What Goes In is What Comes Out: How Feeding Program Influences and Can Influence Manure Nutrient Content

Matt Oryschak

Technical Services Division, Alberta Agriculture, Food and Rural Development
Edmonton, AB
Phone: (780) 422-1791
E-mail: matt.oryschak@gov.ab.ca

Take Home Messages:

1. Manure nutrient content is ultimately a result of the feeding program. By concentrating on improving the efficiency of the feeding program we can also influence the nutrient profile of the manure.
2. Nutrients in animal rations exceeding animal requirements are excreted in the urine and feces, making economical and environmentally responsible manner more difficult. Producers can address this situation through precision diet formulation, based on feed test information, credible animal nutrient requirements and careful selection of ingredients.
3. The real benefits of precise ration formulation are not realized until coupled to the implementation of animal management practices designed to achieve maximum feed efficiency, such as phase/group feeding and managing feed wastage.
4. Optimizing particle size of feed ingredients, using enzyme products such as phytase to enhance digestion, and using ionophores in ruminants are examples of advanced strategies that are not only effective at reducing manure nutrient excretion, but in certain cases can further reduce feed costs.
5. Not all practices designed to reduce manure production or manure nutrient content will be feasible on all operations. Producers and those that are working with producers to must carefully assess what is appropriate for a particular operation.

Introduction

When looking at the risks posed to the environment by manure nutrients, there can be little dispute that the greatest risks are posed by on-farm storage, handling and application procedures. In recognition of this fact, these aspects have traditionally been the primary focus of extension programming designed to mitigate environmental impacts of manure nutrient management.

In other parts of the world however, particularly in regions where there is considerable environmental pressure due to intensive livestock production (e.g., the Netherlands), it has been recognized for some time that in order to facilitate environmentally responsible manure management, there must also be a focus on what happens at the front end of the animal.

Manure nutrient content is a direct result of dietary nutrient content, feed intake and the animal's ability to extract and sequester these dietary nutrients in the form of useful products (i.e., offspring, growth, milk production, etc.). This relationship can be expressed conceptually as:

Livestock nutrient excretion = (dietary nutrient content) x (feed intake) x (nutrient digestibility) x (efficiency of nutrient utilization for productive functions)

Based on the relationship above, in order to alter the nutrient content of the manure we must alter one or more of the factors on the right side of the equation. The remainder of this article will focus on various strategies that producers can use to minimize the nutrient content of their manure.

Diet Formulation

Nutrients (in particular N and P) that are consumed at levels exceeding animal requirements are excreted in the urine and feces, creating a potential headache when it comes to managing the manure that results in an economical yet environmentally responsible manner. One of the primary ways that producers can address this situation is by paying careful attention to the recommended steps in developing rations for their animals, namely defining nutrient requirements.

Defining nutrient requirements

One of the key steps when developing feeding programs for animals is to define the nutrient requirements for the animals that are to be fed. A feeding program that is not based on scientifically derived nutrient requirements can potentially cost the producer money in two ways: through unnecessarily inflating feed costs and by impacting animal performance. In addition, feeding programs not designed to achieve a particular objective (i.e., meeting animal requirements) in an efficient manner can lead to excess nutrients being excreted by the animal. This can increase the costs associated with handling nutrient rich manure.

Animals require nutrients for:

1. Maintenance
2. Growth
3. Lactation
4. Reproduction

Of these four functions, maintenance is the only "non-productive function" which in a nutritional context can be considered as the overhead cost associated with keeping that animal. An animal that is not growing, lactating or reproducing (i.e., animal is at maintenance) is not retaining any significant portion of the nutrients it digests and is essentially in a net balance situation (i.e., what goes in equals what comes out). As such, special care should be taken not to feed animals at maintenance (e.g., dry beef cows in the first trimester of pregnancy, mature horses) in excess of their nutrient requirements.

By ascertaining an animal's nutrient requirements for a given level of production in a particular production environment, this provides the producer with a target to strive to meet when developing rations. Producers who aim to meet these requirements without grossly exceeding them have taken the first step towards minimizing nutrient excretion (and minimizing feed costs) resulting from overfeeding their animals.

