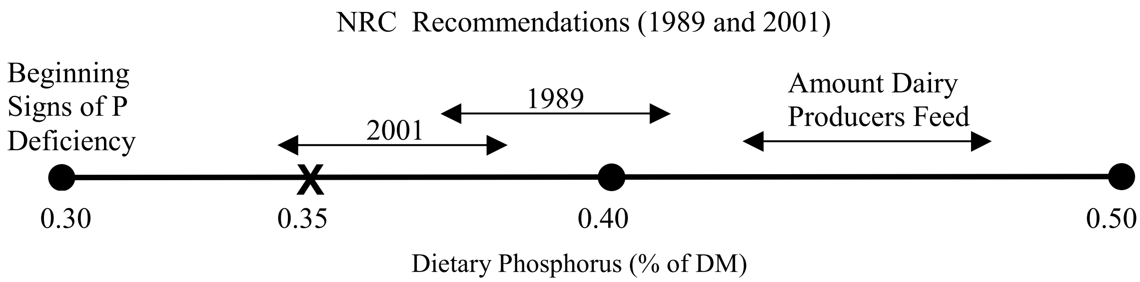
Table 2. Reproductive measurements for lactating cows fed diets containing .37% or .57%P (Lopez et al., 2002).

	0.37%P	0.57%P	*P*
Days to first P_4 increase[1]	53 ± 3 (n=133)	53 ± 3 (n=133)	0.97
Days to first natural estrus[2]	68 ± 1.1 (n=103)	67 ± 1.2 (n=109)	0.87
Days to first service	89 ± 2.0 (n=127)	90 ± 2.0 (n=131)	0.87
Conception rate at first AI[3], %	39.4 (50/127)	42.0 (55/131)	0.67
Overall conception rate at 30 d[4], %	34.3 (99/289)	38.0 (111/292)	0.35
Overall conception rate at 60 d, %	29.1 (84/289)	31.8 (93/292)	0.47
Pregnancies lost (30 to 60 d), %	15.2 (15/99)	16.2 (18/111)	0.83
Pregnancies lost after 60 d, %	6.0 (5/84)	5.4 (5/93)	0.87
Days open	112 ± 3.5 (n=99)	116 ± 3.8 (n=111)	0.45
Services/conception[5]	2.9 (289/99)	2.6 (292/111)	0.35
Double ovulation rate, %	19.9 (47/236)	18.4 (50/272)	0.66
Anovulatory condition[6], %	29.9 (40/134)	27.1 (36/133)	0.61

[1]First increase in progesterone concentration >1 ng/ml.
[2]First natural estrus detected by the Heatwatch system between 50 and 100 d.
[3]Number of pregnancies detected at 30 d divided by the number of first services
[4]Number of pregnancies detected at 30 d divided by the total number of services
[5]Total number of services divided by the number of pregnancies detected at 30 d.
[6]Cows with no new CL for at least three weekly consecutive ultrasound examinations after d 50.

Figure 1 also shows the requirements for P as indicated by the NRC (1988 and 2001). For ease of illustration, the NRC requirements are expressed in terms of percent P in the diet. This is based on dry matter intakes suggested by the NRC. The most recent NRC (2001) publication has lowered slightly the requirement for P feeding, a change that is fully justified by research results. The NRC presents requirements, and does not include a margin of safety. In calculating the requirement, however, it appears the NRC committee used a somewhat conservative estimate for P availability, or the P absorption coefficient. The NRC (2001) model used P absorption (availability) coefficients of 64 and 70% for forages and concentrates, respectively. We have been examining P availability in some common dairy feedstuffs and with the feedstuffs examined to date, it appears that true digestibility or availability is in the range of 70-85% (Aguerre and Satter, unpublished). The long term lactation studies mentioned earlier would confirm that the NRC (2001) requirements are more than sufficient, and one might in fact consider the NRC (2001) requirement to include a reasonable margin of safety.

