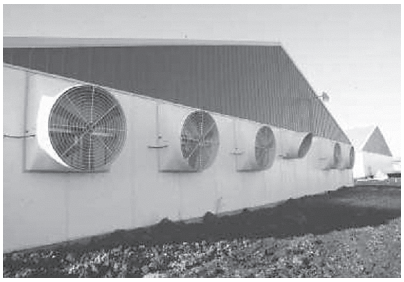
Lesson 13

Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle

By Galen Erickson, University of Nebraska, and
Todd Milton, formerly of the University of Nebraska



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Disclaimer

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Intended Outcomes

The participants will

- Develop a general understanding of nitrogen (N)(protein) and phosphorus (P) metabolism in feedlot cattle.
- Learn the recommended N and P requirements for feedlot cattle to minimize overfeeding of these nutrients.
- Develop an understanding of potential dietary strategies that will maintain or maximize animal performance and minimize total nutrient excretion.

Contents

Activities

1. Calculate the amount of N and P excreted by feedlot cattle.
2. Evaluate the effects of ration formulation changes on N and P excretion.

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:

- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application and Nutrient Management
- Outdoor Air Quality
- Related Issues

Note: Page numbers highlighted in green are linked to corresponding text.

Introduction

Consumers of agricultural goods continue to demand safe, economic, and high-quality food products. In addition, more attention is being placed on food production systems that are economically and environmentally sustainable. Dietary and other management strategies have continued to increase the efficiency of beef production in the feedlot. Possibly the next greatest challenge for feedlot producers and nutritionists will be the proper formulation of finishing diets for further enhancement of production while simultaneously minimizing the environmental impacts of nitrogen (N) and phosphorus (P) excretion in beef urine and manure.

The goal of future formulation will be to meet the animal's requirement with balanced rations using economical feedstuffs, but considerable emphasis will also be given to formulations and dietary management strategies that reduce any negative environmental impacts.

In most cases, a properly formulated diet that precisely meets the feedlot animal's requirements for maximum, efficient growth and maintenance will also reduce excessive N and P excretion. Ration formulation software that allows the end user to more accurately formulate for animal requirements is becoming increasingly available. This lesson will present the basics of feeding feedlot cattle to minimize excess N and P excretion into the environment.

...more attention is being placed on food production systems that are economically and environmentally sustainable.

Nitrogen and P Excretion in Feedlot Cattle and its Fate

How much is excreted?

The design of manure management systems often uses standardized values to estimate the amount of N and P that will be excreted during the course of a feeding period, often considered one year. The USDA Natural Resource Conservation Service has tabulated these values (Table 31-7, Lesson 31, Manure Utilization Plans), and estimates the amount of N and P excretion for a 1,000-pound steer. However, these values do not consider the large variation among feedlot cattle in level of feed intake, diets fed, feeding management programs, performance, and consequently, actual levels of N and P excretion.

Research conducted at the University of Nebraska (Bierman et al. 1999, Erickson et al. 2000, Erickson and Klopfenstein 2001a) studied the impact of dietary N and P concentrations on waste management in feedlot cattle. This research demonstrates the magnitude that diet formulation can have on N and P excretion in feedlot cattle. Tables 13-1 and -2 summarize the impact of total N and P intake on the excretion of these nutrients. Clearly, the amount of N and P excretion is highly correlated to the amount of N and P intake during the feeding period. For instance, increasing the amount of crude protein from approximately 12% to 13.5% increased the amount of N (crude protein) excretion by 13.5 pounds per steer in yearling steers and by 9 pounds per steer in calf-fed steers fed approximately 150 or 200 days, respectively (Table 13-3). Many feedlot producers and nutritionists formulate for excess crude protein (CP) to ensure that feedlot performance is not limited, providing an example of one formulation practice that deserves greater attention from an environmental standpoint. However, diet formulation strategies are not as simple as just removing protein from the diet. Protein requirements must be met for optimal performance. These

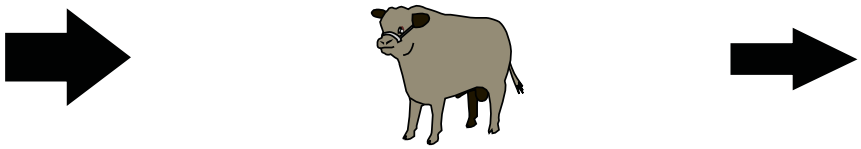
...the amount of N and P excretion is highly correlated to the amount of N and P intake during the feeding period.

