CHALLENGES IN INTEGRATING CAFO NUTRIENT MANAGEMENT WITH ENVIRONMENTAL STEWARDSHIP[1,2]

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INTRODUCTION

In general, 70 to 90% of nutrients fed to livestock subsequently end up in manure and can potentially be lost to the environment. Thus, the effects of livestock operations, especially larger concentrated animal feeding operations **(CAFO),** on the environment are a growing concern among many groups. The role of nutrition (i.e. pre-excretion strategies) and manure management (post-excretion strategies) in controlling possible adverse effects on the environment are receiving increased emphasis.

With the advent of the new EPA Clean Water Regulations [USEPA, 2003a, 2003b], all CAFO, and many smaller AFO, must have comprehensive nutrient management plans (**CNMP**) that address factors such as feed management, manure handling, and land application of manure (NRCS, 2000). Manure nutrients must be applied to farm lands at no greater than agronomic rates: thus, meeting nutrient application standards may require CAFO to spread manure over a much larger land area than they currently use. Ribaudo (2003) reported that only 18% of large hog farms and 23% of large dairies currently apply manure on enough cropland to meet a N management plan. Lander et al. (1998) estimated that only 20 (P-based) to 50% (N-based) of AFO operate with enough land to meet new land application requirements. Today at least 2 to 5% of U.S. counties produce more manure than can be assimilated by total crop land and pasture in the county (Kellogg et al., 2000; Lander et al., 1998). New, and potential new, air quality regulations on PM-2.5, PM-coarse, ammonia, and hydrogen sulfide emissions may also lead to requirements for nutritional and management controls. Even pasture-based operations such as cow-calf ranches may be challenged by Total Maximum Daily Load regulations that may limit access to wetlands and alter fertilizer use.

CAFO ENVIRONMENTAL CONCERNS / BACKGROUND

The nutrients of primary environmental concern to agriculture are N and P. Phosphorus concerns revolve primarily around potential contamination of surface waters; whereas, N concerns revolve around both water (nitrates in surface & ground water) and air quality (ammonia, odors) issues. These concerns may be legal (ie. nuisance lawsuits, etc.) as well as regulatory.

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Water quality. Beef and dairy feeding operations with properly designed and maintained runoff retention ponds and(or) lagoons normally have little, if any, effect on surface or ground water quality, although dry deposition of ammonia may increase N content of waters in close proximity to CAFO. The potential for water contamination generally occurs after the manure leaves the CAFO and is used as a fertilizer on fields or pastures. When applied at P utilization rates, rather than N utilization rates, the quantity of farm land required to dispose of manure is increased by 5- to 10-fold.

Air quality. The major air quality concerns of beef and dairy cattle operations vary with location, but, in general, are dust, odors, and ammonia. Concerns with dust and odors are generally local and revolve around "quality of life," health, and litigation issues; whereas, concerns with ammonia are mainly global or regional and revolve around it's designation as a PM-2.5 precursor (NRC, 2003) or possibly to its listing as a "hazardous substance" under the Emergency Planning and Community Right-to-Know Act (EPCRA).

PROGRESS IN DECREASING CAFO EFFECTS ON THE ENVIRONMENT

Changes in livestock production over the last several decades such as improved genetics, improved feed processing, diet modifications, and growth and lactation enhancers have directly increased production efficiency and indirectly reduced environmental hazards. Today, diets are more digestible and less manure is produced per unit of production. For example, incorporation of new technologies into the beef cattle feeding industry has decreased the amount of feed required per unit of gain from over 7 in the early 1980's, to less than 6 today. Although the driving force for these changes has been economics, these changes have also had a positive impact on many of the environmental issues now facing feedyards. Thanks to these new technologies, the quantity of feed fed annually to feedlot cattle in the southern Great Plains is 5 million tons less and the annual dry manure output is 3 million tons less than without these technologies (Greene and Cole, 2003).

