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NUTRIENT CYCLING ON A DAIRY FARM

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Nutrient management is a key facet of all phases of a dairy farm operation. In livestock nutrition, nutrients are added and balanced to provide for optimum milk production and animal health at maximum economic returns. Nutrient containment and conservation are environmental goals of animal manure storage, handling, and application. And soil nutrient credits and nutrient/fertilizer application rates are agronomically based to ensure proper crop growth and production. It is evident that proper nutrient management can mean several things to various people involved in the various aspects of a dairy operation.

The nutrients that are used in the animal nutrition phase can be the same nutrients in the manure, soil, and crop phases on a given farm. Nutrients cycle from the animal to the soil via manure application; and from the soil to the crop via plant uptake; and from the crop to the animal via feeding.

Nutrient cycling awareness and management is a key factor in creating and/or maintaining environmental balance for a farm. Of particular concern on a dairy farm are nitrogen (N) and phosphorus (P) for environmental reasons. Nitrates in drinking water poses a human health concern as methemoglobinemia can occur with infants and nitrosomines can be produced which are linked with cancer in adults. Phosphorus entering surface waters increases algal and plant vegetation growth and overall reduces the quality of the water body.

To better understand nutrient cycling on a dairy farm, examining all of the entry and exit points for these nutrients would be helpful (see Figure 1). Nutrients enter a dairy farm from several sources; however, the primary entry points are through purchases of feed/supplement and commercial fertilizers.

Nutrients leave a dairy farm primarily through product sales--either milk, animal, or crops. Obviously these nutrient losses are the economic basis for the entire dairy enterprise. The other nutrient exit mechanisms pose an environmental risk rather than an economic risk/gain. One mechanism includes manure nutrient loss from noncontainment or loss of some gaseous nutrients from the manure in the storage, handling, and application phases. When nutrients being imported onto a farm exceed those being exported, the excess nutrients build-up in the soil component because the crop does not take more nutrients than it needs and livestock will pass through any excess nutrients in the manure. Therefore, those fields receiving manure are at risk of excess nutrient loading.

Environmental stewardship on a dairy enterprise consists of proper management of all the components. While specialization creates component management on a farm, the link of all these components are the nutrients. The sooner everyone realizes that feeds affect manure analysis, manure handling affects crop fertilization, and crop selection and quality, the sooner everyone will have a more efficient and economical system.

Nutrient Management in Dairy Nutrition and Utilization

Efficient use of nutrients is a major factor in nutrition programming on dairy farms in 1990's. Consideration of nutrients for production as well as excretion of unused nutrients are critical management issues. The two nutrients of most concern to the environment are nitrogen and phosphorus. Mass nutrient balance studies on dairy farms show large net accumulations of these nutrients on farms (Klausner, Van Horn). Approximately 65 to 80 percent of the N and P imported onto a dairy farm remain on the farm. The nutritional challenge is how to convert more of the imported nutrients like N and P into milk and other animal products and excrete fewer nutrients into the environment.

NITROGEN

Dutch research indicates 75 to 85 percent of the N ingested by a dairy cow is excreted in the feces or urine (Tamminga). Nutrient balance study on New York dairy farms indicated two thirds of the imported N onto the farm remained on the farm (Klausner). Thus, the efficiency of N conversion from feed into milk on our dairy farms is a dismal 15 to 30 percent. Chase reported milk N represented 26 to 34 percent of the total N intake. Fecal N excretion ranges from 26 to 40 percent with the remainder, 20 to 43 percent, of the N intake excreted in the urine. As crude protein concentrations in diets increase from 12 to 20 percent, more N is excreted via urine than feces or milk.

Several opportunities exist for decreasing the purchase of feed N onto farms and improving the efficiency of N utilization in the cow.

1. Improving forage quality can reduce N inputs onto farms. Approximately thirty percent of the purchased N imported onto a dairy farm is in the form of concentrates. Production of high quality forages is a good way to decrease the need for purchased protein supplements. Forages, particularly grasses, are a good N sink and an efficient way of recycling N on the farm.

2. Balancing diets for carbohydrate to maximize microbial protein production decreases the need for purchased protein and maximizes the use of degradable protein in the diet. Lactating cow diets should be 38 to 41 percent NFC (nonfiber carbohydrates) and approximately 65 percent degradable protein to maximize microbial protein production.