Table 13-1. Effect of dietary P level on excretion.

	High P[a]		Low P[a]		Low P/All Con[a]	
Phosphorus[b]	**Lbs[c]**	**%[d]**	**Lbs**	**%**	**Lbs**	**%**
Input	8.1	100	5.4	100	5.2	100
Retention	0.98	12.0	1.0	18.5	0.94	18.0
Excreted	7.1		4.4		4.2	

[a] High P = high P diet, 0.45% of diet dry matter; Low P = low P diet, 0.35% of diet dry matter; Low P/All Con = Low P diet (0.35%) all concentrate diet.
[b] Retention by the animal based on NRC equations.
[c] Pounds of P per head over the feeding period (87 days).
[d] Retention values expressed as percentage of N and P intake; the remaining values expressed as percentage of excreted N and P.
Source: Bierman et al. 1996.

Table 13-2. Total manure nutrients excreted by a livestock operation based on feed rations.



Feed Nutrient Intake — **Nutrients Retained by Animals or Animal Products Excretion** = **Nutrient**

Feed Nutrient Intake

Animal Group	A. Daily Feed Intake	B. Feed Nutrient Concentration (lbs)	Protein	N[a]	C. Total Nutrient in Feed (lbs) = A x B P	N P
Example: 1,000 feedlot cattle	*22,00 lbs DM/day (22 lbs/hd/d)*	*0.135*	*0.135 ÷ 6.25 = 0.0216*	*0.0035*	*22,000 x 0.0216 = 475 lbs/day*	*22,000 x 0.0035= 77 lbs/day*

Nutrients Retained by Beef Feeder

Animal Group	D. Number of Animals (maximum one-time capacity)	E. Average Daily Gain	F. Live Weight Nutrient Concentration N	P	G. Nutrients Retained by Animal (lbs) = D × E × F N	P
Example: Beef	*1.000*	*(1,249-652)/147 d = 4.06 lbs/d*	*0.016*	*0.0070*	*1,000 x 4.06 x 0.016 = 65.0 lbs/d*	*1,000 x 4.06 0.0070 = 28.4 lbs/d*
			0.016	*0.0070*		
			0.016	*0.0070*		
			0.016	*0.0070*		

Nutrients Excretion by Livestock

Animal Group	H. Days Fed per Year	Annual Nutrient Excretion in Elemental Form = H x (C - G) or = H x (C-J) N	P	P_2O_5[b]
Example: Beef finisher	*350 days*	*350 x (475 - 65) = 143,5000 lbs/350 days*	*350 x (77 - 28.4)= 17,010 lbs/350 days*	*17,010 x 2.27 = 38,613 lbs P_2O_5/350 days*

[a] N in feed = Protein ÷ 6.25
[b] lbs P_2O_5 = lbs P × 2.29

requirements and new methods for determining requirements will be discussed further in subsequent sections.

The total N and P intake and animal production dictate the amount of N and P that feedlot cattle excrete. Each individual feeding operation needs to calculate the total N and P fed and the total production (pounds of beef gain) to evaluate the status of N and P excretion. With the previously discussed variation that exists across the feeding industry, book values simply are insufficient. One tool that is available for estimating the N and P output of feedlots on an individual basis is a worksheet developed at the University of Nebraska (Koelsch 1999); it is available at the following website: <http://www.manure/Koelsch.html>. The worksheet allows users to input the number of animals, daily feed intake, dietary CP (N) and P concentrations, and animal performance. The spreadsheet also allows users to estimate the land requirements for manure application, and more importantly, evaluate the influence of a ration change on the amount of land required for manure application.

