

Balancing the Animal's Nutritional Needs With Environmental Stewardship

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■ Take Home Messages

- Livestock operations will need to meet increasingly stringent regulations regarding nitrogen and phosphorus release into the environment.
- While livestock operations contribute to nitrate contamination of groundwater as well as ammonia and nitrous oxide contamination of the atmosphere, it will be the volatile releases to the atmosphere that will prove most difficult to control.
- Nitrogen losses to the environment can be reduced somewhat through diet manipulation, but the potential is limited (10-15%).
- Dietary phosphorus supplementation of dairy cows is usually excessive and can be reduced by approximately 20%, saving \$15-20 per cow per year.
- Depending upon crop yields, approximately one hectare of land will be required per lactating cow (including her replacement heifer) to utilize the manure without phosphorus accumulation in the soil.

■ 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 nitrogen and phosphorus, from animal manure 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.

The objective of this paper is to review aspects of our protein and phosphorus supplementation of lactating dairy cows, with a view to decreasing feed costs and reducing environmental impact of our dairy operations.

■ **Increasing Efficiency of Protein Utilization by Dairy Cows**

The importance of nitrogen in acidifying ecosystems and causing eutrophication in estuaries and coastal seas is clearly recognized, and intergovernmental efforts in Europe are underway to reduce N emissions. Industrial as well as agricultural systems are targeted for tighter regulation. Animal operations in Holland are having to make significant capital investments to reduce loss of ammonia from animal and manure storage facilities. While these concerns may seem distant at this moment to livestock producers in North America, it is very likely that we will have to address these same concerns in due course.

Much of the needed effort in nitrogen management will target the reduction of gaseous N emissions from manure. The focus will be on manure management within the barn or lot, in the manure storage, and finally during field application of manure. The role of nutrition will be to reduce, as much as possible, the nitrogen content of our dairy diets, thereby reducing nitrogen content of urine and feces and the potential for nitrogen losses. What can we do from a nutritional standpoint?

The remedies fall into basically two categories: (1) Improve the balance between rumen degraded protein and rumen fermented organic matter in the diet, thus enabling a possible reduction in total dietary protein; and (2) use of protected amino acids to fine tune the supply of amino acids to the small intestine, also providing opportunity for slight reductions in dietary protein. Aspects of each of these remedies will be discussed.

Improving the balance between rumen degraded protein and rumen fermented organic matter.

Forage Sources. Legume and grass hays and silages have an abundance of degradable protein, or conversely, a relative shortage of undegraded protein. For example, the amount of ruminally undegraded protein in alfalfa ranges between 15-30% of total protein, with high moisture alfalfa silage (<35% DM) at the lower end of this range and hay or relatively dry alfalfa silage (>50% DM) at the higher end.

Conventional wisdom suggests that forages are limited in energy content, and that high forage diets are supplemented with grain to increase energy density of the diet. We designed an experiment to challenge this view (Dhiman and

Satter, 1993). High forage diets (75% alfalfa silage-25% supplement) were supplemented with fish meal and blood meal (high by-pass protein sources), fat (calories), and protein + fat or protein + glucose. The diets and the results are in Table 1.

Table 1. Ingredient composition of diets and milk production of cows supplemented with protein or energy. (Dhiman and Satter, 1993)

Item	Diet				
	Control	Protein	Fat	Protein + fat	Protein +glucose
	-----(% of DM)-----				
Alfalfa silage	75.0	75.0	75.0	75.0	75.0
High moisture ear corn	23.2	15.1	18.2	9.7	9.7
Fish meal	--	6.0	--	6.0	6.0
Blood meal	--	2.1	--	2.5	2.5
Fat	--	--	5.0	5.0	--
Glucose (postruminal)					5.0
Mineral/vitamin mix	1.8	1.8	1.8	1.8	1.8
NE _L , Mcal/kg of DM	1.42	1.40	1.62	1.59	1.37
CP, % of DM	18.7	23.8	18.2	23.6	23.6
RUP, % of CP	26.6	37.7	25.9	38.1	38.1
Milk, kg/day	29.6	35.7	31.0	33.5	35.4
Milk protein, kg/day	.86	1.04	.88	.99	1.00

Supplementation of protein, in contrast to supplementation of fat (energy), increased milk and milk protein production. Supplementation of fat alone had little effect on milk production. Supplementation of both protein and calories resulted in milk yields similar to supplementation of protein alone. We have completed other studies where cows fed high alfalfa silage diets responded with a substantial increase in milk production to feeding of rumen undegraded protein (Cadorniga and Satter, 1993), or to infusion of protein directly into the abomasum, but not to glucose infusion into the abomasum (Dhiman and Satter, 1993).