The National Research Council (NRC) has published several references on nutrient requirements for individual species and have also produced software models that allow the nutrient requirements for specific circumstances to be calculated (the software for beef, swine, dairy and horses can all be downloaded free of charge from www.nap.edu). Requirements tables based on NRC estimates have also been published by several government agriculture departments (including Alberta Agriculture), and many take into consideration regional conditions.

Testing your feed ingredients

Nutritionists and government extension personnel have been promoting the concept of feed testing for quite some time as a means for producers to collect another piece of information they need in order to help them make financially and environmentally responsible decisions for their feeding programs. There are several agencies that have published "book" values for average nutrient content of feedstuffs used in their area. While these values are certainly better than using nothing at all, they do not give the kind of precision that is required to develop a precise, operation-specific feeding program in a production climate where feed costs represent as much as 70-80% of production costs and every cent counts.

A feed test gives producers a second valuable piece of information: the nutritional value of the feeds they are dealing with on their specific operation. This is important because there can be tremendous variation in nutrient content between samples of a single ingredient, grown in the same area in the same season. This variation is particularly important if a producer is buying feed for their operation since two batches of an ingredient may cost the same amount, but may differ widely in nutrient content.

From a manure nutrient content standpoint, rations that are developed in the absence of feed tests are prone to both over- and under-supplying nutrients to the animal – both of which are situations that can lead to increased nutrient content in the manure. While the impact of oversupplying nutrients to the animal on manure nutrient content might seem obvious, undersupplying may not be as clear.

If an average (i.e., "book value") nutrient content for a particular ingredient is used but the real nutrient content is actually lower, the nutrient in question may in fact be deficient. If this nutrient is one of the key limiting nutrients influencing an animal's productivity (e.g., energy, protein, calcium, phosphorus) it may restrict the animal to a lower production level, resulting in the excretion of nutrients (amino acids/N, P) that are present in excess of the animal's productive capabilities.

Many producers cite difficulties in interpreting and applying the results of a feed test to their feeding program as a major obstacle in the adoption of this practice as part of the routine. There are several ways that AB producers can get help with this, such as contacting the Ag-Info Centre or by consulting one of several online resources are available to assist producers with this task.

Choosing digestible feed ingredients

Producers in Western Canada are relatively fortunate in that there are a variety of feedstuffs that are grown locally that are potentially accessible to livestock producers. It is important however that producers take into consideration the fact that different feeds and ingredients will have different levels of digestible nutrients. For instance, a general rule that applies across all feeds and species is that the higher the fiber content of a feed, the less digestible the feed will be, and consequently fewer nutrients will be absorbed and more will be excreted.

To counter this, when considering different feed ingredients compare their digestible nutrient content, rather than their total nutrient content (this information can also be found in the NRC nutrient requirement publications for most species). Ingredients that may have similar total crude protein or phosphorus content may differ considerably in their digestible crude protein (or amino acid) and digestible phosphorus content, and consequently may result in very different manure nutrient concentrations.

Balancing your rations

In order to properly balance rations, we need three pieces of information:

1. **Nutrient requirements for the animals.** As previously mentioned, there are several sources for this information, but the standard in North America are the requirements published by the NRC. These requirements are usually expressed in terms of grams of a nutrient required per day or as a percentage of the diet.
2. **Nutrient content of the ingredients available for inclusion in the ration.** A feed test will provide this information, or in the absence of a feed test published averages may be used.
3. **An estimate of animal feed intake.** Producers may either use published feed intake estimates or they may use estimates based on personal experience under their specific production conditions

Once this information has been collected, it is then possible to come up with a ration formula (i.e., relative proportions of ingredients) that will meet the animals' nutrient requirements to achieve a certain level of performance at a particular feed intake level.

While some producers may like to work things out on paper (there several methods of doing so), there are numerous software packages available to assist producers in balancing their rations. Alberta Agriculture's CowBytes program is an example of an integrated ration-balancing program that already has the nutrient requirements included and average nutrient content for several feeds. This means that producers need only input the number and general description of their animals (weight, etc.), and select the feeds they intend to use. The program also allows producers to use the results of feed tests on homegrown ingredients in the balancing operation. There are also more scaled-down programs such as the "User Friendly Feed Formulation" program which the department of poultry science at the University of Georgia has made available for free download from their website.