Similar improvements have been noted in the dairy industry. Tylutki et al. (2004) noted that over a 5-year period, by modifying diet nutrient content and better managing manure, a dairy farm in New York was able to increase the proportion of home grown forages used in their diets by 38% and decrease manure N and P per acre by 17 and 28%, respectively. In 1998 the farm was accumulating P at the rate of 7.2 lb/acre; whereas, in 2002 it was accumulating P at only 0.26 lb/acre. At the same time, feed cost per unit of milk produced was decreased 48%. Similarly, in England, Withers et al. (1999) noted that surplus P in a whole-farm dairy system could be decreased from 21 lb/ac to 2.1 lb/ac via changes in the crops grown and dietary P concentration without adversely affecting milk production. From 1975 to 1995, the annual P excess (ie. soil storage) in Wisconsin decreased from 54 million kg to 14 million kg due, in part, to improved nutrition and management of dairy cows (Bundy and Sturgul, 2001).

Today, the livestock industry needs to develop and implement additional feeding and management strategies that continue the trend of improved feed efficiency while at the same time, reducing nutrient excretion to the environment, and producing a "higher quality" manure to be used as a fertilizer.

CHALLENGES

Excessive intake of nutrients by livestock leads to excessive excretion in manure. The term "precision feeding" has been coined to suggest that livestock can be fed with greater precision than currently practiced. However, at the present time, it is still not clear how effectively precision feeding can be applied in the field. It has been said that there are at least four different diets in any livestock operation: 1) the diet formulated by the nutritionist, 2) the diet actually mixed, 3) the diet delivered to the animals, and 4) the diet consumed by the animals. Making diets 1 and 4 the same is difficult.

Most nutritionists incorporate safety margins in their diet formulations to protect against variation in the nutrient content of ingredients and the nutrient requirements of animals. The point at which a safety margin becomes excessive is not clear. Galyean (1996) and Galyean and Gleghorn (2002) reported that beef cattle consulting nutritionists fed diets that varied from 12.5 to 14% (dry matter basis) in formulated crude protein **(CP)** concentration with a mode of 13.5%. Formulated P concentrations ranged from 0.25 to 0.35% with a mode of 0.3%. Surveys of Virginia and Wisconsin dairy herds indicated that, on average, the dietary P concentrations were 45% greater than NRC recommendations (Knowlton, 2002) and that 85% of dairies fed P in excess of NRC (2001) recommendations (Powell et al., 2002).

Some of the factors that limit the use of precision feeding in AFO include 1) variability in animal nutrient requirements, 2) seasonal / climatic effects, 3) variability in composition of feed ingredients, 4) logistics (Cole, 2003). Additional factors such as the low cost of urea and many by-product feeds, and as-yet undetermined ingredient associative effects also are important. Most of these limitations revolve around the risk of adversely affecting animal health or performance.

Animal Variability. Cattle producers are normally faced with large variations in the genetics of cattle within a single lot. Factors such as finished weight (i.e. body weight at 28% body fat), gain potential, stage of production, tolerance to weather extremes, milk production, etc. all affect the nutrient requirements of individual animals within a lot.

When formulating diets for large, genetically diverse, groups of animals, diets can be balanced based on the genetic potential of the best animals in the group or the genetic potential of the worst animals in the group. As an example of the effect of animal growth potential on CP requirements, we calculated the performance and N excretion of 100 hypothetical steers fed diets formulated to meet the CP requirements of the lowest 50%, lowest 84%, or 100% of the animals in the pen (NRC, 1984; Table 1). In addition, we calculated the overall pen performance and N excretion if 100 steers were "precision fed" (fed three different diets – one balanced for the bottom-performing 50 steers, one for the middle 34 steers, and one for the best-performing 16 steers). Restricting the dietary CP concentration to meet the requirements of 50% of the cattle in the pen had adverse effects on animal performance and did not decrease total pen N excretion because more days were required to reach market weight. Feeding to meet the requirements of 84% of the cattle, rather than 100%, had a slight adverse effect on calculated animal performance but a beneficial effect on calculated N excretion. As expected, precision feeding provided the best performance and lowest N excretion but was not "attainable" in a real world situation. Based on these calculations, diets need to be formulated to meet the requirements of at least 84% of the cattle in a pen. Interestingly, these simulated results agree well with results we obtained in feeding and metabolism trials (Gleghorn, et al., 2004; Gueye et al., 2003; McBride et al., 2003; Cole, 2006).

