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Nutrient Management

Reducing Dietary Phosphorus in the Dairy Herd

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INTRODUCTION

Phosphorous (P) is the second most abundant mineral element found in the dairy cow's body. Approximately 80 to 85% of the P is in bone and teeth. Phosphorous is also involved in almost all metabolic reactions and may be the most versatile of all mineral elements. It is an essential component of buffer systems in the blood and other body fluids, including ruminal fluid. Phosphorous is essential for proper functioning of rumen microorganisms, especially those that digest plant cellulose.

Until recently, almost all dairy nutritionists have been formulating dairy rations with P levels higher than what the National Research Council (NRC) has recommended. It is not uncommon for P levels to exceed requirements by 130 to 160%. Environmental concerns with P have forced a re-evaluation of the necessary levels needed in the dairy cow's diet.

The effect P has on the environment is eutrophication. This is defined as an increase in the fertility status of natural water that causes accelerated growth of algae or water plants. There are nutrient management laws that could soon take effect, forcing producers to control the P coming into and out of the farm. The objective of this publication is to address the P needs of the dairy cow and evaluate the manner in which dietary P can be reduced.

SOURCES

Concentrates and forages vary widely in their P content. Seeds are uniformly higher in P than forages. Seed byproducts, i.e. wheat midds and oilseed meals, i.e. soybean meal are especially high in P. Table 1 lists the ranges in P content for several common feed ingredients.

Controlling the P level in the diet requires regular testing of feed ingredients for P and not solely relying on book values. In situations where test results are not available, the 2001 NRC is a good resource. An improvement with the new NRC is their composition tables. Data were compiled from various sources, including commercial laboratories. The tables include means, standard deviations, and number of samples used to generate the statistics.

Some protein supplements have similar protein contents but widely different P concentrations. A careful selection of protein supplements to meet the protein requirement based on the nitrogen to P ratio can reduce P importation to the farm.

All the naturally occurring P compounds are phosphates and always occur on the surface of the earth in the form of orthophosphates, which can be used to produce several biologically available feed phosphates. However, the inorganic phosphates used to provide supplementary dietary P are generally considered the major potential source of fluorine (F) for animals. Fluorine can be toxic to cattle and is therefore removed from feed grade compounds.

Fluoride is removed to a great extent from most commercial feed grade phosphates. For a phosphate compound to be classified as defluorinated, it must contain no more than one part F to 100 parts P. Dicalcium-monocalcium phosphate mixtures and defluorinated phosphate are the major P supplements. Table 2 lists the P and F content of some commonly used sources. Figure 1 shows the production process of several P supplements.

REQUIREMENTS

The 2001 NRC adopted research results developed since the release of its previous version (1989 NRC) and made several modifications in estimating the P requirement for lactating dairy cows. The requirement is calculated as the sum of absorbed P utilized for maintenance, lactation, and pregnancy. Absorbed P is then divided by the availability of feed P in the gut.

Absorbed P

- Maintenance: 1.0 g/kg of feed intake
- Lactation : 0.9 g/kg of milk
- Gestation for 190-280 days: 2.5 g/d

Feed P availability

- Forages: 0.64
- Grains: 0.70
- Dical: 0.75
- Mono Phos: 0.90
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The 2001 NRC recommends an overall lower dietary P amount than the 1989 NRC. Using the new NRC calculations, P can range from 0.29% to 0.40% for milk production of 40 to 130 pounds per day, respectively. Realistically, 0.35% to 0.38% P can cover most the herds while maintaining a safety margin.

A shortcoming of the 2001 NRC is that it failed to address the effect of body P reserves on the P requirement. This was due to the lack of research data. Available P from bone mobilization in early lactation and the need for bone P restoration in late lactation should be considered when formulating diets.

