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Managing the Dairy Feeding System to Minimize Manure Nutrients

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Introduction

Applying manure nutrients in excess of crop requirements increases the risk of nutrients leaking into surface and groundwater (Fox et al., 1998; Wang et al., 1999). Reducing nutrient excretion in dairy cattle involves two main areas: lowering the levels of nutrients fed (especially purchased nutrients) above animal requirements and increasing the overall farm management. Rations have typically included safety factors for many nutrients. These safety factors are included to minimize production risk due to not being able accurately predict animal requirements, and variation in composition of the ration delivered to each group of animals in each unique production situation. Increased knowledge about the supply and requirements for nutrients in ruminants coupled with improved analytical methodology for feeds and management of critical control points in delivering the formulated diet to the intended group of animals is allowing us to decrease these safety factors.

A major factor limiting the adoption of very low safety factors is the management level required on the farm. Management's role in decreasing nutrient excretion covers many areas. High levels of management are required throughout the entire feeding system. This includes silo management, adequate feed analysis to describe the feeds fed, feeding accuracy, feed bunk management, and other areas One of the most critical variables affecting nutrient accumulation on the farm and profitability is the quality and quantity of homegrown feeds

(Wang , 1999). Homegrown feed quality includes: harvesting at the correct stage of maturity and dry matter, storage management, and minimizing variation in the feed. Tylutki et. al. (1999) simulated the impact of observed dry matter and fiber variation with corn silage at harvest. Variation observed in this feed resulted in variations in income over feed costs greater than $40,000 and nitrogen excretion of 240 pounds per 100 cows annually.

In this paper, we summarize the prediction of the supply and requirements of phosphorus and nitrogen, and feeding management required to decrease nutrient excretion. We end with an example of how to implement recommended management practices, using a case-study farm that has been implementing them.

Accurately meeting requirements for phosphorus

The first step is using accurate feed composition values in ration formulation. Typical phosphorus levels and normal ranges for many feedstuffs analyzed by DairyOne are found in Table 1. These levels can be quite different from 'book' values. As an example, NRC (1989) reports a P level of .22% for alfalfa hay early bloom. The average analyzed value is .26%, or 18% higher than the NRC value. This demonstrates the need for laboratory analysis of feeds used in ration formulation.

One form of phosphorus is bound to phytate. In ruminants, this is not a concern as the rumen produces high levels of the enzyme phytase. Estimates of phytate digestibility in the rumen are in excess of 99% (Morse et. al., 1992). Inorganic sources of P vary in their availability. They can be ranked (from highest to lowest availability) as: sodium phosphate, phosphoric acid, monocalcium phosphate, dicalcium phosphate, defluorinated phosphate, bone meal, and soft phosphates (NRC, 1989). As can be seen in Table 1, the high protein feeds (e.g. soybeans) are high in phosphorus.

The next step is to accurately determine P required. Nutrient requirements are often expressed as dietary percentages. However, this only represents the concentration of a nutrient needed when the assumed amount of dry matter intake is consumed by the animal. As we move towards decreasing nutrient excretion, diets need to be formulated and evaluated based upon the grams of nutrient fed compared to the grams required. As an example, differences in diets containing .41% P versus .40% P may appear unimportant. When this difference is computed on an annual basis per 100 cows, this difference becomes 161 pounds of additional excreted P to manage. In addition, the concentration of a diet may appear higher or lower than expected due to differences in dry matter intake. As an example, a requirement of 100 grams of P for a cow consuming 55 pounds of dry matter is a .40% concentration required. At 40 pounds of dry matter intake, the concentration required increases to .55%.

Approximately 86% of the phosphorus in dairy cattle is in the skeleton and teeth (NRC, 1989). It is a key mineral in energy metabolism, and is an essential component of blood and other body fluid buffering. Phosphorus is absorbed in the small intestine. Absorption is dependant on the P source, level of intake, intestinal pH, animal age, and the amount of other minerals in the diet. If P is fed in adequate amounts, the calcium to phosphorus ratio does not seem to be a concern. There is little published information regarding the absorption efficiency of different feedstuffs, and phosphorus recycling increases the difficulty in obtaining these numbers (NRC, 1989).

Table 1. Average Phosphorus content of feeds (adapted from Chase, 1999).