Feeding Program Management

The real benefits of precise ration formulation are not realized unless coupled to the implementation of animal management practices designed to achieve maximum feed efficiency. Two key management practices producers can use to this end are phase/group feeding and managing feed wastage.

Phase/group feeding practices

Animal nutrient requirements are dynamic, in that an animal's nutrient requirements are constantly changing during the production cycle. A cow in early lactation is not going to have the same nutrient requirements as a cow in late lactation, and a 650-lb feedlot calf is not going to have the same requirements as a 1000-lb finishing steer. The key question then is how do producers deal with these fluctuations in a practical context. The answer is to group animals with like nutrient requirements and develop customized rations.

As growing animals increase in weight, the required concentration of nutrients in the diet decreases for two reasons (1) their growth rate is gradually declining as they approach their mature weight, and (2) their average daily feed intake increases with age (i.e., gut capacity gradually increases). In order to have nutrient supply closely approximate the animal's requirement, producers can divide the growth period into phases and formulate specific rations for each phase.

Similarly, producers that are dealing with breeding females or with dairy animals can group animals based on the stage of their production cycle (e.g., early/late lactation, early/late gestation) and/or by age, where replacement animals are involved (e.g., heifers and first calvers grouped together, mature cows fed separately).

Research with several species has demonstrated that grouping and developing group-specific rations is an effective way to reduce nitrogen and phosphorus excretion and that there are potential cost savings to be realized, depending on local feed costs.

Managing feed wastage

In most typical confined feeding operations, feed wastage ends up with the manure and can be a significant contributor to the nutrient content of manure, particularly if feed wastage is a significant problem on the operation. A good rule of thumb is that if you can observe wasted feed accumulating around a feeder or feeding area, feed wastage is probably at least 15%. This has not only serious financial implications for the producer, but also has environmental implications if the wasted feed becomes part of the manure.

For practical purposes, wastage is a combination of spillage and spoilage. Producers should strive to minimize feed wastage through appropriate management strategies for their operation. Using efficient feeder designs and making sure that they are properly adjusted will reduce the opportunity for animals to waste feed while eating. Using a feed delivery system that minimizes feed spillage will reduce the amount of feed that is lost before the animal even has a chance to consume it. Making sure that feed is stored in such a way that spoilage is inhibited (e.g., silage facilities, feed bins) will reduce feed refusal by animals and will also preserve the quality of the feed.

Advanced Processing and Feed Additives

Producers who are already using precision feed formulation and have implemented efficient management practices can consider looking at more advanced strategies to minimize manure nutrient content. These strategies are not only effective at reducing manure nutrient excretion, but in certain cases can further reduce feed costs.

Some examples of advanced strategies include optimizing particle size of feed ingredients, using enzyme products such as phytase to enhance digestion, and using ionophores in ruminants.

Optimizing particle size

Perhaps the most common processing technique applied to feeds for animals is reducing particle size either through grinding, rolling or some other mechanical treatment. For producers who process their own feed ingredients on site it is very important that they monitor the particle size that results from processing and that adjustments are made as necessary.

Studies with both ruminants and non-ruminants have shown substantial benefits for reducing the particle size of cereal grains on both nutrient digestibility and feed efficiency. When nutrient digestibility and feed efficiency are increased, less feed is required to get an animal up to market weight, thereby reducing total manure production. For swine, the recommended particle size for the cereal component of the ration is between 600-800 microns. This will give the optimum balance between feed efficiency, ease of feed handling and the incidence of stomach ulceration. For broilers there doesn’t appear to be an ideal particle size, unless the ration is fed in mash form, in which case producers should try to achieve 500 microns.

For feedlot cattle, particle size is measured slightly differently through what is referred to as the processing index. The processing index (PI) for a processed grain sample is calculated as follows:

$$\text{Processing index (PI)} = \frac{\text{(bushel weight after processing)}}{\text{(bushel weight before processing)}} \times 100$$

Research conducted in Southern Alberta a few years ago suggests that processing barley to a target PI of 81 will give an ideal balance between feed efficiency, nutrient digestibility and the incidence of rumen acidosis.