It is still a common practice for nutritionists or consultants to formulate rations with P levels exceeding the animal's requirements. Some reasons why rations are balanced with higher P levels include: 1) added safety margins to account for animal variation and variation in P content of feeds, feed delivery accuracy, feed bunk management, etc., 2) uncertainty about P availability, and 3) the view that addition of P to the ration improves reproduction. None of these, however, can substantiate an increase in dietary P from what the 2001 NRC recommends. The NRC already contains a safety margin and is adequate for maximum performance. An Excel spreadsheet has been developed with the 2001 NRC equations to calculate P levels for various groups of dairy cattle. See page 10 for the URL.

DEFICIENCIES AND TOXICITIES

Deficiencies

Signs of P deficiencies are not easily recognized except in severe cases characterized by fragile bones, general weakness, weight loss, emaciation, stiffness, and reduced milk production. Reduction in dry matter intake is the most likely consequence of P deficiency. There are three possible feedback mechanisms to the satiety center that may result in reduced intake:

1. Low ruminal P results in reduced fiber digestion by limiting microbial activity.
2. Low ruminal P reduces microbial protein synthesis and intestinal absorption of amino acids causing an amino acid inadequacy.

DEFICIENCIES AND TOXICITIES, CONT.

3. Low P in metabolically active tissues results in reduced P for intermediary metabolism.

Toxicities

Dietary P is not considered toxic when animals consume single large doses. Under normal conditions, P is absorbed according to the needs of the animal and the excess is excreted. The maximum tolerance for ruminants is 1.0% on a dry matter basis.

High levels of dietary P may cause mild diarrhea. Prolonged consumption of high-P diets may cause severe metabolic problems because of disorders associated with calcium absorption and metabolism.

ENVIRONMENTAL ISSUES

Phosphorus, if accumulated in cropland, is subjected to runoff and erosion losses to surface waters. Excessive P in lakes and streams promotes algae blooms, deteriorating the water bodies. Accumulation of P in soil results when P applied in fertilizer and manure exceeds the uptake by crops.

A growing number of federal and state regulations are under discussion that would limit manure application to cropland based on a P standard. At present, manure application guidelines in Pennsylvania are nitrogen-based, but P will likely be included. A P standard makes sense for places where soil P levels are high and a mechanism for P to be transported into water bodies exists.

The question is: what can the producer do when the time comes that P becomes the limiting factor for manure application to cropland? Better use of fertilizer, proper crop rotation, improved land conservation, and efficient manure application techniques all are helpful, but the fundamental way is to reduce the P content of manure.

Reducing dietary P for lactating dairy cows without affecting milk production

Reducing manure P has been proven possible through dietary management. Several recent studies have shown that P fed to lactating dairy cows can be reduced from the amounts currently fed for many herds. These studies were conducted long term, ranging from one to three years. Figure 2 is the lactation curve of cows fed 0.38-0.31% or 0.48-0.44% dietary P (dry matter basis) for two years in one of the studies. It shows no difference in milk production between the two P groups during the two-year period. Similar results were obtained in the other studies.

To ensure that animal health is not compromised with reduced dietary P, bone characteristics were evaluated. A section of the 12th rib bone was surgically removed from cows fed different amounts of P at the end of their second or third lactation. Bone strength and P content were tested. Results showed that bone strength was not affected by dietary P amount. Feeding 0.31% P for two to three years slightly reduced bone P content compared to feeding 0.49% P, but the same did not occur when 0.37% P was fed.

Figure 3 is a summary of what is considered the status of P feeding for lactating dairy cows (>20,000 lb/lactation). The bare minimum of dietary P consistent with normal animal performance is 0.30%. At this level, signs of P deficiency may start appearing. At the other extreme in Figure 3 is what most dairy producers in the United States are actually feeding.

The level considered adequate (0.38%) is consistent with the NRC recommendations. Feeding at 0.35% P will provide a margin of safety above what might be considered a borderline deficient diet containing 0.30% P, and may be the choice for dairy producers facing serious nutrient management problems.

Effect on manure P content

Taking the average dietary P level for lactating dairy cows in US herds, which is 0.48% according to several surveys, a reduction from this amount to 0.38% can result in 30-35% less manure P excretion. This results because there is a linear relationship between P intake and fecal P excretion when P is fed at amounts that meet or exceed the requirement (Figure 4).