This series of experiments clearly indicated that, despite the high protein content of alfalfa, dairy diets containing large amounts of alfalfa protein were first limiting in protein, and secondarily limiting in energy. It is likely that one reason milk production is usually increased with addition of grain to high alfalfa diets is that microbial growth in the rumen is stimulated with the readily fermented energy of grain. This results in trapping of more degraded alfalfa protein in microbial protein, thus improving the protein status of the cow. Using this line of reasoning, one can almost consider corn or small grains to be the cheapest protein supplement available when high alfalfa diets are fed.

One way of managing the excessive amount of degradable protein in alfalfa and grass forages is to feed them with some corn silage. It is clear that corn silage is not available to all producers in Western Canada, but it can be a wonderful complimentary forage to alfalfa or grass in those areas where it can be economically produced. Usually lower dietary protein levels can be fed if a blend of alfalfa and corn silage is in the diet. More will be said about this in the paper on corn silage. (See Chapter 31)

Decreasing degradability of protein supplements. Heat processing of supplements. The protein in soybean or canola meal is quite easily degraded. Only 30-35% of soybean meal protein escapes degradation, somewhat less than the 50% or more that escapes degradation for meat and bone meal, blood meal, distillers and brewers grains, and fish meal. Full fat soybeans, while containing less protein (37%) than soybean meal (44% or 48%), do contain about 18% oil. Most high producing dairy herds are fed some fat or oil in the form of oilseed, tallow, or vegetable oil. Thus, full-fat soybeans are capable of providing both protein and oil to the dairy cow. Canola seeds, while containing more oil and less protein than soybeans, can serve a similar purpose in dairy rations.

A large number of lactation studies have been conducted with heat processed soybeans and there is little doubt that heated soybeans can be a very effective supplement, particularly when alfalfa silage or hay are the principal forages. Table 2 contains a summary of published and unpublished studies where roasted or extruded soybeans were compared to soybean meal or unheated soybeans in dairy diets. The average milk production response of 1.3-1.6 kg milk/day is perhaps an underestimate of potential response because underheated soybeans were used in many of the comparisons summarized in Table 2.

Table 2. Summary of animal response to feeding of heated soybeans¹
(Socha, 1991).

Treatment	Milk kg/d	Change in Milk fat %	Change in milk protein %	Dry matter intake kg/d
Roasted soybeans	1.6 (16) ²	+.06 (16)	-.07 (16)	-.1 (16)
Extruded soybeans	1.3 (20)	-.17 (19)	-.06 (17)	+.1 (18)

¹Soybean meal or unheated soybeans served as the control.

²Number in parenthesis is the number of comparisons.

Based on the average milk production response shown in Table 2, properly heated soybeans are worth approximately Can\$160 more per ton than soybean meal or unheated soybeans. Cost of roasting typically ranges between Can\$30-45 per ton. Roasted soybeans are very palatable and have become a popular supplement for dairy cows.

There is also much potential for protected soybean or canola meal supplements. There has been rapid growth in the use of soybean meal produced by the old expeller process (with some enhancements), such as Soy-Plus and Soy-Best. Proprietary soybean meal products produced with a combined heat and sugar treatment are also marketed. Both types of products have 50-60% rumen undegraded protein. Wider use of heat processed soy or canola supplements, or protein supplements that are naturally more resistant to microbial degradation in the rumen, would often enable some reduction in dietary protein while maintaining or increasing milk production.