Table 13-2 provides a more simplistic approach for users to estimate the amount of N and P excretion based on feed intake, daily gain, and ration nutrient composition.

The fate of N and P following excretion

It is important to understand the fate of N and P that is excreted onto the pen surface. The data presented in Table 13-3 (Erickson and Klopfenstein 2001a) suggest that a large fraction of the N that is excreted onto the pen surface is lost during the course of the feeding period. This estimate of N loss was determined by measuring the amount of N in runoff manure that remained in the pen's soil surface after cleaning and by using estimates of the animal's N retention based on daily gain. The yearling steers were fed during the summer months, while the calf-fed steers were finished during the winter. These data suggest that up to 70% of the N excreted may be lost to

...a large fraction of the N that is excreted onto the pen surface is lost during the course of the feeding period.

Table 13-3. Performance and N balance of yearling and calf-fed steers fed a typical feedlot finishing diet (control) or a finishing diet adjusted to match the animal's protein requirement with time on feed (phase).

	Yearlings		Calves	
Feedlot Performance	**Control**	**Experimental**	**Control**	**Experimental**
Daily gain, lbs	3.98	4.07	3.45	3.40
Feed efficiency	6.33	6.02	5.88	6.10
Nitrogen				
Intake, lbs	72.82	59.39	81.40	72.23
Retention[a], lbs	7.90	7.92	10.14	10.04
Excretion[b], lbs	64.92	51.47	71.26	62.18
Manure, lbs	12.91	19.61	43.51	41.53
Soil[c], lbs	3.85	-0.89	-3.66	-6.46
Runoff, lbs	2.12	1.51	2.10	2.21
Volatilized[d], lbs	46.04	31.25	29.31	24.91
% Volatilized	70.9	60.7	41.1	40.10

[a] N retention based on daily gain, NRC (1996) equation for retained energy and retained protein.
[b] N excretion calculated as intake minus retention.
[c] Soil is core balance on pen surface before and after trial; negative values suggest removal of nutrient present before trial.
[d] Volatilized calculated as excretion minus manure soil minus runoff. Source: Erickson et al. 1999.

volatilization, especially in cattle fed on open dirt lots during summer months. Microbial activity on the pen surface would be greater during summer compared with winter feeding conditions. The data in Table 13-3 also suggest that only small amounts of N exit the pen in runoff water. Properly designed pens and settling systems filter most of the N and P from the runoff water before it enters the holding pond. It appears that most of the excreted P remains in the manure (Erickson et al. 2000). Only small amounts of either N or P, less than 5%, have been measured in runoff from the pen surface (Bierman et al. 1999, Erickson et al. 2000, Erickson and Klopfenstein 2001a).

...either increase N in manure or decrease P to produce manure with more environmentally favorable N:P ratios.

Because N volatilizes off the pen while P remains in manure, the nitrogen-to-phosphorus (N:P) ratio of manure can lead to challenges when utilizing manure for crops. This creates a unique problem with regard to the N:P ratio of most feedlot manure. Typical feedlot manure contains between 2 and 3 parts N to one part P at the time of removal. At the time of excretion, the N:P ratio of excrement (feces and urine) is approximately 6:1. Corn, for example, requires a N:P ratio of approximately 5 parts N to one part P. Thus, if the N:P ratio of manure could be improved, the need for supplemental N could be reduced when manure is applied on the basis of agronomic P needs, adding value to manure as a fertilizer source. If manure is applied according to the N needs of crops, less P would be supplied, resulting in lower risk manure management strategies for feedlots. Certain options may increase the N:P ratio of manure to more closely meet the needs of row crops. Nutritionists would need to either increase N in manure or decrease P to produce manure with more environmentally favorable N:P ratios. Increasing the amount of organic matter on the pen surface through diet manipulation appears to trap more N in manure (Erickson and Klopfenstein 2001b). Other research projects suggest that lowering dietary P will also improve the N:P ratio by lowering the amount of P without influencing N content (Erickson et al. 2000; Bierman, unpublished data). Other management techniques, such as frequency of cleaning, deserve attention and are currently being explored.