Feed	Mean	SD	Normal Range
Legume Hay	.26	.06	.21 - .32
Legume Silage	.32	.06	.27 - .38
Grass Hay	.24	.08	.16 - .32
Grass Silage	.31	.07	.24 - .38
Corn Silage	.23	.03	.2 - .36
Bakery byproduct	.40	.08	.32 - .49
Barley grain	.28	.16	.12 - .44
Beet pulp	.10	.03	.06 - .13
Blood meal	.20	.16	.05 - .39
Brewers grain	.62	.06	.56 - .68
Canola meal	1.14	.16	.98 - 1.29
Corn, ear	.30	.05	.26 - .35
Corn, shelled	.32	.11	.2 - .43
Corn germ meal	.71	.54	.17 - 1.25
Corn gluten feed	.90	.21	.68 - 1.11
Corn gluten meal	.77	.41	.37 - 1.18
Cottonseed hulls	.21	.08	.13 - .29
Cottonseed meal	.97	.28	.69 - 1.24
Cottonseed, whole	.66	.11	.55 - .78
Distillers grains	.82	.12	.71 - .94
Feather meal	.28	.06	.22 - .33
Fish meal	3.39	1.14	2.25 - 4.53
Hominy feed	.56	.21	.36 - .77
Linseed meal	.92	.11	.81 - 1.03
Meat meal	4.35		
Meat and bone meal	3.05	.98	2.07 - 4.04
Molasses	.68	1.20	up to 1.88
Oats	.39	.06	.32 - .45
Soyhulls	.17	.12	.05 - .29
Soybeans	.66	.11	.55 - .76
Soybean meal, 48	.68	.11	.57 - .79
Wheat	.47	.23	.24 - .69
Wheat bran	1.03	.31	.72 - 1.34
Wheat midds	.88	.21	.67 - 1.08

Post-absorption, large amounts of P are recycled through the salvia (NRC, 1989). Excess P is then excreted in the feces (Very little P is excreted through the urine.) (INRA, 1989). Preliminary results from INRA suggests that as P levels increase with increasing levels of concentrate feeding, P begins spilling into the urine (Agabriel, personnel communication, 1999).

Much research over the last several years has focused on the impact of phosphorus on reproductive efficiency of lactating cows (Satter and Wu, 1999). Satter and Wu (1999) summarized 13 trials where P levels were varied from .32 to .61% of the diet. No differences were found in any of the trials in days to first estrus, days open, services per conception, days to first breeding, or pregnancy rate. Satter and Wu (1999) also summarized the data from several trials that varied the P level to determine differences in milk production. Again, as long as the grams of P required daily were met, no differences were seen in milk production.

In an attempt to improve accuracy in predicting dietary requirements, the Cornell Net Carbohydrate and Protein System version 4.0 (CNCPSv4.0) calculates the phosphorus (and the other macro-minerals) requirements for cattle using the INRA (1989) system. Table 2 lists the equations used for various classes of cattle and Table 3 shows example calculations based on these equations. The INRA system was chosen for macro-mineral calculations due to its factorial approach. This system describes net macro-mineral requirements by physiological function (maintenance, lactation, growth, and pregnancy). The maintenance requirements are further partitioned into endogenous fecal and urinary losses. Varying transfer coefficients (based upon body weight or physiological state) are then applied to the net requirements to calculate dietary requirements. The INRA system utilizes a Total Absorption Coefficient (TAC) to convert net P required to dietary P required. The TAC is a combination of absorption efficiency as well as P digestibility.

The mineral section of the CNCPSv4.0 can be used to evaluate mineral balances, calculate macro-mineral excretion, and optimize mineral utilization within groups. At the herd level, the mineral section predicts herd phosphorous and potassium excretion, efficiency of mineral use (product/input), and a mass nutrient balance for the feeding program.

Table 2. Equations used to calculate Phosphorus requirements (gms/d) for dairy cattle (INRA, 1989)[1].

	Heifer	Dry cow	Lactating Cow
Maintenance			
Fecal	(23 * SBW) / 1000	(23 * SBW) / 1000	((22 + (0.2 * Milk)) * SBW) / 1000
Urinary	(2 * SBW) / 1000	(2 * SBW) / 1000	(2 * SBW) / 1000
Growth	(7 * SWG)	(7 * ADG)	(7 * ADG)
Pregnancy	If Days Pregnant > 187 Then Pregnancy Requirement = 4		
Lactation			(0.9 * Milk)
Total Absorption Coefficient	SBW < 150, 80% SBW < 250, 75% SBW < 350, 65% SBW > 350, 55%	57.5%	57.5%

[1]Where: SBW = shrunk body weight, kg; Milk = milk production, kg/d; SWG = shrunk weight gain, kg/d; ADG = average daily gain, kg

Table 3. Phosphorus requirements (gms/d) of various classes of cattle calculated using the equations in Table 2 as applied in the CNCPS v 4.0.