Stimulating the rumen fermentation, thus increasing microbial growth and capture of ammonia in the rumen. Processing of cereal grains, such as fine grinding, steam rolling and steam flaking can increase both rate and extent of starch digestion in the rumen, and can increase microbial protein production in the rumen. Thus, grain processing presents a means by which we can manipulate the ratio of rumen available protein : fermentable carbohydrate, and achieve some increase in efficiency of nitrogen utilization. Steam flaking of corn has increased milk production in several studies at the University of Arizona (Santos et al., 1999; Theurer, 1986; Theurer, 1996; Yu et al., 1998). Fine grinding of corn grain increased milk production in 11 of 11 studies reviewed by San Emeterio (1998). The average increase was 1.1 kg of milk per cow per day. While efficiency of protein utilization will increase because of the increase in milk production, no one has tried to measure the potential for reducing dietary protein when processed grain is fed.

Use of protected amino acids to fine tune dietary protein requirements for lactating dairy cows. As with poultry and swine, some potential exists for balancing dairy diets to provide the appropriate amounts of individual amino acids. The opportunity for improving efficiency of protein utilization through manipulation of dietary amino acid supply is not as great with ruminants as with swine and poultry. The reason is that the large amount of microbial protein produced in the rumen, representing 40-70% of protein reaching the intestine, is already pretty well balanced regarding amino acids. Nonetheless, it is well documented that lysine and methionine are usually the most limiting amino acids for milk production, and that under the appropriate dietary situations that small improvements can be made in nitrogen utilization by supplementing rumen protected lysine and methionine.

Since supplemented amino acids for ruminants have to be protected against degradation in the rumen, cost of amino acid supplementation is higher than for poultry or swine. Supplementing two or more protected amino acids is generally cost prohibitive, but supplementing one protected amino acid oftentimes is feasible. It is less costly to provide the likely requirement of protected methionine than it is for protected lysine. The strategy is to formulate diets with feeds that are relatively rich in rumen undegraded lysine, and if necessary or beneficial, supplement with protected methionine (Garthwaite et al., 1998).

These workers have summarized a group of studies where either methionine, methionine plus lysine, or just lysine were used to supplement lactating cows. Overall, supplementing rumen protected amino acids increased dry matter intake by .51 kg, milk production by .5 kg, milk protein by .15 percentage units (68 g) and milk fat by .06 percentage units (45 g). While these are indeed modest production increases, it is likely that some diet formulations will benefit from supplementation of rumen protected methionine. The reader is referred to recent discussion of this topic (Garthwaite et al., 1998; Sloan et al., 1998).

How much can we reduce dietary protein for lactating dairy cows? Milk production response to incremental additions of dietary protein is a diminishing response. The optimal amount of dietary protein would be where the last incremental addition of dietary protein resulted in just enough milk production to slightly exceed the cost of the added protein. In other words, feeding enough protein to obtain the maximum amount of milk is not likely to be profitable because the last bit of increase in milk production does not pay for the cost of protein needed to achieve that small production increase. A milk production response curve has been published with cows fed primarily corn silage as the forage and soybean meal as the protein supplement, but that was done some years ago, and milk production levels were substantially lower than they are now (Roffler et al., 1986). We recently completed a study where four different levels of protein were fed to four groups of cows for a complete lactation. The diet was formulated to maximize rumen undegraded protein and to enhance rumen microbial growth. The diets contained (dry basis) 33% of alfalfa silage, 22% corn silage, between 22 and 32% of finely ground high moisture ear corn, 10% roasted soybeans, and 0-10% of Soyplus®, a soybean meal product having approximately 50-60% of its protein as rumen undegraded protein. Minerals and vitamins made up the balance of the diet. The four dietary protein treatments were as follows, where the first number refers to the dietary crude protein level (dry basis) for the first 16 wks of lactation, and the second number refers to the dietary protein level fed during wks 17 through 44 of lactation. The alfalfa silage fed during wks 17-44 had higher than expected protein content, causing slightly higher dietary protein than intended. The treatments were: 15.4 → 16.0% CP; 17.4 → 16.0 % CP; 17.4 → 17.9% CP; and 19.3 → 17.9% CP. The milk production response, along with N intake, milk N, and manure N is in Table 3.