Nitrogen and P Use by Feedlot Cattle

The N requirements for feedlot cattle

Most all beef cattle finishing diets are formulated on the basis of CP and are commonly formulated to contain greater than 12.5% CP. Crude protein systems consider all protein equal in value; even urea is considered equal in value to other natural protein sources. Over the past 15 to 20 years, research has distinctly pointed out that all protein sources are not nutritionally equal in beef cattle diets.

Much of this work has led to the development of a metabolizable protein (MP) system (Figure 13-1). Currently, the National Research Council (NRC 1996) has published an MP system for beef cattle. The MP system describes animal requirements and differentiates feedstuffs into two categories: degraded intake protein (DIP) and undegraded intake protein (UIP). Crude protein systems use a single requirement (dietary CP). The MP system determines the requirements of the ruminal microorganisms, also known as DIP, and the protein requirement of the host animal. Metabolizable protein is defined as the total amount of protein entering from the animal's small intestine. The MP is derived from microbial protein (BCP) arising from ruminal fermentation and UIP presented to the small intestine.

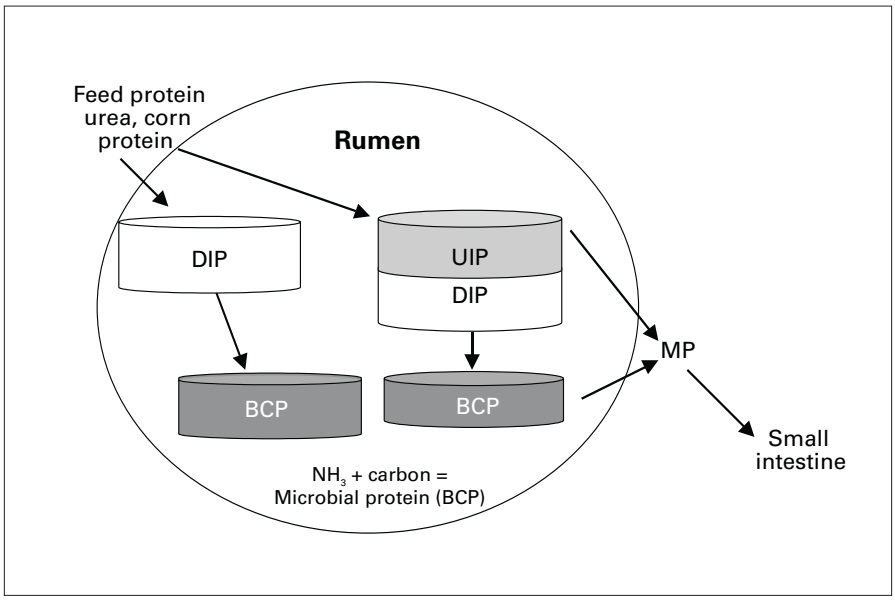


Figure 13-1. Metabolizable protein system.

Basically what this protein model attempts to control is the balance of DIP and UIP from feed grains and supplemental protein sources to ensure that microbial N requirements and the host animal requirement for MP are satisfied. For example, corn grain contains about 8.5% CP. Of that CP, 60% is considered UIP and 40% is considered DIP. Therefore, dry-rolled, corn-based finishing diets typically need sources of supplemental protein that are degradable (DIP). The microbial protein that is produced from the digestion of corn grain in combination with the high UIP fraction of corn protein will meet the animal's MP needs. Conversely, high-moisture ensiled corn is 8.5% CP, but only 40% of the CP is UIP and 60% is DIP. When high levels of high-moisture corn are used in finishing diets, especially for young calves, a supplemental source of UIP may be needed in combination with the supplemental DIP to ensure that the animal's MP requirements for maximal growth are met. Feeding the incorrect source of protein will result in subpar performance and unnecessary overfeeding of protein. **The bottom line: Reducing N excretion in feedlot cattle depends on the total amount of protein (N) fed and on the source of protein.** This protein model may allow producers to formulate for lower total CP requirements but still meet the animal's MP needs for optimal gain and efficiency. This was the basis for the experiment presented in Table 13-3. The control diet was formulated simply on CP alone, while the experimental diet was formulated based on the animal's supplemental DIP and UIP needs. Without compromising animal performance, the researchers in that study lowered the CP fed by 1.5% to 2% of diet dry matter (DM) and reduced N excretion by 15% to 20%.