	Heifer	Dry Cow	Lactating Cows		
Body weight, lb	750	1400	1350	1350	1350
Milk production, lb/d	0	0	60	80	100
Gain, lb/d	2	0	0	0	0
Days pregnant	0	200	0	0	0
Expected dry matter intake, lb	15	28	42	48	54
Maintenance requirement, g/d					
Fecal	7.8	14.6	16.8	17.9	19.0
Urinary	0.7	1.3	1.2	1.2	1.2
Growth requirement, g/d	6.4	0.0	0.0	0.0	0.0
Pregnancy requirement, g/d	0.0	4.0	0.0	0.0	0.0
Lactation requirement, g/d	0.0	0.0	24.5	32.7	40.9
Total Absorption Coefficient	65.0	57.5	57.5	57.5	57.5
Total requirement, g/d	22.9	34.6	74.0	90.2	106.3
Dietary concentration, % of DM	0.34	0.27	0.39	0.41	0.43

Satter and Wu (1999) report survey data showing the average lactating dairy cow is fed a diet containing .48% P. As seen in Table 3, this level is in excess of that required to produce 100 pounds of milk. Figure 1 represents the relationship between three P dietary concentrations to daily milk production and the percent of the 1989 Dairy NRC recommendations. It is evident in this Figure that a diet containing .55% P results in severe P over-feeding over this range of milk production. The .45% level also results in excesses over most of this range.

Meeting requirements for Nitrogen

Ration formulation/evaluation systems using the CNCPS model (CNCPSv4, CPM Dairy, DALEX) to more accurately match sources of N with animal requirements partition protein supply into five pools:

1. A fraction: rapidly available non-protein nitrogen
2. B1: rapidly available true protein
3. B2: intermediate ruminal degradation rate
4. B3: slowly degradable
5. C: indigestible, bound to lignin.

These pools are calculated from feed analysis as shown in Table 4.

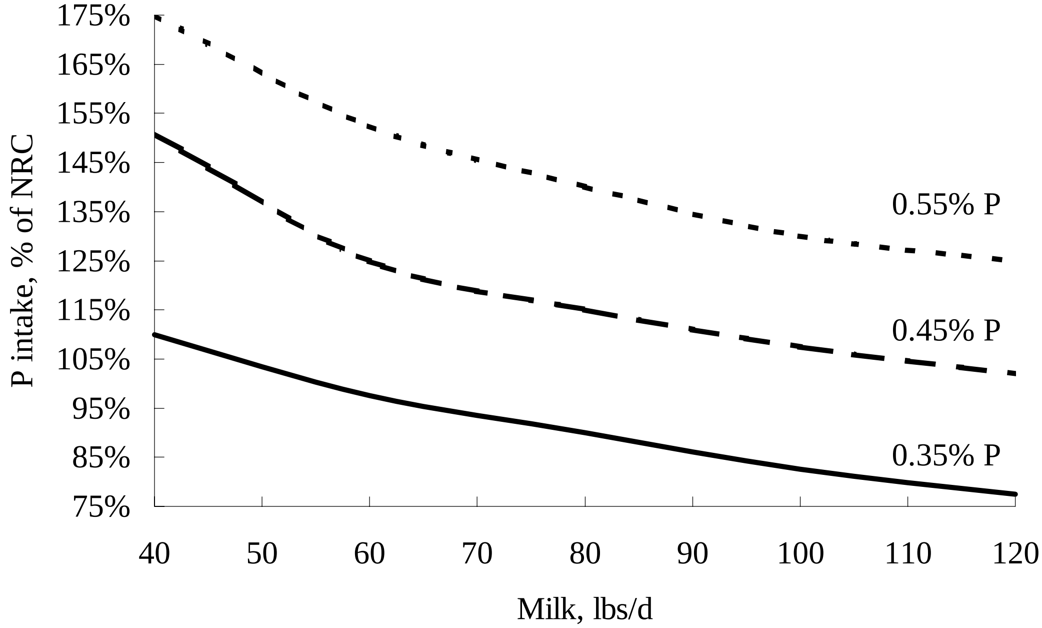

Figure 1. The relationship between daily phosphorus requirement and three levels of intake to milk production (adapted from Chase, 1999).

Table 4. CNCPS protein pools from feed analysis (Sniffen et. al., 1992).

Analytical result and the pool it contains	Protein Pool A[1]	B1[2]	B2[3]	B3[4]	C[5]
Crude Protein	X	X	X	X	X
Soluble Protein	X	X			
N-bound to NDF				X	X
N-bound to lignin					X

[1] A protein = Soluble Protein - NPN
[2] B1 protein = Soluble Protein – A protein
[3] B2 protein = 100 – A protein – B1 protein – B3 protein – C protein
[4] B3 protein = N-bound to NDF (NDICP) – C protein
[5] C protein = N-bound to lignin

The purpose of these pools is to predict dietary N required to maximize rumen microbial growth, and the amount needed to supplement microbial protein to meet animal metabolizable protein requirements. This is accomplished by predicting microbial growth from ruminally-degraded carbohydrates, based on their digestion and passage rates. Then metabolizable protein and amino acids are predicted from intestinally available microbial protein. In order to meet the amino acid demand of high producing cows, feeds are included as needed that have a low ruminal protein degradability to supply feed amino acids to the small intestine to supplement the bacterial amino acids.