The diminishing response in milk production to incremental additions of dietary protein is evident in this experiment. The most profitable level of dietary protein was the 17.4 → 17.9% CP treatment, although the 17.4 → 16.0% CP treatment wasn't much less profitable. The 17.4 → 16.0% CP treatment resulted in 10 kg less N being excreted, a significant but modest reduction in N excretion. It might be possible to fine tune the basic diet used in this experiment to increase efficiency of protein utilization. Use of supplemental methionine might allow a slight increase in milk protein secretion. However, it seems unlikely that dietary

protein could be reduced much below 16-17% of ration DM and still sustain lactation production levels of 11,000 kg or more.

Table 3. Milk yield and nitrogen excretion of lactating cows fed different dietary protein levels during a complete lactation.

	Treatment ¹			
	15.4 → 16.0	17.4 → 16.0	17.4 → 17.9	19.3 → 17.9
Number of cows	15	15	14	14
Milk yield (kg/44wk)	10,056 ^c	10,832 ^b	11,095 ^a	11,132 ^a
Intake N (kg/44wk)	178 ^c	189 ^b	214 ^a	214 ^a
Milk N (kg/44 wk)	51.2 ^{ab}	48.9 ^b	51.5 ^{ab}	53.0 ^a
Manure N ² (lb/44 wk)	127 ^c	140 ^b	162 ^a	161 ^a

¹Dietary crude protein content: 15.4% during lactation wk 1 through 16, and 16.0% during wk 17 through 44; 17.4% during wk 1 through 16, and 16.0% during wk 17 to 44; 17.4% during wk 1 through 16 and 17.9% during wk 17 to 44; and 19.3% during wk 1 through 16, and 17.9% during wk 17 to 44.

²Equal to intake N minus milk N. This assumes no net deposition or mobilization of tissue N.

The relatively high cost of protein supplements has forced producers to stay closer to the minimum acceptable level of dietary protein than is the case with phosphorus supplementation, our next topic for discussion. We can still make improvements in our use of dietary N for dairy cattle, thus reducing N losses to the environment, but there is not as much room to maneuver as there is with phosphorus. The greatest opportunities for reducing the threat of excess N on our environment is through managing the cropping and manure portions of the overall dairy enterprise. That is a topic for another day.

■ Reducing Phosphorus Excretion in Dairy Manure

Based on a telephone survey of university extension specialists, nutrition consultants, and feed industry personnel, it appears that dairy producers feed phosphorus far in excess of National Research Council (NRC) (1989) recommendations. While the NRC recommends approximately .34 to .41% (dry basis) phosphorus in typical dairy diets (depending upon level of milk production), producers feed closer to an average of .48% dietary phosphorus, with a few herds receiving close to .60% dietary phosphorus. Is the NRC recommendation out of line, or are producers simply feeding more than they need to?

Table 4 makes a comparison of phosphorus feeding recommendations, as of 1992, for several countries (Tamminga, 1992). (Note: Since the 1992 publication of Tamminga, Great Britain has increased and Germany has decreased the suggested feeding level for phosphorus.) Compared to other standards shown in Table 4, the NRC recommendation is relatively low for the

maintenance portion of the requirement, but very high for the milk portion of the requirement. The high dietary allowance suggested by NRC for milk production (1.98 g/kg fat-corrected milk) reflects the low value NRC uses for phosphorus availability in the gastrointestinal tract (50%).

Table 4. Phosphorus requirements for dairy cattle (29).

Maintenance	Milk Production	% Availability	Country
(g/kg of BW)	(g/kg of FCM)		
.0286	1.98	50	Natl. Res. Council (US and Can)
.042	1.50	60	Netherlands
.0207	1.56	58	Great Britain
.062	1.25	70	France
.040	1.66	60	Germany

Compared to standards used in other countries, it is fair to say that NRC is on the high side of phosphorus recommendations. Caution is advised, however, in putting too much faith in any of the standards. All of the standards used in the various countries are based on a very old and meager database. In the case of the 1989 NRC dairy recommendations, 30 references on phosphorus averaging now 32 years of age are cited. Only 20% of these 30 studies used lactating dairy cows, with the balance utilizing laboratory or nonlactating animals. A combination of relatively new information, and a revisit of some of the older studies, allows us to put phosphorus feeding recommendations on firmer footing. What must we consider if we are to develop more reliable standards for feeding phosphorus?