Phytase and other enzymes

Unlike ruminants, non-ruminant animals must rely almost exclusively on the ability of their own digestive system to extract nutrients from the feeds they consume (as opposed to having the assistance of rumen microbes). Consequently, pigs and poultry have a limited ability to efficiently utilize certain components of the diet such as fiber to meet their nutrient requirements.

Another of these feed components that non-ruminants have a limited ability to digest is phosphorus bound in the form of phytic acid, which is the major storage form of phosphorus in many of the feedstuffs used in non-ruminant feeding programs. As a consequence of the limited ability of non-ruminant animals to digest phytic acid and the phosphorus that it binds, it is often necessary to supplement animals with a source of inorganic phosphorus to meet their requirements. Meanwhile, much of the phosphorus bound to phytic acid passes through the animal and is excreted in the manure. This represents both a nutritional and financial inefficiency in the feeding program, since the addition of inorganic phosphorus to the diet increases the cost of the ration.

With the advent of large-scale industrial fermentation processes and recombinant DNA technologies, several enzyme products designed to enhance digestibility of feed nutrients for non-ruminant animals are now available. Phytase enzymes derived from a variety of microbial species (including *E. Coli* and *Aspergillus spp.*) have been shown to be extremely effective at liberating phosphorus bound to phytic acid. The cost effectiveness of including microbial phytase in the diet is dependent on feed costs, but producers who feed diets in mash form may also consider including ingredients that have high natural phytase activity (Table 1). Much of the natural phytase activity of feed ingredients is destroyed during processing where even moderate heating of the feed occurs (e.g., pelleting).

Table 1. Natural phytase activities of selected ingredients and estimated inclusion levels in order to achieve phytase activity levels of 250 and 500 FTU/kg in the ration (adapted from Eeckhout and DePaepe, 1994).

Ingredient	Phytase activity (Units/kg)	Estimated inclusion rate to achieve 250 FTU/kg[1] in ration	Estimated inclusion rate to achieve 500 FTU/kg in ration
Rye	5130	5%	10%
Wheat middlings	4381	6%	12%
Wheat bran	2957	9%	18%
Triticale	1688	15%	30%
Wheat	1193	21%	41%
Barley	582	43%	86%

[1]Most manufacturers of microbial phytase recommend 500 FTU/kg as the optimal inclusion level in the diet, however several researchers have recommended 250 FTU/kg as being more cost effective while still liberating enough phosphorus to be effective.

One of the key tips when using phytase is that since the digestibility of phosphorus in the ingredients will improve, the amount of inorganic phosphorus in the rations must be reduced. Producers that fail to do so will not realize the potential cost savings that might be realized through using phytase, and more importantly phosphorus content of the manure will remain the same.

Agriculture and Agri-Food Canada (2003) have developed equations to quantify the benefits of supplementing pig diets with microbial phytase, based on an analysis of several experiments.

% Improvement in phosphorus digestibility	$= [0.334(FTU) – 0.0001297(FTU)^2] / 10$
% Digestibility of phytate-bound phosphorus	$= [0.753(FTU) – 0.000339(FTU)^2 – (1.047)BW] / 10$

where FTU is the phytase activity (U/kg) and BW is the weight of the pigs (kg).

For instance, if 45-kg pigs were receiving a diet that contained 450 U/kg of supplemental phytase, from these prediction equations it would be expected that:

% Improvement in phosphorus digestibility	$= [0.334(450) – 0.0001297(450)^2] / 10$
	= [150.3 – 0.0001297(202500)] / 10
	= [150.3 – 26.3] / 10
	= 124 / 10 = 12.4% improved P digestibility
% Digestibility of phytate-bound phosphorus	$= [0.753(450) – 0.000339(450)^2 – (1.047)45] / 10$
	= [338.85 – 0.000339(202500) – 47.12] / 10
	= [338.85 – 68.65 – 47.12] / 10
	= 223.08 / 10 = 22.3% of phytate-P is digestible

Other enzymes are commercially available to assist non-ruminants digest some of the components of fiber in feed ingredients (i.e., pentosans and beta-glucans), which have shown very positive results in helping poultry overcome anti-nutritional effect of these components on nutrient digestibility and feed efficiency.