Figure 1. Current status of P nutrition of lactating dairy cows milking > 20,000 lb/305 d of lactation



It is difficult to determine what a reasonable margin of safety is with regard to P feeding. It will depend upon uniformity of milk production of cows within the feeding group, variability of P content of diet ingredients, and how quickly cows exhibit P deficiency symptoms. Variability in DM intake between animals of comparable milk production will also be a factor. The NRC (2001) suggests that Holstein cows weighing 1496 lb, having a body condition score of 3.0, that are 65 mo of age, and producing milk containing 3.5% fat and 3.0% true protein will have a dietary requirement (using a sample diet) of 0.32, 0.35, 0.36 and 0.38% P for milk production amounts of 55,77,99 and 120 lb/d. Certainly grouping cows by milk production level would enable a closer match between dietary P and P requirement.

Based on information in NRC (2001) feed composition tables, it appears that the coefficient of variation for P content within a feedstuff listed is about 15%. The NRC (2001) tabular values for P content of feedstuffs appear more accurate relative to the NRC (1988) tabular values, as the older NRC values for P content were systematically lower than recent laboratory analysis (Berger, 1995). This may be a reflection of increased soil P levels in more recent years, since high soil P concentrations can result in elevated plant P content.

Cows lose both calcium and P from bone to help supply these elements in early lactation. Ternouth (1990) suggested that up to 30% of bone P can be removed during early lactation. Based on this estimate for beef cows, a dairy cow weighing 600 kg could mobilize 600 to 1000g of P in early lactation. Phosphorus mobilized from bone would need to be restored in later lactation, but the sizeable bone reserve provides a buffer against short term P deficiencies that might result from underestimating P content of a batch of feed. Also, mobilized bone P reduces the need for elevated dietary P levels in the first weeks of lactation when feed intake lags behind milk production.

With this background, a reasonable approach might be to formulate group rations using NRC (2001) recommendations to match the average production level of the top 25% of cows in a feeding group. If this is done, then high production groups in the highest producing herds would have their P requirement met, with a reasonable margin of safety, with diets containing .36-.40% P. This amount of dietary P can be supplied with little or no use of P supplements, and it represents a 15% reduction in P content of the average dairy diet fed in the United States in 2002.

How well does the literature support the NRC (2001) recommendations? Table 3 contains a summary of lactation studies where the control group of cows was fed an amount of P approximately equal to or below the requirement suggested by NRC (2001), and the treatment group received P that was approximately equal to or greater than the NRC recommendation. This series of studies indicate that feeding P in excess of the current NRC (2001) recommendations was without benefit in terms of milk production. The average milk production for the low P groups was 66.9 lb/day, and for the high P groups it was 66.7 lb/day. The NRC (2001) recommendations were of course based on this type of literature information.

Phosphorus fed in excess of the requirement is excreted, with the vast majority appearing in the feces. Typically cows fed just enough P to meet their requirement will excrete < 1 g P/d in urine. Cows fed P 20-30% in excess of their requirement may excrete 3-5g P/d in urine (Wu et al., 2000). Table 4 contains results from a lactation study where cows were fed diets containing .31, .39 or .47% P for a 308 d lactation (Wu et al., 2001). Based on bone P and ash content, cows fed the .31%P diet were marginally deficient. Phosphorus fed in excess of the requirement, which in this example was close to .31%, was excreted. Referring to Figure 1, reducing P content of average U.S. dairy diets from .44-.45 to .36-.40% represents a 15% reduction in dietary P, and at least a 20% reduction in manure P.

Reducing dietary P concentration not only reduces P content of manure, but it reduces the vulnerability of P in manure from being solubilized in runoff water following field application. Ebeling et al. (2001) obtained manure from lactating cows fed dietary P concentrations of .32 or .48%. These dietary levels resulted in feces with P concentrations of .48 and 1.28%, respectively. This manure was surface applied to field plots without incorporation. Phosphorus load in water run-off from the plots was about ten times greater in plots amended with manure derived from cows fed the high-P diet than manure from cows fed the low-P diet. When these manures were applied at equivalent rates of P (36 lb/acre), the high-P manure had P runoff loads about four times that of the low-P manure. A related study was reported recently by Dou et al. (2001). They measured water solubility of P in manure obtained from cows fed different amounts of dietary P. Their study indicated that almost all of the P fed in excess of the cows requirement ended up as water soluble P in the manure. This is depicted in Figure 2. Increasing dietary P above the minimal requirement (0.3% P in this figure) did not increase P secretion in milk. Dietary P in excess of the requirement was simply excreted in the manure, and largely in water soluble form.