The relationship depicted in Figure 4 has several applications. It allows the concentration of P in manure to be predicted based on the amount of P fed. Furthermore, if dry matter intake is known, the amount of fecal P daily excreted can also be predicted with an assumption of the diet digestibility.

Table 3 illustrates the impact increasing the level of P can have on manure P. Table 4 illustrates the difference in manure P produced over a lactation and how that affects the acreage needed to compensate for feeding P at 0.24 pounds compared to 0.19 pounds. A producer would need 0.31 acres per cow more to handle only the extra P excreted compared to the lower P diet. If the manure was not applied to the additional area, then the soil test P (STP) could increase over time on this smaller area.

Feeding the high P ration can result in an increase as high as 4.8 lbs/year in STP if the manure is applied in excess of the crop's requirements in the rotation. If the starting STP is at optimum (60 lbs./A, Mehlich 3), it would take approximately 8 to 11 years to nearly double the STP levels (100 lbs./A).

Economics

Reducing dietary P has significant economical meanings. Using an average feed intake of 50 lb/day, a reduction in dietary P from 0.48 to 0.38% can result in 23 g/cow/day less P to be fed, saving about 6 cents/cow/day or $18/cow/year on P supplementation.

Effect on reproductive performance

Reproductive performance is a big concern with reducing dietary P. A traditional view is that P is very important to reproductive performance of cows. However, an increasing amount of evidence suggests that supplementation of P does not make a difference in reproductive performance of modern dairy cows fed moderate to high quality diets. The majority of the cited literature and some earlier studies showed no difference in reproduction measures with the levels of P fed. However, there is a weakness with these studies. The numbers of cows used were too small to allow statistically sound conclusions to be drawn. It is difficult to have hundreds of cows to be used in a defined experiment conducted in a research unit. Field studies are needed for this purpose.

Summary

Recent studies have shown that manure P from lactating dairy cows can be reduced to 0.38% without affecting animal performance. A reduction in manure P will give producers leverage in complying with environmental regulations and enhance their ability to stay viable.

TABLES AND FIGURES

Table 1. Phosphorus content of feeds (Dairy One Forage Lab)

Feed	Number of samples	Average (% of dry matter)	S.D.[1]	Normal range[2]
Legume hay	11,962	0.26	0.06	0.21-0.32
Legume silage	3,384	0.32	0.06	0.27-0.38
Grass hay	2,136	0.24	0.08	0.16-0.32
Grass silage	2,030	0.31	0.07	0.24-0.38
Corn silage	16,992	0.23	0.03	0.20-0.26
Beet pulp	106	0.10	0.03	0.06-0.13
Blood meal	25	0.20	0.16	0.05-0.36
Brewers grains	27	0.62	0.06	0.56-0.68
Corn grain	306	0.32	0.11	0.20-0.43
Corn gluten feed	36	0.90	0.21	0.68-1.11
Corn gluten meal	18	0.77	0.41	0.37-1.18
Cottonseed, whole	252	0.66	0.11	0.55-0.78
Distillers grains	183	0.82	0.12	0.71-0.94
Feather meal	6	0.28	0.06	0.22-0.33
Fish meal	31	3.39	1.14	2.25-4.53
Meat and bone meal	8	3.05	0.98	2.07-4.04
Molasses	60	0.68	1.20	up to 1.88
Soy hulls	70	0.17	0.12	0.05-0.29
Soybean meal	277	0.68	0.11	0.57-0.79
Wheat	31	0.47	0.23	0.24-0.69
Wheat midds	90	0.88	0.21	0.67-1.08

Source: Chase, L. E. 2000. Phosphorus Nutrition of Dairy Cattle. Proc. Mid-Atlantic Environmental Management Conference.

[1]S.D. = standard deviation

[2]Average value plus or minus one standard deviation.

Table 2. Mineral content of phosphorus supplements.