With regard to finishing younger animals, like calf-fed steers (550-lb starting weight), the type of supplemental protein needed to meet the MP requirement changes significantly during the feeding period. Figure 13-2 illustrates the need for supplemental UIP and DIP in finishing calves fed a corn-based finishing diet. The total MP requirement does not necessarily change with time, but the ratio of DIP and UIP needed in the diet does. As time on feed increases for the calf-fed animal, two things happen. First, feed

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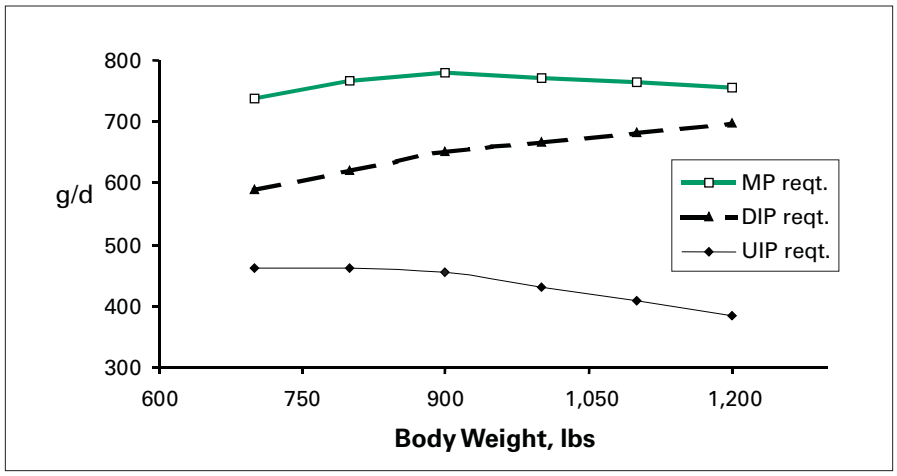

Figure 13-2. Influence of body weight on MP, DIP, and UIP requirements (reqt.) in finishing calves.

intake increases and more feed (typically) protein is consumed. Thus, a larger supply of UIP is provided to the animal. Second, as the animal approaches finished weight, the composition of gain changes from less muscle to more fat deposition, reducing the amount of MP needed for muscle growth. Although the amount of muscle growth decreases, the need for MP for maintenance increases as the animal becomes larger. With these biological changes of the animal and increased UIP supply from the basal ration, supplemental UIP can be reduced, and consequently, the total amount of supplemental protein fed can be reduced as the animal approaches finished weight. This point is demonstrated in Table 13-3 with the calf feeding experiments. The control diet was formulated to provide 13.5% CP throughout the feeding period. By changing the amount of supplemental UIP during the feeding period, calves on the experimental diet consumed about 9 pounds less protein and maintained similar performance.

Obviously, protein supplementation for feedlot cattle is a rather dynamic and complex issue. When formulating diets to reduce N excretion in feedlot cattle, consider the following issues:

- Type of animal being fed (calf-fed steer vs yearling steer)
- How much and what type (DIP or UIP) of protein the basal dietary ingredients provide
- What type of supplemental protein source (DIP or UIP) is needed to complement basal ingredients, meeting the animal's needs

As a general rule, feedlot diets contain excess UIP, which leads to excess N excreted in the urine.

As a general rule, feedlot diets contain excess UIP, which leads to excess N excreted in the urine. In the future, methods to lower the UIP content of the diet need attention and the DIP requirements of various diet scenarios need further evaluation. In conclusion, performance does not need to be sacrificed to minimize N excretion from feedlot cattle.