3. Do not over feed protein. Excess protein feeding can occur as total quantity and/or as an incorrect quantity and form in relation to the energy source in the diet. Feeding a high amount of degradable protein with high fat in a diet increases the amount of N excreted in the urine as insufficient rumen available carbohydrates would be available for microbial growth.

4. Feed supplemental protein sources which are high in amino acid quality and high in digestibility. Microbial protein and undegraded dietary protein are the primary amino acid sources for absorption in the intestine. Feed proteins which are heat damaged or low in digestibility are a primary source

of fecal N. The amino acid profile of microbial protein is relatively constant and similar to milk protein, but that of the undegraded dietary protein can be highly variable. Imbalances of amino acids in the ingesta can limit both milk and milk component production.

PHOSPHORUS

Phosphorus is the most expensive nutrient in most diets. Excess feeding is a concern from both a cost and environmental standpoint as 65 to 85 percent of the P fed in excess of requirments ends up in the manure. Therefore, the primary way to control P excretion is to control P intakes.

Florida researchers (Van Horn) have calculated the total yearly excretion of P for a lactating dairy cow producing over 21,000 pounds of milk per year is 40, 46 and 69 pounds when fed a diet containing either .4, .45 or .6 percent, DM basis, P (Van Horn). For almost all lactating dairy cows, consumption of a diet containing .45 percent P, DM basis, will meet or exceed P requirements.

Estimates of daily P excretion can be predicted from the following formula:

$$P_{\text{excreted (grams/day)}} = 9.6 + .472X + .00126X^2 + .323(\text{kg milk/day})$$

X = grams/day of P intake

How can excess P feeding be avoided?

1. Analyze all feeds in the diet. Forages grown on high P soils are often higher than "book" values, Table 1. Byproduct feeds can be quite variable and often higher than stated values, particularly for animal byproducts.

2. Formulate diets to meet animal requirements. Avoid the use of extra safety factors for better reproduction across all animals or the herd. In most situations, a shortage of P in the diet is not the cause of poor estrus expression.

3. Use high quality P supplements. Dicalcium phosphate, mono-sodium or mono-ammonium phosphates are superior to rock phosphates.

Manure Handling, Storage, and Application

The primary goal of any dairy farm's manure handling and storage plan is to not have any direct losses of manure off the farm. Therefore, containment is the operative term to prevent manure/nutrients from directly leaving the feedlot area. For example, manure from cows loafing in an outdoor area should not be able to directly run off the enclosed area into a creek, lake, or tile inlet. Likewise, any storage structure should hold, or contain, both the solid and liquid components of the manure. Direct losses of manure are most easily controlled through a well-planned feedlot design and thorough construction process.

Manure, and its corresponding nutrient amounts, found in the storage structures have significantly changed from the initially excreted material. As soon as manure is excreted, volatile chemical compounds start entering the atmosphere, thus the chemical composition starts changing. As the manure is handled in going to a storage structure, some biological decomposition of the organic products may start occuring as well.

Dilution of excreted manure occurs in many ways on a dairy farm. Diluting materials include milk washwater/parlor waste, bedding, feed spillage, and rainwater. While most of these materials change the solid:liquid ratio of the manure, be mindful that nutrients are also being added from contaminants such as feed spillage, bedding, and soil runoff after rainfalls. For solid manure handling systems, often times some of the water contained in the manure is evaporated to the atmosphere; thus, the solid:liquid ratio is altered in a different direction.

The major nutrient loss issue with stored manure regards N. Again, whenever excreted and stored manure is in contact with the atmosphere, the equilibrium between the ammonium concentration in the manure and the ammonia concentration in the air favors N loss. The amount of volatile N loss is dependent on such factors as the surface area between the stored manure and the air, pH of the stored manure, and wind speed. Although storage N losses are common, they pose an environmental risk of atmospheric/ozone pollution as well as create an odor pollution issue that many people find objective.

Settling of solids in liquid manure storage systems is another concern regarding nutrient cycling on a farm. While the nutrients are not "lost," their build-up on the bottoms of various storage systems can pose environmental problems when the storage structure becomes inactive. Effective agitation systems and proper maintenence of multi-stage settling basin systems will minimize settling concerns.

Manure application to soil is a key step in nutrient cycling. The goal of these application strategies is to have all of the nutrients as part of the soil system--eventually being available for plant uptake.