Mineral	Calcium	Phosphorus	Sodium	Fluorine[1]	Nitrogen
		-%-			
Phosphoric acid	-	23.7	-	0.09-0.21	-
Defluorinated phosphate	30.0-32.0	18.0	4.8-5.5	0.17	-
Di-monocalcium phosphate	20.0-24.0	18.5	0.5	0.15	-
Mono-dicalcium phosphate	15.0-18.0	21.0	0.5	0.18	-
Monosodium phosphate	-	26.3	16.0	0.10 (ppm)	-
Monoammonium phosphate	-	24.0	-	0.22	11.0[2]

Source: Axe, D. E. Mallinckrodt Feed Ingredients, Macrominerals.

[1]Supplements should contain no more than 0.30% fluorine, preferably no more than 0.20%.

[2]Equivalent crude-protein content of 68.75%.

Table 3. Predicted manure phosphorus (P) for a cow consuming 50 pounds of dry matter per day with various P concentrations, assuming a P digestibility of 68% and an average milk production of 75 pounds per day (22,875 lbs of milk in 305 days).

Dietary P (%)	P intake from feeds (lbs./day)	Manure P %	Manure P lbs./day	Manure P lbs./ton	[1]Manure P_2O_5 lbs./ton
0.35	0.18	0.62	0.10	1.9	4.4
0.38	0.19	0.69	0.11	2.2	5.1
0.40	0.20	0.74	0.12	2.3	5.3
0.42	0.21	0.78	0.12	2.5	5.8
0.45	0.23	0.85	0.14	2.7	6.2
0.48	0.24	0.93	0.15	2.9	6.7

[1] The factor to convert between elemental and oxide P is 2.3.

Table 4. Land requirement for utilizing manure P and possible changes in soil test P (STP).

	Dietary P intake (lbs./d) 0.19	Dietary P intake (lbs./d) 0.24
P intake (lbs./305d)	58.0	73.0
Manure P (lbs./305d)[1]	33.6	45.8
P removal by crops (lb./A/yr)[2]	40.0	40.0
Land needed to utilize manure P (A)[3]	**0.84**	**1.15**
P removed by 0.84 A	33.6	33.6
P in excess of crop removal (lbs./A)[4]	0	14.5
Increase in soil test P (lbs/A/yr)[5]	**-**	**3.7-4.8**
Going from optimum STP to above optimum STP (yrs)[6]	-	8.3-10.8

[1] Manure P calculated using values from Table 3.
[2] Crop P removal assumes an alfalfa and corn silage system (fed on a 50:50 basis).
[3] Land needed to recycle manure P = Manure P ÷ P removal by crops.
[4] P in excess of crop removal = (Manure P – P removed by 0.84 A) ÷ 0.84
[5] Seven to nine lbs. P_2O_5/lb STP increase. Ex: 14.5 lbs. P/A x 2.3 lbs P_2O_5/lb = 33.4 lbs. P_2O_5 / 7-9 lbs. P_2O_5 = 3.7 – 4.8 lbs./yr.
[6] If starting at optimum STP (60 lbs. P/A) and go to above optimum (100 lbs. P/A), then 40 lbs. P/A in the optimum window. Ex: 40 lbs. P/A / 3.7-4.8 STP/A/yr = 8.3 to 10.8 years.