Nitrogen requirements need to be viewed as bacterial requirements and animal requirements. In ruminant nutrition, the objective is to maximize rumen microbial growth to supply the cow with energy and protein and then supplement the microbial supply with feed. Properly matching microbial requirements with animal requirements allows for less total protein to be fed resulting in lower nitrogen excretion.

Microbial nitrogen requirements are dependant upon the type of carbohydrate being fermented. Two primary pools of bacteria ferment feed in the rumen: those that ferment NSC, and those that ferment fiber. There is another pool that ferments amino acids; however they represent a small proportion of the total microbial population. Microbes that ferment NSC prefer peptides (B1 and some B2 protein) as their nitrogen source. Adequate peptide levels act as a growth stimulant. In the absence of peptides, they can meet their nitrogen requirements with ammonia (A protein). Fiber fermenting microbes rely strictly on ammonia as their nitrogen source. CNCPS v4 predicts that inadequate ruminal ammonia decreases microbial protein and reduces fiber digestibility (Tedeschi et al., 2000). Excess ruminal ammonia is absorbed through the rumen wall. Some is recycled back to the rumen; the remaining is excreted in urine and milk.

The animal requires protein for maintenance (tissue turnover, scurf, and metabolic fecal), pregnancy, growth, and lactation. Protein supply in excess of requirement is excreted primarily in the urine. This excretion requires energy to convert the excess ammonia to urea, resulting in decreased animal performance (growth or lactation).

Nitrogen excretion in CNCPSv4.0 is predicted by partitioning N excretion from the predicted N balance into feces and urine:

1. Fecal nitrogen (gms/d) = (FFN + BFN + MFN)
2. Urinary nitrogen (gms/d) = (BEN + BNA + NEU + TN)

Where:

FFN = fecal nitrogen from indigestible feed;
BFN = bacterial fecal nitrogen, primarily bacterial cell wall;
MFN = metabolic fecal nitrogen;
BEN = excess bacterial nitrogen;
BNA = bacterial nucleic acids;
NEU = metabolizable nitrogen supply – net nitrogen use (i.e., inefficiency of use); and
TN = degraded tissue nitrogen.

Minimizing nutrient excretion through ration and management strategies

General principles

Methods that can be used to minimize nutrient excretion include short-term (can be implemented within days or weeks) and longer-term (require one or more crop years to implement). Implementation of these changes must be done so that milk production, growth, reproduction, and animal health are not compromised. These methods revolve around two areas: 1) decreasing N and P inputs brought on the farm by more accurately formulating rations, and 2) improving the efficiency of nutrient utilization through improved feed and crop management strategies.

Short-term methods

1. Use more accurate ration formulation to decrease P fed to NRC or INRA requirements where possible. This will decrease P excretion and ration cost, as P is an expensive nutrient. Even though P levels are decreased to recommended levels, many groups will be overfed P due to the P levels in the forages and concentrates fed to meet energy and protein requirements.
2. Use more accurate ration formulation to decrease N fed to rumen and animal requirements. To accomplish this, feed carbohydrate and protein fractions must be known and combined optimally to maximize rumen microbial growth. Programs using the CNCPS such as CPM-Dairy, DALEX, and CNCPSv4.0 can be used to accomplish this.
3. Modify grouping strategies to improve accuracy of ration formulation. Logical alternative grouping strategies need to be investigated for each farm. Through proper grouping, it may be possible to reduce N and P and ration cost while maintaining milk production and body condition replenishment goals. As Figures 1 and 2 show, the nutritional needs of lower producing cows can be met with lower ration N (figure 2) and P (figure 1). A cow producing 120 pounds of milk may need an 18% crude protein diet while a cow producing 60 pounds only requires 14% crude protein. These values may even be lower if ration formulation maximizes ruminal microbial production and N supplementation by matching feed carbohydrate and protein fractions.