The P requirements of feedlot cattle

Phosphorus is both expensive to supplement and may have some of the most deleterious effects on the environment. Most of the beef cattle research conducted on P requirements has been performed with cattle less than 5 months of age and weighing less than 500 pounds, clearly a different animal

than is typically found in a feedlot. Erickson and coworkers (1999b) have demonstrated that supplemental P in feedlot finishing diets appears to be unnecessary. Their research was conducted on yearling steers (850 lbs) fed diets in which the P concentration ranged from 0.14% to 0.34% of the diet dry matter (Table 13-4). Normally, corn grain contains about 0.32 ± 0.04% P (NRC 1996) on a DM basis. Thus the contribution of P from corn grain alone is adequate for feedlot cattle.

However, the steers used in the yearling trial were larger than some calves that may be fed in feedlots (initial weights of 550-600 lbs) subsequent to weaning. Therefore, an experiment was conducted that evaluated the P requirements of finishing calves (580 lbs) fed for 204 days. Calves were fed one of five different levels of P ranging from 0.16% to 0.40% P (76%-190% of NRC recommendations). Similar to the yearling steer study, performance and bone data were not affected by P supplementation (Table 13-5). Based on more recent data about feedlot cattle and the fact that corn contains relatively large amounts of P, P supplementation is unnecessary and should be discontinued.

Phytate-P is readily available to ruminants such as feedlot cattle. On

Based on more recent data about feedlot cattle and the fact that corn contains relatively large amounts of P, P supplementation is unnecessary and should be discontinued.

Table 13-4. Effect of dietary P level on finishing steer performance and bone ash concentration for yearlings.

	Dietary P level, % of Dry Matter				
Item	**0.14**	**0.19**	**0.24**	**0.29**	**0.34**
Phosphorus intake, g/d	16.4	19.9	27.6	32.0	36.2
Performance					
Dry matter intake, lbs/day	24.3	22.7	25.4	24.5	23.8
Daily gain, lbs/day	3.88	3.57	3.79	3.85	3.37
Gain/feed	6.49	6.36	6.71	6.32	7.04
Bone ash					
Grams	28.3	27.5	28.9	27.5	28.5
Grams/100 kg of BW	8.01	8.02	8.20	7.83	8.46

Source: Erickson et al. 1999.

Table 13-5. Effect of dietary P level on finishing steer performance and bone ash concentration with calves fed 204 days.

	Dietary P level, % of Dry Matter				
Item	**0.14**	**0.19**	**0.24**	**0.29**	**0.34**
Phosphorus intake, g/d	14.2	20.2	23.4	31.7	35.5
Performance					
Dry matter intake, lbs/day	19.7	19.8	18.1	20.4	19.5
Daily gain, lbs/day	3.35	3.38	3.95	3.54	3.24
Gain/feed	5.85	5.85	6.13	5.75	6.02
Bone ash					
Grams	27.8	29.3	27.8	30.9	27.6
Grams/100 kg of BW	3.96	3.71	3.78	3.81	3.58

Source: Erickson et al. 2001.

Based on current data, supplementation of inorganic P is not necessary to compensate for phytates in feed grains or other feedstuffs for feedlot cattle.

average, 95% or more of the P bound to phytate is released during ruminal fermentation for the animal's subsequent use (Morse et al. 1992). Based on current data, supplementation of inorganic P is not necessary to compensate for phytates in feed grains or other feedstuffs for feedlot cattle.

Dietary Management Strategies that Reduce N and P Excretion in Feedlot Cattle

Several valid approaches reduce the excretion of N and P from feedlot cattle. A brief discussion regarding some of those methods is provided below.

Test feedstuffs from your operation. One of the most important steps in reducing excess N and P excretion from any operation is to determine as precisely as possible their level in the diet.

Supplement the diet with the correct source of protein. Based on ingredient analyses, balance your diet so that the basal feed ingredients, supplemental protein, and P complement each other to meet animal requirements.