Broadcast manure applications pose the biggest threat to nutrient cycling inefficiencies. Overland flow of manure off the fields to which they were applied must be eliminated. Conditions that enhance the potential for direct manure losses of a given field are; 1) applications made onto frozen fields and/or steeply sloped fields; 2) high application rates of liquid manure; and 3) the potential for intense rainfall events.

Application methods of manure also has a major bearing on the loss of N via volatilization. Broadcast applications of either solid or liquid manure are subject to immediate losses of the inorganic N. If subsequent incorporation of the manure-N is not made through incorporation of the manure by a tillage implement or by rainfall, there is the potential to lose all of the inorganic N contained in the manure. While volatilization of manure-N is not considered an environmental concern, the odor issue associated these losses, the economic loss of the N, and the global awareness of atmospheric pollution provide justification for minimizing volatilization losses.

Crop Uptake and Utilization of Nutrients

Crop production strategies on most midwest dairy farms are to produce forage and grain crops to feed the dairy herd. The crop enterprise allows for a profitable dairy farms when nutrients grown, harvested and stored are offered to cattle at cheaper than purchase prices. Dairy cattle require minimum fiber levels in diet at various production cycles which necessitates forage crop production. Most profitable dairy farms need cattle's fiber requirements, but also provide significant portions of the animal's nutrient requirements for energy, protein, minerals and vitamins. Now that farmers must be aware of nutrient contamination in water crop uptake and utilization of N, P, and potassium (F) become added criteria to consider in corp production strategies. Crop selection and utilization decisions influence crop removal. Crop production strategies must be made to minimize nutrient build-up within soil which can be controlled by crop selection, harvest decisions, fertilization and manure applications. Crop analysis at critical points in the nutrient cycle are needed to manage nutrients .

Nutrient Removal vs. Recommendation

Nutrient removal information of six major crops grown and harvested on Minnesota dairy farms is shown in Table 1. The quantities of N recommended to produce yields indicated varies from 0 for soybeans to 120 pounds per acre for corn. Yield of grasses (corn, grass hay, and oats) is dependent on the rate of N application. Legumes (soybeans and alfalfa) do not require N fertilization because they can fix their own N through N fixation. However, both legumes and grass have high N requirements as seen by their high crop removal rates, Table 1.

Two methods of estimating nutrient removal - Removal C is estimated from crop and soil research and Removal D uses nutrient concentration taken from Dairy NRC (Nutrient Requirement) tables. Estimating crop removals by "book valves" over or under estimates N, P, and K. Managers need knowledge of crop removal of crops to determine if potential build-ups can occur in the soil.

Crop Removal - Corn

Strategies to consider with corn are issues influences of nutrient uptake and management choices which monitor nutrient removal.

Corn is a luxury consumer of both N and K. The crop takes up nutrients during the entire season after all nutrients have been preplant-incorporated. Corn only has a narrow window for manure application and the amount of nutrients removed is influenced by the amount of crop removed; grain vs. silage, Table 1.

Alfalfa and hay crop silage.

Nutrient uptake of alfalfa is cyclic during the season, because the crop consumes nutrients necessary for each harvest. Alfalfa is a luxury consumer of N and K. The amount of nutrient removed is dependent on yield and nutrient concentration. Unlike corn, alfalfa will remove more N (shown in Table 2) and K (data not shown) under more frequent harvest schedules than less frequent (2 vs. 3 vs. 4 cuts/yr). Also different from corn is that the concentration of N and K is influenced by stage of maturity. Immature alfalfa, being highest in quality, will also provide concentrations in animal diets higher than in lower quality alfalfa.

Alfalfa and other legumes fix their own N. Hence, this process adds N to the system. Alfalfa and clover under low soil nitrate availability conditions may fix as much as 66% of their total N. However, alfalfa will use available soil nitrate before fixing its own N. Using alfalfa or alfalfa-grass mixtures as N sinks can be misleading without soil N analysis.

Alfalfa has more nutrient management options than corn. Harvesting several cuttings per season opens up cropland acreage for manure application may times during the growing season. However research has shown no yield advantage from liquid manure applications on established alfalfa compared to fertilization with similar amounts of P and K. Liquid manure applications on established alfalfa will burn alfalfa unless applied at low rates (3,000 gallons or less) and applied immediately after crop removal to prevent burning of regrowth. Top Dressing alfalfa with manure increases potential for stand reduction by increasing crown root disease incidence from traffic. In addition, N in manure encourages grasses and weeds which reduces forage quality.