Table 3. Milk production response to dietary phosphorus level.

Study	Dietary P % of Diet DM		Milk Production Lb/day	
	Lo P	Hi P	Lo P	Hi P
Kincaid et al., 1981 (20 cows/trt)(10 mo trial)	.30	.54	61.6	66.0
Brintrup et al., 1993 (26 cows/trt)(two complete lactations)	.33	.39	55.9	53.9
Satter and Dhiman, 1996 (23 cows/trt)(12 wk mid-lactation)	.39	.65	52.6	53.7
Valk and Sebek, 1999				
Year 1 (6-8 cows/trt)(wk 17-37)	.28	.34	53.0	53.8
Year 2 (6-8 cows/trt)(wk 2-31)	.28	.34	75.1	72.7
Wu, Satter and Sojo, 2000 (9 cows/trt)(complete lactation)	.40	.49	80.2	79.5
Wu and Satter, 2000				
Year 1 (21 cows/trt)(complete lactation)	.31-.38[1]	.44-.48[1]	64.8	62.7
Year 2 (26 cows/trt)(complete lactation)	.31-.38[1]	.44-.48[1]	81.8	81.1
Lopez et al, 2002 (123 cows/trt)(first 23 wk of lactation)	.37	.57	77.2	76.8
Average	.34	.47	66.9	66.7

[1]Phosphorus content was 0.38 and 0.48% during confinement feeding for approximately two-thirds of the lactation, and 0.31 and 0.44% during grazing for the remainder of lactation for the low and high P diets, respectively.

Table 4. Performance of cows fed diets differing in phosphorus content for an entire lactation (Wu et al., 2001).

	Dietary P (% of DM)		
Item	0.31	0.39	0.47
Number of cows	10	14	13
Dry matter intake, lb/d	55.0	55.0	54.1
Milk, kg/308 d	28,684	26,200	26,677
Milk fat, %	3.64	3.50	3.64
Milk protein, %	3.16	3.13	3.10
P intake, g/d	77.5	97.5	115.6
Fecal P excretion, g/d[1]	43	66	88

[1]Estimated using 68% as the diet DM digestibility, and the means for DMI and fecal P concentrations (.538, .829, and 1.12% for the three treatments, respectively).