Discontinue use of supplemental P in feedlot diets. When grain is the major feed ingredient in the diet, current research indicates that supplemental P is not needed.

Consider a phase-feeding program. This is especially true in finishing younger animals, where the protein requirement changes considerably over time. The phase-feeding approach of supplementing protein means using more than one finishing diet in the feedyard. Yearling steers are less of an issue since the change in N and P requirements during the feeding period remains relatively similar.

Take advantage of the type of protein in the feedstuffs. Utilizing differences in the DIP and UIP of feedstuffs to complement each other in the diet can reduce the need for supplemental protein. A good example is feeding combinations of high-moisture and dry-rolled corn based on the desired level of UIP in the diet. Additionally, many byproducts can deliver a considerable amount of DIP and/or UIP to the diet.

Evaluate your rations with available tools. Evaluate your feedlot rations with regard to the need for supplemental DIP and UIP with such tools as the NRC (1996) model. You can download this software from the following website: <http://www.nap.edu/readingroom/books/beef model/>.

APPENDIX A

Environmental Stewardship Assessment: Nutritional Evaluation of Feedlot Operations

For each issue listed in the left column of the worksheet, read across to the right and circle the statement that best describes conditions on your farm. If any categories do not apply, leave them blank.

Issue	Low Risk (Risk 1)	Low to Moderate Risk (Risk 2)	Moderate to High Risk (Risk 3)	High Risk (Risk 4)	Environmental Benefit
	Nutrient concentration in diet				
Feedlot calves	MP system (UIP of 4.5% DIP, matched with needs of microbes), phase-fed diets			CP system (one diet fed to maximize performance), not formulated with UIP/DIP	N, NH_3
	Not supplementing P in grain-based or grain-based with byproduct diets			Supplementing P, not distributing excess dietary P from byproducts and grains	P
Feedlot yearlings	MP system (UIP of 4.0%, DIP matched with needs of microbes), phase-fed diets			CP system (one diet fed to maximize performance), not formulated with UIP/DIP	N, NH_3
	Not supplementing P in grain-based or grain-based with byproduct diets			Supplementing P, not distributing excess dietary P	P

Practices in the low-risk category produce environmental benefits according to the following key:

N: Reduced nitrogen excretion

NH_3: Reduced ammonia emissions

P: Reduced phosphorus excretion

Adapted from the Guide to Agricultural Environmental Management in New York State 2001.

APPENDIX A

Environmental Stewardship Assessment: (continued)

For each issue listed in the left column of the worksheet, read across to the right and circle the statement that best describes conditions on your farm. If any categories do not apply, leave them blank.

Management of Feedlot Cattle Feed Nutrients

Issue	Low Risk (Risk 1)	Low to Moderate Risk (Risk 2)	Moderate to High Risk (Risk 3)	High Risk (Risk 4)	Environmental Benefit
P supple-mentation	Not supplementing	Supplementing grain-based diets to achieve NRC recommendations or feeding by-products without supplemental P	Supplementing grain-based diets to achieve 0.35% P	Supplementing P and feeding byproducts	
P distribution	Regardless of dietary P, managing manure P to distribute manure at agronomic rates (removed by crop).	Minimizing dietary P, but applying to closest acres	Applying manure based on N content of feedlot manure	Supplementing P, applying on closest acres, and applying manure based on N content	N NH_3 P
Analysis of feed/ manure	Analyze feedstuffs for both N and P, AND analyze manure for N and P.	Analyze manure nutrients only.	Analyze feed ingredients only.	No analysis conducted	O
Protein supplementation	Formulate using the MP system to minimize excess protein, i.e., phase feed.	Formulate using MP system, but feed one diet throughout despite changing requirements.	Formulate using CP system, but try to minimize excess.	Formulate using CP system with no regard for requirements, only maximal gain.	
Salt and potassium	Minimize salt and K inclusion to NRC recommendations.	Salt greater than 0.25%, K greater than 0.6% (except newly received calves)	Dry climate areas with high dietary salt		

Practices in the low-risk category produce environmental benefits according to the following key:

N: Reduced nitrogen excretion

NH_3: Reduced ammonia emissions

P: Reduced phosphorus excretion

O: Reduced odor emissions

Additional Information:

Acres available for spreading?