Seasonal /Climatic Variability. Animal performance and ammonia emissions vary with seasons (Erickson et al. 2000, 2003; Cole, 2003). Thus, to more precisely feed cattle, environmental and seasonal factors may need to be taken into account.

Feed Ingredient and Diet Variability. A major factor limiting the use of precision feeding is feed and diet variability. Loads of feed ingredients vary in nutrient composition because of growing conditions, time in storage, etc. Many tabular values are based on "old" and limited data and thus their validity today is questionable. In an 8-year survey of corn CP concentrations at a Texas feedyard, only 6% of corn samples had a CP concentration equal to or greater than NRC (2000) values (Table 2; Figure 1: Cole, 2003).

Many factors affect nutrient composition of diets including the nutrient composition of the ingredients, sampling errors, mixing errors, and laboratory variability/errors. To reduce diet variability employees should receive training in proper feed mixing and sampling, and feed mixers and scales should be tested routinely to be sure that ingredients are mixed properly and to determine the optimal mixing time (McCoy, 1994; Jones, 2001).

The analyses of 110 samples of a finishing diet formulated to contain 13.5% CP based on historical corn composition data (Table 2: Figure 1) demonstrated that although there was some variation in analyzed CP concentrations of the diets, the mean and median values were close to the formulated concentration and over 75% of the samples contained at least 13.13% CP. Only 10% of ration samples had a CP concentration of less than 12.75%. Similarly, Dou et al. (2003) noted that 67% of dairy rations were within 10% of the formulated protein concentration. Thus, if the nutritionist has a good chemical analysis or a history of the composition of feed ingredients, it is possible to mix diets that meet formulated diet specifications at least 75 to 90% of the time.

Chemical Analyses. Chemical analyses of feeds can vary from lab to lab and from method to method. In Table 3 are presented the analyzed CP concentrations of 5 feedyard diet samples sent to 3 different labs. The diet was formulated to contain 13.5% CP and on average analyzed to contain 13.7% CP. However the analyzed CP concentrations ranged from 12.7 to 14.5%. Obviously, the difficulty in obtaining precise feed analyses makes the formulation of diets more difficult.

Logistic challenges. One of the advantages of modern concentrated livestock feeding operations is the economy of scale. However, the sheer size of many operations also makes it more difficult to adapt some technologies. In large operations, modifying feeding practices may require feed mill modifications or may increase the feed truck miles and/or employee time required just to get cattle fed. Requirements of additional fuel, employees, or feed trucks can result in significant costs to the enterprise.

Feed Selection. Ingredient selection can have a major effect on the nutrient concentration in diets. Many by-product feeds such as distiller's grains, corn gluten feed, and high protein meals are high in N, P, S, and(or) other nutrients. Their use may result in diets and manure with excessive P concentrations. For example, Gueye et al. (2003) and McBride et al. (2003) noted that replacing cottonseed meal with urea as the supplemental N source in finishing diets reduced diet P concentration by 29.4% and P excretion by 20.5%. Many of these co-products fit well into beef cow supplements or dairy rations if other supplemental forms of P are removed.

Feed intake. Animals require quantities of nutrients rather than dietary proportions (ie. lbs/day vs. %). However, in most cattle feeding operations animals are provided ad libitum access to complete diets. Therefore diets are formulated to contain designated concentrations of nutrients with the assumption that feed intake will be within a specified range. Overestimating feed intake will lead to under-feeding specific nutrients, whereas underestimating feed intake will potentially lead to feeding excessive quantities of nutrients. For example, a 5% change in the dry matter intake of a dairy cow can affect the required dietary CP concentration by 0.5 to 1% (Chase, 2002).