Ionophores

Ionophores (e.g., monensin, laidlomycin, lasolacid, narasin) are a commonly used feed additive in ruminant feeding and are sold commercially under trade names such as Rumensin® and Bovatec®. Ionophores are essentially antimicrobial compounds, many of which are derived from *Streptomyces* species.

Ionophores were originally promoted for their ability to improve feed efficiency in cattle, which occurs through a reduction in dry matter intake with little impact on average daily gain. They accomplish this through targeting specific microbial populations in the rumen, causing a shift the pattern of fermentation in the rumen that favors propionate production over acetate (the two major volatile fatty acids produced in the rumen that ruminants then use to meet their energy needs).

It has also been observed that the addition of ionophores suppresses methane production and degradation of dietary protein in the rumen, which allows more of the dietary protein to be absorbed by the animal.

The effect of ionophores on nutrient excretion are two-fold, (1) by increasing feed efficiency, the total volume of manure production is reduced, and (2) by increasing the amount of dietary protein (i.e., N) digested, absorbed and retained by the animal, which reduces the N content of the manure.

One very important caution is to not allow horses access to feeds that contain ionophores as it can often prove fatal. As with using any feed additive, producers should carefully follow the manufacturers recommendations.

Conclusion

The previous sections show that there are several things that producers can do to alter the nutrient content of the manure produced by their animals. In reviewing these recommendations, there are two messages that become clear:

1. Anything a producer can do to optimize the efficiency of their feeding programs will ultimately have a positive impact on the volume and nutrient content of manure produced; and,
2. It is possible for producers to implement practices that enhance environmental quality and improve (or at least not adversely impact their bottom line.

An important point that needs to be made is that not all practices designed to reduce manure production or manure nutrient content will be feasible on all operations. Producers and those that are working with producers to implement these and other environmentally focused beneficial management practices must carefully assess what is appropriate for a particular operation.

The table below provides summarizes potential reductions in manure N and P content that can be achieved by implementing specific practices.

Species-specific strategies	Potential reduction in manure N content (%)	Potential reduction in manure P content (%)
Strategies for beef cattle[1]		
Precision diet formulation	0-25%	0-30%
Protein manipulation	0-25%	N/A
Using growth promotants	5%	5%
Phase feeding	5-10%	5-10%
Strategies for dairy cattle[2]		
Precision diet formulation	10-15%	10-30%
Protein manipulation	15-25%	N/A
Increase number of feeding groups	5-10%	5-10%
Strategies for poultry[3]		
Precision diet formulation	10-15%	10-15%
Reduce crude protein/synthetic amino acid supplementation	10-25%	N/A
Selecting digestible feeds	5%	5%
Phytase/reduce inorganic P supplementation	N/A	20-30%
Supplementing selected enzymes	5%	5%
Phase feeding	5-10%	5-10%
Split-sex feeding	5-8%	N/A
Strategies for swine[4]		

Species-specific strategies	Potential reduction in manure N content (%)	Potential reduction in manure P content (%)
Precision diet formulation	10-15%	10-15%
Reduce crude protein/synthetic amino acid supplementation	20-40%	N/A
Selecting digestible feeds	5%	5%
Phytase/reduce inorganic P supplementation	2-5%	20-30%
Supplementing selected enzymes	2-5%	5%
Phase feeding	5-10%	5-10%
Split-sex feeding	5-8%	N/A

[1]USDA-NRCS Nutrient Management Technical Note #2: Feed and Animal Management for Beef Cattle
[2]USDA-NRCS Nutrient Management Technical Note #5: Feed and animal Management for Dairy Cattle
[3]USDA-NRCS Nutrient Management Technical Note #4: Feed and Animal Management for Poultry
[4]USDA-NRCS Nutrient Management Technical Note #3: Feed and Animal Management for Swine (Growing and Finishing Pigs)

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