One of the persistent questions through the years has regarded availability or true digestibility of phosphorus. This is of great importance for swine and poultry, because phytate phosphorus is largely unavailable to them, and the majority of phosphorus in feed grains is in phytate form. Phytate phosphorus is readily available to ruminants because the ruminal microorganisms produce phytase, the enzyme responsible for cleaving phosphorus from its phytate form. Nonetheless, questions about phosphorus availability persist. The availability of phosphorus was reduced from 55% in the 1978 NRC Nutrient Requirements of Dairy Cattle to 50% in the current NRC revision. The reason for this is not clear, because there appears to be no evidence supporting such a change. The available evidence would in fact suggest that the values used for availability or true digestibility of phosphorus should be increased. Most studies have underestimated true digestibility of phosphorus, because true digestibility can only be measured under conditions of phosphorus deficiency. Some studies and their measure of availability are as follows: Kleiber et al., 1951—50 to 64%; Lofgreen and Kleiber (1953 and 1954)—81 to 96%; Weiss et al (1986)—60 to 65%; Koddessbusch and Pfeffer (1988)—~90%; and Martz et al. (1990)—64 to 75%. The working group responsible for developing the dairy feeding standards

in Germany has adopted a value of 70% for phosphorus availability (Kirchgeßner, 1993). We believe this is a fair value to use.

The phosphorus feeding standards are undergoing review in several countries. The NRC committee has not yet announced what changes, if any, will be made. We would encourage adoption of standards similar to those in Germany. The German system (Kirchgeßner, 1993) utilizes a factorial approach to calculating the requirement, and the component parts of the requirement are as follows:

Phosphorus secreted in milk	1 g/kg milk
Phosphorus deposited in uterus during last two months of pregnancy	2.0 to 2.5 g/day
Phosphorus accretion during growth	7.4 g/kg gain
Inevitable loss (maintenance)	1.0 g/kg dry matter intake

These are summed, and the amount is divided by .7 to give the recommended amount of dietary phosphorus. The .7 value reflects what they consider to be availability of dietary phosphorus. The values used above provide some margin of safety, and thus this system might be considered as providing the maximum recommendation for phosphorus feeding.

Table 5 illustrates a comparison of current phosphorus recommendations based on Table 6.4 of the NRC publication, and the new recommendations developed in Germany. This example is for a 600 kg Holstein producing milk containing 3.75% butterfat. The dry matter intake values are those suggested in Table 6.4 of the NRC publication. The dry matter intake value used will of course have a direct effect on the phosphorus requirement when expressed as a percent of diet dry matter.

Table 5. Phosphorus feeding recommendations

600 kg cow 3.75% milkfat kg milk/ day	Estimated Dry Matter Intake kg/d	Current NRC <u>Recommendations</u>		Recent German <u>Recommendations</u>	
		P, g/day	Dietary P, % ¹	P, g/day	Dietary P, %
10	13.0	36.0	.27	33.0	.25
20	17.0	55.5	.33	52.8	.31
30	20.4	74.5	.37	72.0	.35
40	23.4	93.0	.40	90.7	.39
50	27.3	112.5	.41	110.6	.40

¹Recommends .48% dietary P during first three weeks of lactation

It is interesting that the two systems project very similar phosphorus requirements. The NRC recommendation is based on what appears to be an unrealistically low maintenance requirement, but this is compensated for by an inflated requirement for lactation. The final NRC recommendation is only slightly higher than what appears to be the more logically calculated German recommendation.

One more thing needs to be said about the NRC phosphorus recommendation. Table 6.5 of the NRC publication suggests that the dairy diet contain .48% phosphorus during the first three weeks of lactation. This is intended to ensure adequate consumption of phosphorus during the early part of lactation when feed consumption lags behind milk production. It is important to recognize that significant bone phosphorus is mobilized during the first few weeks of lactation. Bone provides at least 500-600 g of phosphorus in early lactation, and we should credit this source of phosphorus. Feeding an extra high amount of dietary phosphorus in the first weeks of lactation is likely not necessary.