Feed processing effects. In the newest versions of the beef and dairy nutrient requirements (NRC, 2000, 2001, respectively) diets are balanced based on the quantity of ruminally degradable (**DIP or RDP**) and ruminally undegradable (**UIP or RUP**) protein. Van Horn et al. (1994) calculated that simply balancing the DIP and UIP in the diet of dairy cows would decrease N excretion about 15% compared to NRC (1989) standards.
However, DIP and UIP values of feeds have not been determined experimentally and their requirements vary with other dietary and management factors.

Feedlot studies with dry-rolled corn-based diets suggest the CP requirement of finishing beef cattle is equal to or less than 11.5% of dietary DM (Milton et al., 1997; Shain et al., 1998) and that the DIP requirement is approximately 6.5% . However, results of trials with steam-flaked corn-based diets suggest the optimal CP concentration for finishing cattle performance is closer to 13.0% (Cooper et al., 2002; Gleghorn, et al., 2004) and the DIP requirement is greater than 8%. This difference in DIP (and subsequently CP) requirements is due to greater ruminal starch digestion in cattle fed steam-flaked corn-based diets.

Typically, it is not possible to "balance" DIP and UIP in beef cattle finishing diets because of the high UIP value of the basal ingredients. In an 80% corn beef finishing diet, the corn + forage portion of the diet will usually supply UIP in excess of the animal's requirement. Thus, when supplemental protein is provided to supply required DIP, the "excess" UIP-N in the grain+forage+supplement portion of the diet results in excess total N in the diet. This is in contrast to most dairy diets which require supplemental UIP.

Phosphorus: Most feed grains contain at least 0.30% P. Thus, if fed at 80% of a finishing diet, the basal P content of the diet is 0.25% or more. Erickson et al. (1999) noted that performance of finishing steers was not adversely affected by feeding diets with P concentrations as low as 0.14%. Similarly, in growing beef steers, Greene et al. (2001) noted that decreasing the dietary P concentration from 0.33 to 0.22% decreased P intake 50%, and decreased P excretion by 54% without affecting average daily gain and gain/feed.

Wu et al. (2000; 2001) noted that the P requirement of dairy cows may be substantially lower than concentrations routinely fed in the industry and that any P fed in excess of 0.31% was excreted in the feces.

Availability of feed P has received little attention in ruminant diets because early studies indicated that phytate-P in grains is highly available to ruminants. The current NRC for dairy (2001) assumes a P availability of 64% for forages, 70% for concentrates, and > 70% for most inorganic P sources; whereas, the NRC for beef cattle (2000) assumes a P availability of 68 % for all feeds. Providing supplemental P to dairy and beef cows based on available P, rather than total P, can potentially decrease the quantities of supplemental P fed and excreted by a factor of 3 or more (Table 4).

In general, once beef cattle are adjusted to the high concentrate finishing diet, they are fed a single diet throughout the feeding period. Thus, protein may be deficient early in the feeding period and in excess late in the feeding period. On average, an excess of approximately 2.64 lb of N is fed per animal during a 150 day feeding period (Galyean, 1998). Nitrogen can be conserved by lowering the dietary protein concentration late in the feeding period (phase feeding). To date, most phase feeding studies conducted with beef cattle fed dry-rolled corn-based diets and(or) with moderate implanting strategies suggest that supplemental protein could be partially, or completely withdrawn from finishing diets during the last 30 to 60 days on feed without adversely affecting animal performance (Erickson et al., 2000: Vasconcelos et al., 2006). However, in studies with beef cattle fed steam-flaked corn-based diets, decreasing dietary protein late in the feeding period (from 13.5 to 11.5%) had adverse effects on animal performance (Cole et al., 2006).