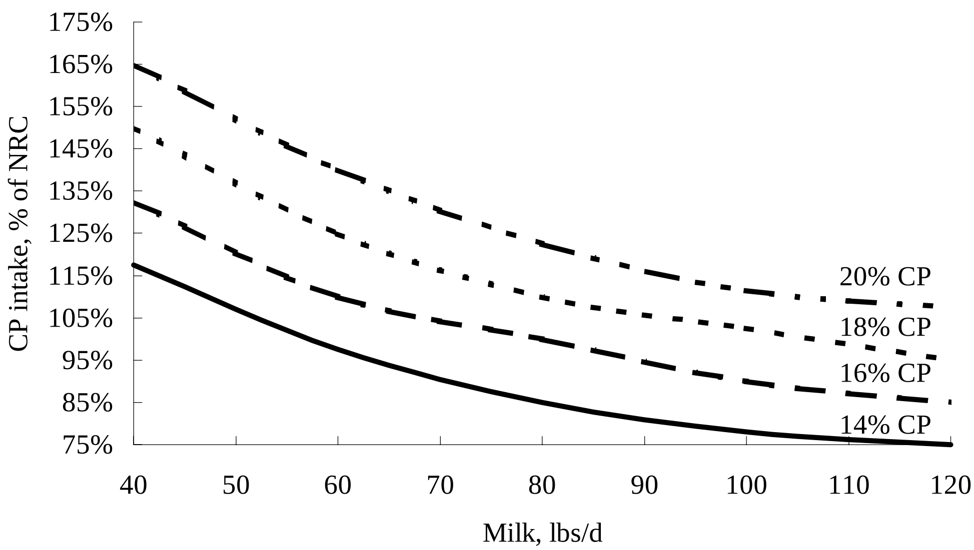

Figure 2. The relationship between daily crude protein requirement and three levels of intake to milk production (adapted from Chase, 1999).

4. Obtain Feed analysis as needed to accurately represent the feeds being fed. In order to decrease nutrient excretion, ration safety-factors need to be reduced in addition to matching protein and carbohydrate feed fractions. To accomplish this, a routine feed analysis protocol needs to be followed. A farm specific feed database should be developed that includes forages as well as concentrates. As is seen in Table 1, the laboratory-analyzed values for P vary considerably. Similarly, protein and NDF in forages (Tylutki et. al., 1999) and concentrates (Kertz, 1998) can vary greatly.
5. Determine dry matters as needed to account for individual feed variation. Tylutki et. al. (1999) simulated the impact of NDF and dry matter variation in corn silage using the average values and standard deviations as sampled on a 500-cow farm. The impact of improper forage analysis and lack of control over the dry matters at feeding resulted in a large annual variation in nutrient excretion (242 pounds N excretion and 64 pounds of P excretion), feed inventory required (61 tons of corn silage), and income over feed costs ($21,792) per 100 cows annually. The majority of variation was due to changes in the corn silage dry matter. Our current recommendation is to determine dry matters of all silages at least twice weekly (more often if wide fluctuations in intakes are observed)., then adjust as fed formulas as needed.
6. Improve feeding accuracy. Most farms assume that what is being mixed and fed is what is supposed to be fed. In many cases, this is not a valid assumption. Tylutki et. al. (1999) evaluated the impact of varying feeding accuracy ± 3%. The addition of feeding error increased annual variation in P excretion (18 pounds), corn silage inventory (9 tons), and income over feed costs ($19,148) per 100 cows annually. Feeding accuracy needs to be tracked to identify sources of variation, as well as to manage inventory. Commercial software and hardware is available that can be linked to the mixer scales to track this information.
7. Monitor dry matter intake to improve accuracy of ration formulation and animal performance.
    a. Track intakes. Proper ration formulation relies on many inputs from the farm, including animal body weight, feed inventory, and actual dry matter intakes. To decrease nutrient excretion, actual dry matter intakes must be known in order to ensure adequate grams of nutrient are provided. The data can also be used as a diagnostic tool. For example “our close-up dry cows are consuming 21 pounds of dry matter, and we are experiencing high levels of post-calving metabolic disease”. Are they related? If so, why are we only achieving 21 pounds of intake?”
    b. Improve feed-bunk management to increase intake, and consistency of animal performance. This includes: daily cleaning, pushing feed up several times daily, and all other good management practices. More consistent performance allows the ration to be more accurately formulated for milk production level.
    c. Make ration changes to improve accuracy. By increasing the dry matter intake 5%, ration nutrient concentrations can be lowered. Chase (1999) calculated that by increasing intake 5%, it is possible to decrease diet crude protein about one percentage unit to achieve the same pounds of crude protein intake. This would result in higher inclusion rates of homegrown feeds, thus decreasing purchased nutrients.

8. Control the level of refusals. Most farms' feed refusals from the lactating herd are fed to replacement heifers. From a bio-security viewpoint, this is not a good practice. From a nutrient excretion viewpoint, this is an expensive practice. Mineral and protein levels that are adequate for lactating cows do not fit most replacement heifer groups. The amount of refusals must be at a level that is consistent with farm management to achieve maximum dry matter intake, however extremely high levels need to be avoided.
9. Use the proper 'tools' to track the impact of changes in ration formulation and feeding management. These 'tools' include:
    a. Milk production,
    b. Milk components,
    c. MUN's,
    d. Manure analysis. Manure needs to be analyzed two ways. The first is to determine what is not being digested by the cow. If large fiber particles or corn grain is evident, rations and feeding management need to be addressed. The second is to analyze manure that is being spread. As N and P levels are decreased in the rations, the levels found in manure will decrease as well. Most of the change in nitrogen will be found in the ammonia N pool. Tracking this analysis over time will provide an index of how consistent nutrient excretion is.