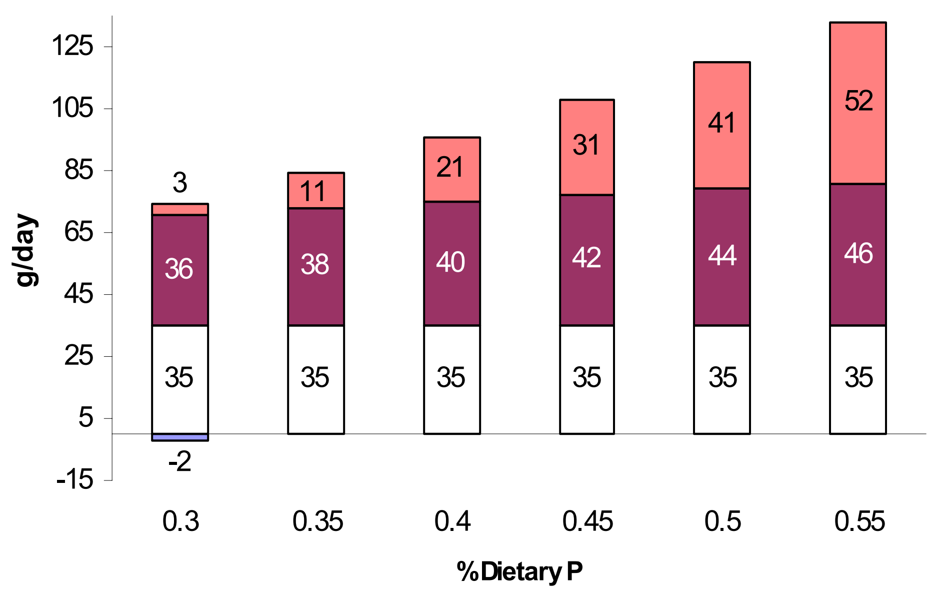


Figure 2. Destination of dietary phosphorus in a dairy cow producing 85 lb milk and consuming 53 lb diet dry matter daily. (Developed from Ebeling et al., 2001; Dou et al., 2001; and Wu et al., 2001). The bottom part of the bar represents P in milk; middle bar is insoluble P in manure; top part of bar is soluble P in manure.

Therefore, reducing dietary P not only reduces P content of manure, but can greatly reduce the potential for field runoff of what manure P is applied.

Reducing dietary P can have a very significant effect on the amount of land required to effectively utilize manure P (Table 5). Most lactation diets that are not supplemented with an inorganic P source contain .35-.40% P. This of course depends upon the ration ingredients used. Since this concentration is similar to the P requirement for lactating cows, it follows that essentially all of the supplemental P fed above the requirement will be excreted in the manure. Assuming a crop uptake of 26.6 lb/acre/yr, the requirement for land increases proportionally with the increase in manure P. Reducing dietary P to an amount that the lactating cow requires often means complete elimination of mineral P supplements. It can also result in a major reduction in the amount of land required to effectively utilize manure P.

Table 5. Amount of phosphorus fed and excreted by a lactating cow producing 20,000 lb milk in 305 day, and the amount of land required to effectively utilize the manure phosphorus.

Dietary P concentration	Estimated Supplemental P	Manure P	Land area needed to recycle manure P	Change in land area
(%)	(lb/lactation)	(lb/lactation)	(acres)[1]	(%)
.35	0	34.8	1.3	Base
.40	7.5	42.2	1.6	23
.48	19.6	54.3	2.0	53
.55	30.1	64.9	2.4	83

1Assumptions: Cow is consuming average of 49.5 lb DM daily, and milk contains 0.09% P. There is no net change in P content of the cow. The cropping area is comprised of 37% corn for grain, 7% corn for silage, 47% alfalfa, and 9% soybeans. Crop yields are typical for the midwest US, and crops remove 26.6 lb P per acre per year.

The dairy industry utilizes large amounts of by-product feeds, many of which serve as important sources of protein in the dairy diet. There is a tendency for feedstuffs that are high in protein content to also contain high concentrations of P, but there are significant deviations from this generalization. Table 6 shows the N:P ratio of some common dairy supplements that are often brought into the ration because of their protein content. Bloodmeal and meat and bone meal represent the extremes in this table. Both feedstuffs are high in RUP content, but bloodmeal supplies a very large amount of protein per unit of P. Meat and bone meal, on the other hand, supplies relatively little protein per unit of P. For dairy producers that are having trouble managing P, choice of a protein supplement or by-product feed can be an important decision affecting P management. A growing number of dairy producers have discontinued using P supplements, but because they utilize large amounts of by-product feeds high in P concentration, overall dietary P content may still be excessive (.40-.45%). It is important that least-cost ration formulation programs do not give credit for P content of a feedstuff if the diet does not need P. A significant part of the dollar value of meat and bone meal is associated with its P content. If P is not needed, then meat and bone meal should not be given credit for the P it contributes in excess of the requirement. In fact, a negative value might be appropriately assigned in some cases.

Table 6. Protein and phosphorus content of some common feeds (NRC, 2001).