While the NRC and European phosphorus standards differ greatly in their component parts, i.e., maintenance, production and phosphorus availability, the final feeding recommendations do not differ greatly. It may be a case of the standards being right for the wrong reasons! The glaring discrepancies in the component parts of the feeding standards do little to build confidence that the final feeding recommendations may in fact be pretty reasonable. This may be one explanation of why our feeding practices call for much more phosphorus than our feeding standards do.

The telephone survey referred to earlier indicates dairy producers feed an average of .48% dietary phosphorus, considerably in excess of what NRC recommends. Why? Mention has been made of significant uncertainties in the feeding standards, and this has perhaps encouraged feeding extra phosphorus to provide a margin of safety. Aggressive marketing of phosphorus supplements has contributed to excessive levels of dietary phosphorus. Perhaps the most important factor responsible for excessive phosphorus supplementation is the notion that phosphorus is crucial to maintaining acceptable reproductive performance in dairy cows. While there is an occasional observation that suggests phosphorus fed at levels recommended by the feeding standards is too low for optimum reproductive performance, **the overwhelming evidence is that phosphorus has no effect on reproductive performance until dietary phosphorus drops below concentrations needed to support maximum microbial growth in the rumen.** Dietary phosphorus levels of less than approximately .25% can reduce rumen microbial growth (Durand and Kawashima, 1980) resulting in less microbial protein and possibly lowered ration digestibility. Phosphorus can have an indirect effect on reproductive performance through its effect on digestibility and energy supply when very low phosphorus diets are fed. Modern dairy diets, however, never approach the low phosphorus content that can result in impaired function of

rumen microbes. A summary of reproductive performance of heifers and dairy cows fed different levels of phosphorus is in Table 6. It is apparent that dietary phosphorus is having no effect on reproductive performance as reported in the 13 trials represented in Table 6.

Table 6. Reproductive performance of heifers and lactating cows fed a low phosphorus or high phosphorus diet (Summary of 13 trials)

	Dietary P (% of DM)	Number of animals	Days to first estrus	Days open	Services for conception	Days to first AI	Pregnancy rate
Cows	.32-.40	393	46.8	103.5	2.2	71.7	.92
	.39-.61	392	51.6	102.1	2.0	74.3	.85
Heifers	.14-.22	116			1.5		.98
	.32-.36	123			1.8		.94

¹Not all of the measurements listed in this table were made in each and every trial. Thus each measurement is based on most, but not all, of the animals in column two.

The evidence available from lactation studies supports the view that current NRC recommendations, or the new standards being used in Germany, are adequate in their recommendations for phosphorus. Table 7 contains a summary of lactation trials where “low” or “high” levels of dietary phosphorus were fed. The low phosphorus treatments ranged between .30 and .39% dietary phosphorus, and the high treatments ranged between .39 and .65% phosphorus. Cows in these studies were producing approximately 7,500 to 11,182 kg of milk per 305 day lactation. Mean daily milk production values for the “low” and “high” phosphorus groups averaged 29.9 and 30.0 kg per day. The dietary phosphorus content of the “low” treatment groups was, in all but one case, below the level recommended by the NRC and German standards for the level of milk production reported, suggesting that the standards recommend more than an adequate amount of phosphorus.

Table 7. Milk production response to dietary phosphorus level

Study	Dietary P (% of Diet DM)			Milk Production (kg/day)		
	(a)	(b)	(c)	(a)	(b)	(c)
Kincaid et al, 1981 (20 cows/trt) (10 mo. trial)		.30	.54		28.0	30.0
Brintrup et al, 1993 (26 cows/trt) (two complete lactations)		.33	.39		25.4	24.5
Valk and Sebek, 1999 (8 cows/trt)						
Lactation 1 (wk 17 - 37)	.24	.28	.34	23.3	24.1	24.5
Lactation 2 (wk 2 - 42)	.25	.28	.35	--	33.9	32.8
Satter & Dhiman, 1997 ¹ (23 cows/trt) (12 wk mid lactation)		.39	.65		23.9	24.4
Wu et al, 1997 ¹ (24 cows/trt) (complete lactation)		.35	.45		29.7	28.9
Wu et al, 1998 ¹ (26 cows/trt) (first 27 wks of lactation)		.37	.48		39.3	38.5
Wu et al, 1999 ¹ (8-9 cows/trt) (complete lactation)		.32	.41		35.0	36.5
				Ave	29.9	30.0

¹Unpublished studies. U.S. Dairy Forage Research Center. USDA-ARS. Madison, WI.