Figure 1. Production of various phosphorus sources

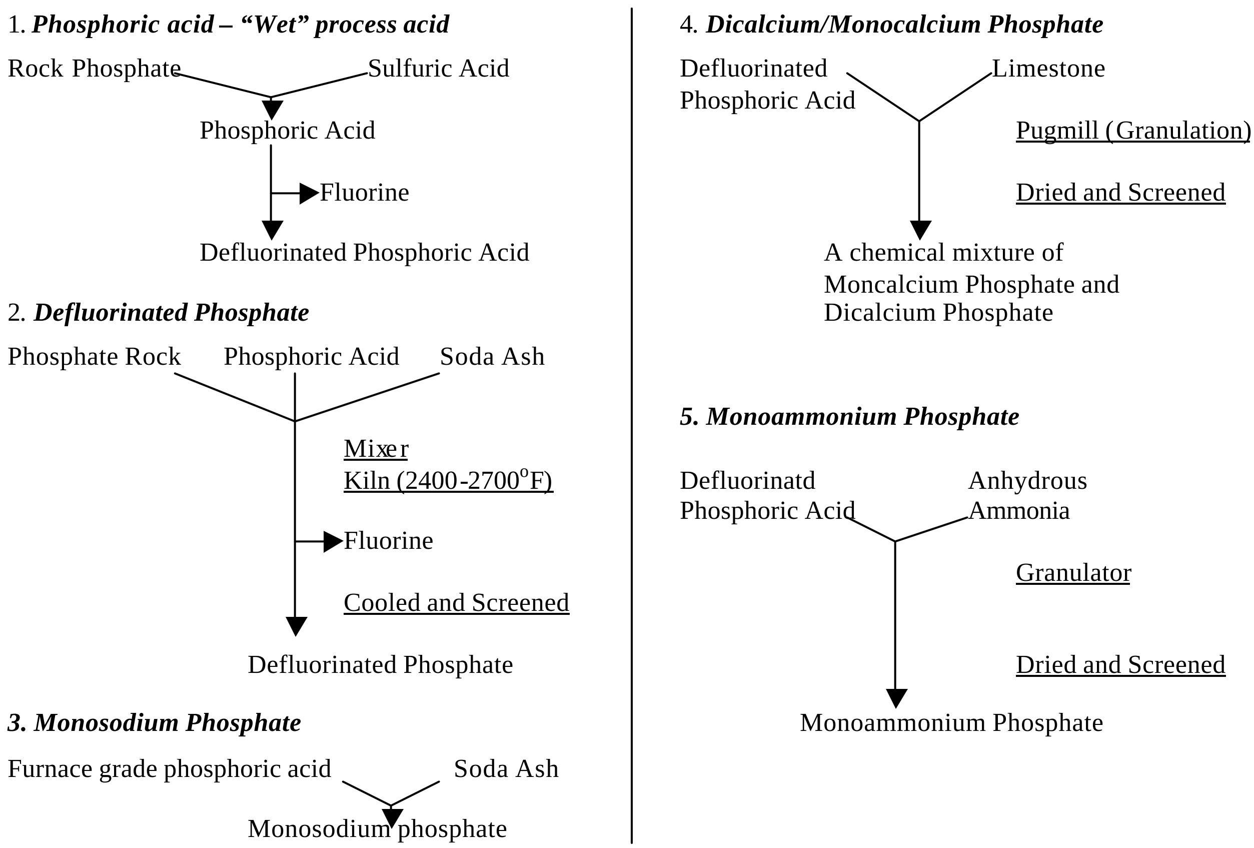
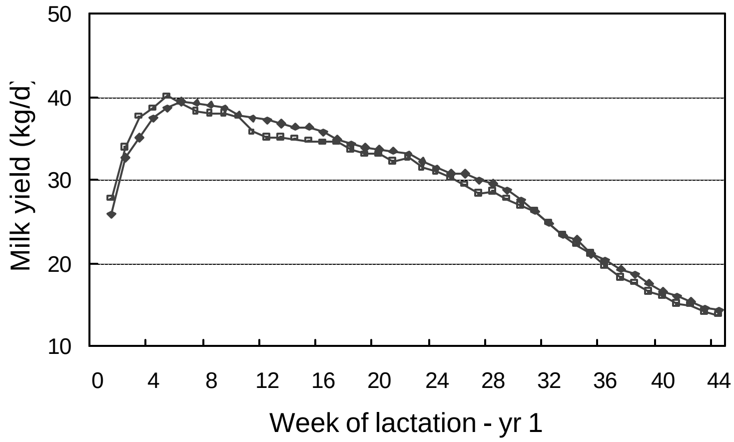


Figure 2. Lactation curve of cows fed diets containing 0.38-0.31% (◆) or 0.48-0.44% (■) P for two years.