Feed	Protein Content % of DM	N content % of DM	Phosphorus content % of DM	N:P
Bloodmeal	95.5	15.3	0.30	51.0
Soybean meal (48%CP)	49.9	8.0	0.70	11.4
Soybean (Roasted)	43.0	6.9	0.64	10.8
Brewer's grains	29.2	4.7	0.67	7.0
Cottonseed	23.5	3.8	0.60	6.3
Corn distillers grains	29.7	4.8	0.83	5.8
Canola meal	37.8	6.0	1.10	5.5
Corn gluten feed	23.8	3.8	1.00	3.8
Wheat midds	18.5	3.0	1.02	2.9
Wheat bran	17.3	2.8	1.18	2.4
Meat and bone meal	54.2	8.7	4.73	1.8

Reducing dietary P in lactating cow diets is perhaps one of the most effective steps that can be taken to reduce the environmental threat of dairy manure. It is a step that reduces cost as well as provides environmental benefits. The P content of most dairy diets can be reduced by about 15%, thus lowering manure P by about 20%.

MANAGING PHOSPHORUS FOR BEEF CATTLE

COW-CALF OPERATIONS

The P requirement, as well as dietary P supply, can vary greatly during the year for a beef cow. Grazing during a period of good grass growth will provide considerably more P than grazing winter pasture or corn stalks. Likewise, the requirement for P is considerably higher during lactation than after the calf is weaned. A comprehensive review of P nutrition of grazing cattle is available (Karn, 2001).

The beef NRC (1996) suggests a range of .11 to .24% dietary P (DM basis) to cover the P needs of cows consuming a wide range of diet energy densities and producing between 10 and 30 pounds of milk at peak production. The requirement is closer to the high end in early lactation, and to the low end in later lactation. Highly digestible diets should contain a little more P than low digestible diets because a little less feed dry matter will be consumed with the highly digested feed. One concern about diets containing less than about .25 % P is the potential for not having sufficient P for rumen microbes. High forage diets, typical of beef cow diets, stimulate saliva production and maximize recycling of P to the rumen. More information is needed to clarify when low P, high roughage diets may not be providing adequate P for rumen microbes.

Performance and P status were studied in two groups of 39 range cows (Angus x Hereford) over a 5-year period in New Mexico (Judkins et al., 1985). One group had free access to salt alone (control), and the other to a mineral mix containing 50% dicalcium phosphate, 45% salt and 5% cottonseed meal. The cows received no other mineral, protein or energy supplements during the whole trial. Lack of P supplementation had a detrimental effect on cow performance only during one year of the experiment, and that was a drought year. The combined effect of no P supplementation and drought caused the non-supplemented cows to calve later (7 April vs. 11 February) and wean lighter calves (497 vs. 557 lb) than the P supplemented cows in the year following the drought. Percent calf crop did not differ between the two groups during one year of the study. The authors concluded that rainfall (green plants have more P than dormant plants) or P supplementation before and during the breeding season may be critical in maintaining early calving date and heavier weaning weights. Other research has also shown that dietary P at approximately 65% of NRC recommendations resulted in no reduction in reproductive performance of beef females (Little, 1980).

A large experiment was done in Utah to determine the P requirements for growth and reproduction of Hereford heifers (Call et al., 1978). Ninety-six seven month-old heifers were divided into two groups, with one receiving a diet containing .14% P (as fed basis), and the other the same diet, supplemented with monosodium phosphate to give .36% P (as fed basis). The experiment lasted two years. The low P diet provided about 66% of the NRC recommended level of P and the high P diet about 174%. The average daily weight gain was .99 lb/day for both groups, and feed efficiency was similar for the two groups. The low P group had a 96% pregnancy rate with 91% live calves, and the high P group had corresponding values of 100 and 93%, respectively. These differences were not significant. After 9 months on trial (approximately 16 months of age), no differences were discernible in rib bone structure based on bone microradiographs.

While it appears that growing replacement heifers and mature beef cows will have adequate P nutrition during periods of active grass growth, it is possible that P deficiency can develop when grass quality is low. Since supplementing P to beef cows or beef replacement heifers is not an environmental issue, and further that with low quality pasture or range conditions that a P deficiency could develop, it seems prudent to routinely provide free-choice phosphorus supplement to beef females, particularly during lactation. A free choice mixture of 50% trace mineral salt and 50% dicalcium phosphate is a good mixture to offer.