Nutritionist accurately formulating diets?

Grain and other feeds grown on own acres or purchased?

Runoff retention facilities ensure no runoff nutrients exiting feedlot to surface water?

About the Author

This lesson was written by Galen Erickson, Assistant Professor, University of Nebraska, and Todd Milton, formerly of the University of Nebraska. Galen can be reached at this e-mail address: geericks@unlnotes.unl.edu

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Glossary

Crude protein (CP). Nitrogen content × 6.25 (commonly used to test feedstuffs).

Degraded intake protein (DIP). That portion of the feedstuff protein that is degraded in the animal's rumen. Supplies nitrogen to the microbial population.

Dry matter (DM) basis. All moisture is excluded from the analysis.

Metabolizable protein (MP). Protein absorbed from the animal's small intestine and used for growth and maintenance.

Phase feeding. Adjusting rations during the feeding period to match the animal's changing nutrient needs over time.

Phytate-P. Phosphorus bound to phytate in feed grains and thus not available to the animal.

Undegraded intake protein (UIP). That portion of the feedstuff protein that bypasses rumen fermentation and is digested in the small intestine of the ruminant animal

Volatilization. Compounds that evaporate readily at normal temperatures and pressures such as ammonium release into the atmosphere as ammonia gas.

Index (Page numbers highlighted in green are linked to corresponding text.)

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Click on road map to return to Contents.

Reviewers

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Ted Funk
Extension Specialist
Agricultural Engineering
University of Illinois

Carol Galloway
USEPA Ag Center
Kansas City, KS

Mohammed Ibrahim
Extension Specialist
North Carolina A&T State University

Gary Jackson
Professor, Soil Science, and Director,
National Farm*A*Syst Program
University of Wisconsin, Madison

Barry Kintzer
National Environmental Engineer
USDA-NRCS
Washington, D.C.

Rick Koelsch
Livestock Environmental Engineer
University of Nebraska

Deanne Meyer
Livestock Waste Management Specialist
University of California-Davis

Mark Risse
Extension Engineer, Agricultural Pollution Prevention
University of Georgia

Peter Wright
Senior Extension Associate, PRO-DAIRY
Cornell University

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Livestock and Poultry Environmental Stewardship Curriculum: Lesson Organization

This curriculum consists of 27 lessons arranged into six modules. Please note that the current lesson is highlighted.

Module A. Introduction

1. Principles of Environmental Stewardship
2. Whole Farm Nutrient Planning

Module B. Animal Dietary Strategies

10. Reducing the Nutrient Excretion and Odor of Pigs Through Nutritional Means
11. Using Dietary and Management Strategies to Reduce the Nutrient Excretion of Poultry
12. Feeding Dairy Cows to Reduce Nutrient Excretion
13. **Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle**

Module C. Manure Storage and Treatment

20. Planning and Evaluation of Manure Storage
21. Sizing Manure Storage, Typical Nutrient Characteristics
22. Open Lot Runoff Management Options
23. Manure Storage Construction and Safety, New Facility Considerations
24. Operation and Maintenance of Manure Storage Facilities
25. Manure Treatment Options

Module D. Land Application and Nutrient Management

30. Soil Utilization of Manure
31. Manure Utilization Plans
32. Land Application Best Management Practices
33. Selecting Land Application Sites
34. Phosphorus Management for Agriculture and the Environment
35. Land Application Records and Sampling
36. Land Application Equipment

Module E. Outdoor Air Quality

40. Emission from Animal Production Systems
41. Emission Control Strategies for Building Sources
42. Controlling Dust and Odor from Open Lot Livestock Facilities
43. Emission Control Strategies for Manure Storage Facilities
44. Emission Control Strategies for Land Application

Module F. Related Issues

50. Emergency Action Plans
51. Mortality Management
52. Environmental Risk and Regulatory Assessment Workbook