Long-term methods

1. Improve silo management. Silo capacity and management can play a significant role in decreasing nutrient excretion.
    a. Have adequate capacity to store separately different crop types and quality. Many farms in the Northeast have varying soil types that are best suited for different crops. The storage system must be able to handle each crop type individually (e.g., corn silage, grass silage, alfalfa silage, and different qualities of each). This will allow the nutritionist to better match protein and carbohydrate pools with specific groups of animals. An example of this would be to feed high quality alfalfa silage and corn silage to the high producing cows and feed the grass silage to lower producing cows and heifers.
    b. Minimize storage losses. During expansion, most farms will over-fill bunk silos for several years until additional capacity can be built. This over-filling results in poorer management of the bunk silo. Tylutki et. al. (1997) and Kilcer (1997) calculated the feed requirements, storage capacity, and storage losses for a 500-cow farm. They found that when the height of the corn silage pile was increased, dry matter storage losses increased (losses were calculated to be in excess of 35%) because of reduced ability to properly pack the silo during filling. By decreasing storage losses, inventory would have been high enough to allow higher home grown forage levels to be fed, thus decreasing purchased nutrients.
2. Match cows/crops/soils. Alfalfa and corn are not always the best choices for dairy producers due to soil constraints. The farms nutritionist and field crops consultant

need to work together to determine what is the best mix of crops to grow and how they can be fed to maximize production and minimize nutrient excretion.

3. Increase the amount of homegrown feeds in the ration. Increasing the amount of homegrown feeds in the ration decreases the amount of purchased nutrients. To accomplish this, homegrown feeds need to be of high quality to maintain or improve production and animal health.
   a. Impact of Forage quality. To increase the amount of forages in the rations, forage quality must be high. Maximum intake from forages can be expected when alfalfa is 40% NDF, grasses are 55%, and corn silage is 40-45% (Chase, personnel communication). A cow is limited in forage NDF intake to (1 to 1.1% of bodyweight (Mertens, 1994). As an example, a 1400 pound cow at 1.1% NDF capacity can consume 28 pounds of dry matter from grass at 55% NDF but only 24 pounds at 65% NDF. This four pounds of dry matter difference would have to be made up with purchased feeds.
   b. Impact of Grains. Homegrown grains (protein sources) decrease the amount of purchased nutrients. Most dairy farms do not have an adequate land base to produce their own grain; therefore, they should maximize forage quality and choose purchased concentrates that accurately supplement their forages.
4. Add more land or export nutrients. After all of these areas are addressed, nutrient excretion will still be in excess of crop requirements on most dairy farms. Increasing the land base to increase homegrown feed production and being able to utilize the manure N and P for crop production will be required. Chase (personnel communication, 1999) calculated the required land base for the 500-cow farm described by Tylutki et. al. (1997) to spread manure based on P recommendations. The resulting required land base was three times the current land base.

Case study

McMahon's EZ Acres is a 500-cow dairy farm located in Homer, NY. It is owned by two brothers in partnership. Four years ago, the herd was moved into a new facility from four old tie-stall barns. Since then, milk production has increased (milked 2x with no rBST) and herd health has improved. This change has been the result of a step-wise consolidation. In 1992, a bunk silo complex with a commodity building was built. This eliminated the use of numerous tower silos. Barns were then setup as production groups and a TMR was delivered twice daily. In 1996, a transition calf barn and a heifer barn were added at the site of the new complex. In 1998, the farm added milk metering and cow identification to the parlor. The farm has been a cooperator with this project since 1997 (Tylutki and Fox, 1998).

In 1997, baseline data was collected and an initial analysis of the herd and cropping system was conducted (Tylutki and Fox, 1997; Bannon and Klausner, 1997; Kilcer, 1997). It was concluded from this analysis that increased bunk silo capacity and improved bunk silo management were required. In addition, an increase in acreage of intensively managed grasses would allow for a higher proportion of homegrown feeds in the rations. The farm has been adopting these recommendations since then.