Liquid manure application plow down before alfalfa establishment has shown yield increases compared to equal fertilizer application of P and K. Plow down application of manure is recommended, but recommended on corn ground going into alfalfa NOT alfalfa ground going into corn(soil already has 100 to 150 credits of N).

Alternative Crops

An alternative crop is needed in a rotation with corn and alfalfa to enable removal of excess N and P in the systems. Cool season grasses offer an excellent alternative for removal of N, P & K from soil, Table 2. Grasses remove large amounts of N and K. Research shows reed canarygrass removes 2 to 3 times the amount of N as corn, persists under high liquid manure applications rates(30 tons/A). Reed canarygrass removes more N when harvested more frequently during the season. The quality of forage under 3-cuts per season in Northern Minnesota or 4-cuts in Southern Minnesota fits the desired quality of dry cow diets (RFV 110 or 120) better than in frequent higher yielding grass, Table 2. Thus, reed canarygrass harvest at prehead stage and every 30 days there after will remove the most N, provide quality hay or haylage for dry cows, and will provide open fields for manure applicaitons more times during the cropping season.

Other alternative crops are soybeans and small grains; both have limitations. Soybeans fix their own N which adds N to the system. Small grains remove smaller amounts of N, P and K, are susceptible to lodging, and have limited dietary value and economic value.

Summary

Man
- Manipulate nutrients
- Be good stewards
- Be a good neighbor

Animals
- Manure occurs
- View manure as a nutrient resource

Nutrients
- Nutrients are dollars
- Meet nutrient requirements of animals and plants

Utilize
- Analyze feeds and manure for nutrient content
- Can't manage if not measurable

Recycle
- Nutrients are never gained or lost but can change in form
- Maximize production/profit with nutrient management