Reference was made earlier to the South African studies of Theiler et al. (1932), and low P supplementation improved performance of beef cows grazing dry season range. It is clear that with low quality forage, as in winter grazing of pastures or corn stalks, that P is likely to be deficient. Phosphorus supplementation should be provided under these conditions of extremely low P intake. Phosphorus is seldom an environmental issue with cow-calf operations, unless soil erosion is carrying P-laden soil particles from the pasture into streams and lakes. Phosphorus requirements, and hence P inputs, are low relative to dairy cows. Usually P does not accumulate in the cow-calf system.

FEEDLOT CATTLE

The situation regarding P supplementation to feedlot cattle is simple-DON'T DO IT. This section could be concluded with this statement, but perhaps some more information is warranted.

A number of studies have been conducted to evaluate P requirements of calves weighing less than about 400 lb (Wise et al., 1958; Miller et al., 1987; Jackson et al. 1988), but relatively little information is available for beef feedlot cattle weighing between 600 and 1300 lb. The beef NRC recommends a range of P contents-from .12% to .34% of diet DM, depending upon body weight and energy density of the diet. Erickson et al. (1999) evaluated P requirements of yearling steers (836 lb) with typical feedlot gains of 3.3 lb/day and concluded that the requirement was less than .14% of diet DM, or 70% of the NRC (1996) recommendations. In another study with finishing feedlot calves weighing 583 lb, Erickson et al. (2002) concluded that the P requirement for finishing calves is < .16% of ration dry matter, or 14.2 g/day. Again, this is less than what the NRC would suggest for this size of feedlot animal. Since virtually all feedlot diet formulations that contain much corn grain will exceed these low requirement levels, these authors suggest that determining the P requirement for feedlot cattle is unimportant. What is important is to remove all supplemental P from feedlot diets, since they already have excess P. Supplementation of mineral P in finishing diets is an unnecessary economic and environmental cost for beef feedlot producers. Reducing dietary P to closely match the requirement would require use of very low P feed ingredients, and this would be neither practical nor cost effective.

An emerging issue is the growing use of by-product feeds from ethanol plants in feedlot diets. These feedstuffs contain 2-3 times the amount of P that shelled corn contains. Incorporating these high P feedstuffs into the feedlot diet further increases the surplus of P in feedlot diets. These high P by-product feeds are usually economical replacements for shelled corn in feedlot rations, and producers can hardly afford not to utilize them. About all that a feedlot operation can do to minimize adverse environmental impact from the high P manure produced with such feed ingredients is to make sure that there is sufficient land upon which to spread manure, and to incorporate manure into the soil so that the soluble P will be less vulnerable to runoff.

CONCLUSIONS

The livestock industry can do more to be good environmental stewards. One management action is to make certain that excess supplemental P is removed from our dairy and beef rations. This will not only reduce the amount of P that is excreted, it will greatly reduce the amount of soluble P in the manure. It is the soluble P that is most likely to get into lakes and streams and cause unwanted algae growth. The frosting on the cake is that producers also save money by eliminating unnecessary P supplements. If the feed industry, nutritionists, veterinarians and producers fail to implement a practice that is a win-win situation for the environment and the producer, how is the public to interpret the livestock industry's interest in supporting the environment?

The only information that might contradict removal of all supplemental P from feedlot diets is a recently reported study by Flatt et al. (2001). In this study involving 221 steers and heifers weighing 650 kg at the start of a 147 day feeding period, animals were fed .34% P for the first 85 days, and then reduced to .24% P for the remainder of the feedlot period. There were no differences in growth rate, feed efficiency and carcass quality except that these were more dark cutters on the low P group (13.6% vs. 4.5%). Morbidity was also higher with the low P group (13.5% vs. 4.5%). These results are surprising, and if these observations can be repeated, then it raises another aspect to the question of supplementing P to feedlot cattle.

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