Since April 1999, rations for all groups have been formulated with CNCPSv4.0 by the farm's herd nutrition consultant. Most of the short and long-term strategies to lower N and P excretion described in this paper have been implemented by the consultant and farm management. These include:

Short-term methods implemented

1. Phosphorus levels in all groups have been decreased to CNCPSv4.0 computed requirements. Lactating cows currently are consuming a diet with .41% P (1 gram in excess). Non-lactating animals range in P excess from 2 to 10 grams with low levels of supplemental phosphorus used.
2. Protein levels have been lowered and are matched with carbohydrate feed fractions to optimize rumen microbial growth as computed by the CNCPS model. Lactating cow diets currently contain only 40 grams of metabolizable protein in excess of requirement (1% excess).
3. Lactating Cows are currently grouped by level of production. Further refinements in the grouping strategies are being explored.
4. Intensive feed analysis is being conducted as part of our research project on the farm. The project is designed to describe the variation in homegrown and purchased feeds and then how to account for this variation in ration formulation and daily feeding management practices. Daily samples of all forages are being collected and analyzed for DM, NDF, and crude protein. Weekly composites are analyzed for all protein and carbohydrate and protein fractions. Results of the weekly composites are used for ration formulation. Tables 5 and 6 show the averages and standard deviations of feed analysis by feed type from the case-study farm. These samples have been collected over the past 18 months. The SD column is the standard deviation and is a statistical measure of the variability around the average. The higher the standard deviation, the greater the variation. Variation in all feeds has been higher than anticipated. Another measure of variation is the coefficient of variation (CV). It is calculated as the standard deviation divided by the average. Calculating the CV for several of the feeds in Table 5, we find a range of 6.5 to 25.0% for phosphorus with homegrown feeds showing the highest variation and 2.7 to 33.2% for crude protein. Methods to account for this variation in ration formulation are being examined.
5. Dry matters of silages are determined at least twice weekly. If a large change is observed either in refusals or in bunk appearance, dry matters will be determined daily until they are consistent. Dry matters are charted by the feeder. The chart is used to look for patterns in changes. If a sample is greater than five units different from the last sample, another sample is taken and analyzed that day. The feeds in Table 6 with "at feeding" as part of their name illustrate the wide range in dry matters observed and the need to track dry matters on a regular basis. The corn silage standard deviation shows that the dry matter ranged from 18.2 to 43.4% as it was fed from the bunk silo (the average $\pm$ 2 standard deviations).

Table 5. Selected feed analysis averages and standard deviations from the case study farm (1999 data).

	Dry matter		Crude Protein		Soluble Protein		NDF		Fat		Phos.		
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	n
Corn meal	89.0%	1.5%	8.8%	.6%	21.7%	14.5%	11.6%	1.7%	4.2%	.2%	.28%	.02%	17
Hi Moist Shell Corn	71.1%	5.7%	8.2%	1.0%	26.9%	9.6%	10.4%	1.2%	4.1%	.3%	.31%	.02%	7
Corn Silage[a]			7.6%	.5%	58.7%	4.6%	50.0%	2.8%	3.8%	1.1%	.20%	.03%	27
Grass hay	89.3%	8.4%	7.5%	2.5%	23.0%	9.4%	68.3%	3.8%	2.5%	.4%	.20%	.05%	15
Grass Silage[a]			20.5%	3.7%	61.7%	9.1%	55.0%	8.4%	6.9%	1.2%	.39%	.06%	3
MMG silage[a]			17.4%	3.1%	55.6%	11.8%	53.4%	7.7%	5.2%	.7%	.39%	.05%	23
MML Silage[a]			20.5%	2.9%	58.7%	13.1%	51.9%	6.4%	4.4%	1.2%	.37%	.04%	6
Whole cotton	87.3%	3.7%	24.6%	2.0%	24.9%	6.9%	54.7%	6.2%	19.7%	3.4%	.65%	.08%	17
Soy 48	88.9%	.7%	53.5%	1.5%	25.3%	9.4%	11.7%	2.0%	3.9%	8.1%	.74%	.06%	15

[a]The forage results are from the composites of daily samples. Within each sample, there are three to seven individual samples. Dry matter values for home grown forages are summarized in table 6.

Table 6. Homegrown forage dry matter and NDF averages and standard deviations from the case-study farm.

	Dry Matter			NDF	
Feed Type	N	Avg.	SD	Avg.	SD
Corn silage at harvest[a]	1057	26.2%	3.5%	50.0%	16.0%
Corn silage at feeding[a]	376	30.8%	6.3%	49.6%	7.6%
Grass haycrop at harvest[b]	29	26.0%	4.2%	58.4%	7.9%
Grass haycrop at feeding[a]	141	33.4%	12.7%	57.5%	6.3%
Legume haycrop at harvest[b]	9	21.8%	8.3%	49.8%	19.4%
Legume haycrop at feeding[a]	63	46.7%	13.1%	42.0%	7.7%
Mixed haycrop at feeding[a]	77	41.7%	27.2%	44.1%	14.8%

[a]1998 forages.
[b]1999 forages.