Based on responses from the aforementioned telephone survey, it appears that U.S. dairy producers are feeding about 25% more phosphorus than the NRC recommends. If NRC tabular values ("book values") for phosphorus content of feedstuffs are relied upon, rather than actual laboratory analysis of the feedstuffs used, it is likely that we are feeding even more phosphorus than we realize. Berger (1995) compared a large number of actual laboratory analyses of some common feedstuffs with their corresponding NRC "book value" (Table 8). In every case, the mean analytical value was higher than the NRC value. With alfalfa, laboratory measurements averaged 38% more than the NRC tabular value.

Table 8. Phosphorus analyses of feed samples submitted to commercial laboratories and the relationship to values reported in the United States-Canadian Tables of Feed Composition (Berger, 1995)

Feedstuff	Number of Samples	Analyzed P % (of DM)	Ratio of Analyzed:NRC	SD
Corn silage	8197	.23	1.05	.06
Alfalfa ¹	4096	.30	1.38	.06
Corn grain	912	.32	1.07	.07
Ear corn	905	.29	1.07	.08
Soybean meal (50%)	148	.72	1.03	.28
Brewers grain	139	.59	1.08	.08
Distillers dried grains	114	.83	1.17	.17
Barley	115	.38	1.02	.07
Oats	38	.43	1.13	.09

¹Only samples reported as pure alfalfa were included. The NRC description for alfalfa hay, sun-cured, early bloom was used as the standard because of similarity in protein values.

The overfeeding of phosphorus is costly and is contributing to environmental risk. You can quickly calculate how much money you are wasting with excessive phosphorus supplementation. You can also easily calculate how much phosphorus (if any) is building up on your farm. Knowing how much feed is imported (and/or exported) from your farm, and also knowing its phosphorus content, calculate the net flow of phosphorus to or from the farm via feed. Estimate the amount of phosphorus imported to the farm in the form of fertilizer. A few farms may be exporting manure (hauling to a neighbor's field). The amount of phosphorus in exported manure will have to be accounted for. Lastly estimate the amount of phosphorus exported in the form of milk and cull animals. Holstein milk contains about 0.09% phosphorus. For a 100-cow dairy, approximately 140 kg of phosphorus will be leaving annually in the form of cull cows and surplus calves. Calculating a simple import-export balance for your farm can be instructive.

Approximately one hectare will be required for each mature cow (this includes her replacement heifer) averaging 9,000 kg per lactation to utilize the phosphorus contained in the manure. Maintaining equilibrium in soil phosphorus levels will be easy for those dairy farms importing only protein supplement and necessary phosphorus supplement and necessary fertilizer. Dairy operations buying in all of their protein supplement and part of their grain needs will manage only if they eliminate excess phosphorus supplementation to the cows, and eliminate phosphorus fertilizer (which in all probability they will not need). Dairy operations growing their forage but importing all of their protein and grain needs will have to find additional land for manure application, for there is no way they will be able to achieve equilibrium in soil phosphorus levels without additional land for manure.

■ Conclusion

The days are numbered for simply disposing of manure. It is likely that in the near future manure application to cropland will be restricted to the amount of nutrients that can be utilized by the crops. Phosphorus content of manure will likely be the determining factor for the application rate of manure, since the P:N ratio in manure is approximately twice the P:N ratio needed by crops. We can reduce dietary phosphorus in dairy diets from approximately .48% to .38%. This will reduce phosphorus excretion in the manure by 25-30%. This translates into 25-30% less land required for manure disposal. A strategy of reducing dietary phosphorus levels is a win-win situation for dairy producers, since both feed costs and environmental risk/cost of manure disposal are reduced.

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