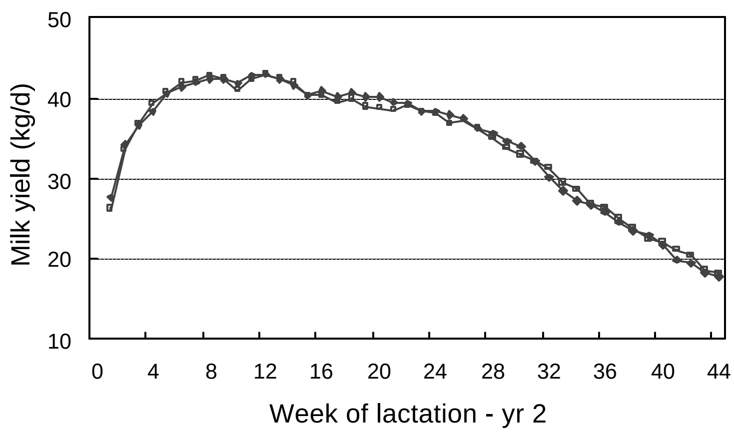


Figure 3. Status of P feeding for lactating dairy cows milking >20,000 lbs/lactation.

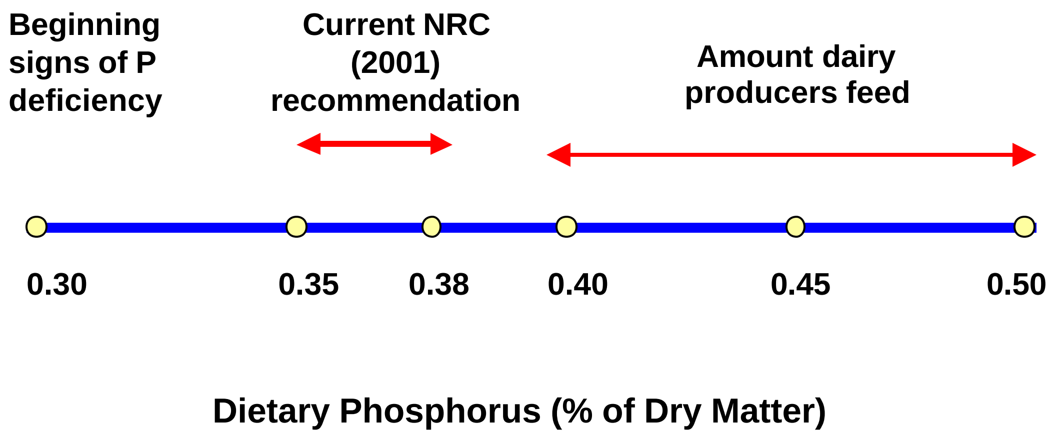
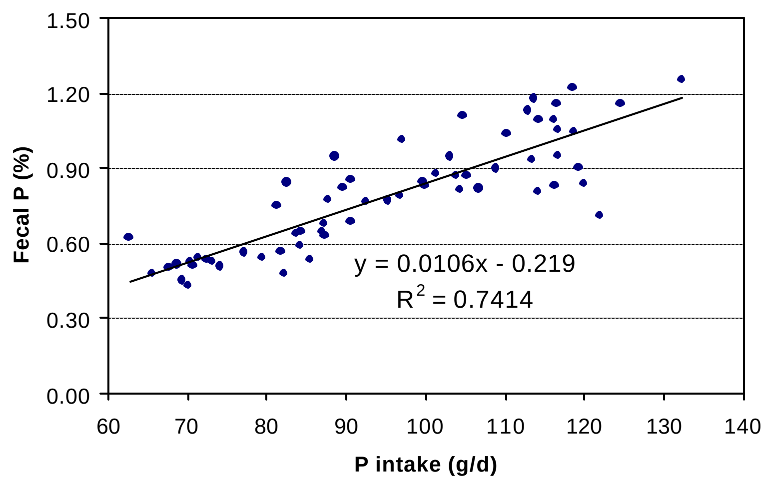


Figure 4. Relationship between P intake and fecal P concentration in lactating dairy cows.



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URL for Excel spreadsheet

http://www.das.psu.edu/indexV6.cfm?PageDefs=Nutrient/Dairy/_incPgDefsNutritionV6.cfm

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