6. In 1998, the farm began using EZ Feed. EZ Feed is a commercial software package that interacts with the scale head on the mixer. It records the actual pounds of each feed added to the mix and time spent loading and unloading each feed/batch. Daily reports can be printed that list for each feed the formulated and actual pounds fed by batch. The use of EZ Feed resulted in the farm changing feeders to improve accuracy. It was calculated that greater than $20,000 was being lost due to over-feeding. The current feeder typically is within .3% of expected amounts (<150 pounds total over-feeding with approximately 60,000 pounds fed daily).
7. EZ Feed is also used to track dry matter intakes of each pen. Feed refusals from the lactating and dry cows are loaded into the mixer by pen and recorded.
    a. Intakes for the lactating cows are charted by the feeder daily. Charts are used to compare expected intakes with observed and intake versus milk production.

Intakes of dry cows are analyzed weekly. It was discovered in April that far-off and close-up dry cows were consuming below expected levels. Rations were adjusted for both groups and the far-off dry cows were moved to another location. Intakes of both groups now are 5% greater than expected values.

b. A feeder checklist was developed. The feeder walks each feed bunk each morning prior to feeding and scores the bunk. Feeding level is adjusted based on changes in cow numbers and this feed bunk score. The farm feeds once daily and pushes feed up every two hours.

c. Ration formulas are reviewed and adjustments made as needed. Time between ration formula adjustments ranges from weekly to monthly depending on inventory and trends in dry matter intake. As an example, weather changes resulted in observed intakes that were 12-15% greater than trend for two weeks. During this time, ration formulas were adjusted based on the higher intakes. When intakes returned to near expected levels, ration formulas were again adjusted based on intake.

8. Given the accuracy of the current feeder, refusal goals have been lowered. A current goal for lactating and close-up dry cows is 3-5% refusal.
9. In August 1999, a milk sampling method was implemented allowing for group composites to be taken weekly. These weekly samples are analyzed for fat, protein, SCC, and MUN. Fat is charted weekly by group. Each is evaluated weekly for changes compared to the trend. Bulk tank milk production is calculated daily and evaluated for trends, and 150-day milk by lactation group is calculated and charted.
10. Since December 1, 1999, weekly manure samples have been collected and analyzed from the lactating cows. Total nitrogen has averaged 40 pounds per 1000 gallons and phosphate equivalent has ranged from 9 to 11 pounds per 1000 gallons.

Long-term methods

1. During the 1999 cropping season, several changes in crop harvest and storage were made. Hay crop silage was stored with grass in one bunk silo, and alfalfa in another; in previous years, they were stored in either bunk by cutting: all first cutting in one bunk, second in another, etc. regardless of hay type. This allowed each forage to be harvested at desired dry matter levels. To accomplish this, a driveway and apron had to be constructed behind the bunks. An unexpected benefit of this was discovered during corn harvest. There are no back walls on the bunks and historically, a steep slope was made while filling. This resulted in poor packing and an impossible slope to keep covered. With the new apron, the corn bunk could be extended and a slope maintained for packing that has allowed for adequate covering. Four 12-foot bags were also filled with corn silage in order to decrease bunk silo height. In 1998, the bunk was measured at 26 feet tall; in 1999, it is 13 feet tall.
2. The farm has been working with their agronomist to increase grass production on the poorer, more erodable hillside soils and maximize corn silage and alfalfa yield on the valley soils. The farm has gone from zero grass acres in 1996 to greater than 225 in 1999.
3. In November 1999, the farm began moving towards higher levels of forage in the diet. The highest level achieved in the lactating cow diets was 48%, a level never achieved on

this farm before. Further, increases in these levels were planned; however given the current low inventory of hay silages they were decreased.

4. The land base has increased greater than 15% since 1997. As more land becomes available, it will either be rented or purchased.

Conclusions

Nutrient excretion is affected primarily by four factors: feed quality (homegrown and purchased), quantities of homegrown feeds, ration formulation, and ration delivery. Farm management directly controls three out of these four with some control over ration formulation. Homegrown feeds (quantity and quality) are the most important factors. Increasing the quantity and quality of homegrown feeds allows for higher inclusion levels during ration formulation. In cases such as phosphorus, there is a gram for gram replacement opportunity (increase homegrown P one gram, reduce purchased P one gram).

Many of the steps discussed in this paper revolve around decreasing the safety factors used in rations. Removing these safety factors requires high levels of farm management to decrease the risk of production fluctuations. If large levels of variation are present in forages, large variations in milk production will be observed. Avoiding these fluctuations requires that a forage sampling and dry matter determination protocol be developed and followed.

Accomplishing a reduction in nutrient excretion requires a team effort including the farm's nutritionist, crop consultant, management, and employees. This requires a Total Quality Management approach where all concerned share a vision for the farm. This includes sharing the farms financial and environmental goals with all parties so that the farm can meet its goals and is sustainable.

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