Environment
- Nutrient management is holistic
  Soil, Plant, Animal and Human

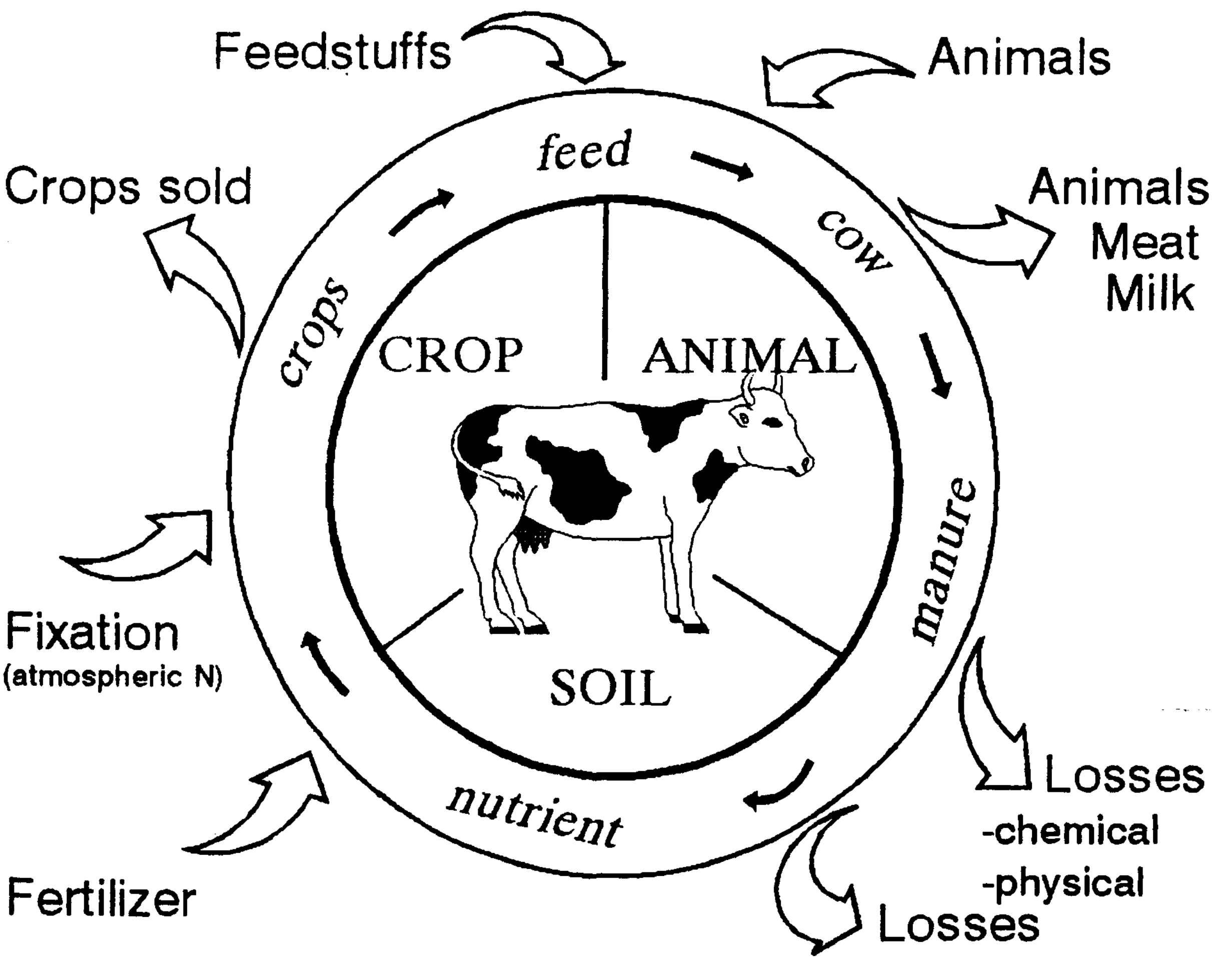

Figure 1. Generalized nutrient entry and exit paths for a typical dairy farm.

Table 1. Crop removal estimates of nutrients relative to recommendations.

Crop, yield/A	Nitrogen			Phosphate (P_2O_5)		Potash (K_2O)	
	rec.	removal C[1]	removal D[2]	removal C[1]	removal D[2]	removal C[1]	removal D[2]
	pounds per acre						
corn grain, 140 bu	120	105	113	62	47	41	31
corn silage, 20 T	120	166	182	72	70	166	161
alfalfa hay, 4.5 T	7	252	245	68	51	225	235
grass hay, 3.0 T	114	100	122	54	40	156	178
soybeans, 35 bu	0	140	129	28	28	49	41
oats, 80 bu	50	64	49	20	20	16	12

[1]Crop removal based on soil fertility estimates
[2]Crop removal based on nutrient concentration published in Dairy Nutrient Requirement Council Tables.

Table 2. Average dry matter, nitrogen yield and relative feed value (RFV) of cool-season grasses and legumes harvested 2 and 3 times per season in Northern Minnesota, Grand Rapids and 3 and 4 times per season at St. Paul, MN.

Grand Rapids[1]

	2 cuts				3 cuts			
	Yield	Nitrogen		RFV	Yield	Nitrogen		RFV
	T/A	lb/T	lb/A	index	T/A	lb/T	lb/A	index
Smooth bromegrass	4.7	36.2	170	93	3.5	44.0	155	87
Orchardgrass	5.1	33.2	170	81	4.7	37.8	180	92
Reed canary grass	5.7	32.4	185	60	5.6	49.6	280	82
Alfalfa	4.2	47.2	200	82	4.5	58.8	265	110
Redclover	4.2	53.8	225	94	4.3	67.2	290	118
Alfalfa grass	4.6		185	76	4.7		230	96
Red clover-grass	4.6		186	76	5.0		285	104

St. Paul[2]

	3 cuts				4 cuts			
	Yield	Nitrogen		RFV	Yield	Nitrogen		RFV
	T/A	lb/T	lb/A	index	T/A	lb/T	lb/A	index
Smooth bromegrass	5.0	42.0	210	81	4.3	57.6	250	118
Orchardgrass	5.5	43.6	240	98	4.9	53.8	265	114
Reed canarygrass	5.4	42.0	225	81	5.0	58.8	295	109
Alfalfa	5.4	58.8	320	126	5.5	67.2	370	146
Alfalfa grass	5.8	55.2	320	116	5.5	64.6	355	138

[1]Harvest dates: 2 cuts (6/28 & 8/15); 3 cuts (6/13, 7/29 & 9/26).
[2]Average of three seasons, 1985.

SOURCE: Sheaffer et al., 1990.

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