Satter and Wu (1999) noted that dairy cows could also be phase fed without adversely affecting milk production. By decreasing dietary CP concentration from 17.9 to 16.0% on week 17 of lactation, N intake was decreased 13%, manure N was decreased 16%, and milk production was not affected.

Because there are a number of obstacles to overcome in using phase feeding systems in commercial feedyards (additional supplements and diets, added time or labor required to feed, possibly increased incidence of acidosis, etc.) the economic practicality of phase feeding under current situations is not clear. With the advent of the new growth promoter, Optiflex (Elanco Animal Health), which will be fed toward the end of the feeding period, the effects of phase feeding will need additional evaluation.

USE OF MANURE AS A FERTILIZER: DIET AND MANAGEMENT EFFECTS

Improper use of organic and/or inorganic fertilizers can result in nutrient accumulation in soils, runoff to surface water or percolation to ground water. Many farmers prefer to use commercial inorganic fertilizers, rather than manure because of factors such as uncertain and inconsistent nutrient content, difficulties in uniform spreading, soil compaction, odor, weed seeds, high salt content, personal opinions, transportation costs, and low N:P ratio. Increased paper work from regulations could potentially further decrease use of manures by farmers.

Most crops require a N:P of 5 to 8:1. However harvested feedlot and dairy manures normally have N:P of 3:1 or less. The major factor affecting the N:P ratio is N volatilization losses. Depending upon weather conditions, pen surface conditions, diet, and other factors, 40 to 60% of N fed may be lost to the atmosphere, primarily as ammonia (Cole 2006; Cole et al., 2005; 2006; Todd et al., 2005, 2006). Decreasing dietary protein concentration from 13 to 11.5% of dry matter decreased potential ammonia emissions by approximately 30% (Cole et al., 2005; Todd et al., 2006). A number of potential soil amendments (Shi et al., 2001) and feed additives (Eng et al., 2003) have the potential to decrease ammonia emissions from feedlot pens. However the economics of these methods have not been clearly determined. More frequent cleaning of dirt surfaced pens will potentially increase N capture in the manure and decrease ammonia emissions (Erickson et al., 2003), especially in the summer months. Although this relationship should hold true for dairy dry lots as well, more frequent scraping of concrete dairy barns does not appear to affect N volatilization losses (Larry Satter, personal communication). Erickson et al. (2003) also noted that increasing dietary fiber (as corn bran) in the finishing diet or adding sawdust to the pen surface decreased the quantity of N volatilized from the pen surface during a winter/spring feeding period. However, these procedures also increase the total quantity of manure than must be removed from the facility.

Application of manure as a fertilizer on pastures is difficult to sustain in the long term because animal product removes less than 30% of the nutrients applied. For optimal utilization of manure nutrients, at least a portion of the forage needs to be removed as hay or silage. In addition, grazing cattle do not distribute manure evenly across a pasture (White et al., 2001).

Thus, fertilizers (organic and inorganic) should not be applied in areas where animals tend to congregate and deposit more nutrients on the land.

The nutrient composition and availability of manures collected from CAFOs vary greatly depending upon animal species, the diet fed, length and type of storage, type of housing, timing and method of manure collection, pen surface, bedding used, application systems, etc. Because many nutrients and trace elements in animal manures are organically bound or contained within structural components, manure may act as a form of "slow release" fertilizer (Loecke et al., 2004). Long-term manure applications may actually help decrease nutrient and soil runoff losses from fields due to increased soil organic matter and improved soil physical properties (infiltration, aggregation, bulk density) (Gilley and Risse, 2000).

Diet and management may also affect nutrient availability of manures. Sorenson and Fernandez (2003) noted that the fiber (r = -0.73) and crude protein (r =0.53) content of swine diets affected the subsequent mineral fertilizer equivalent value of slurry N. Similarly, Sorenson et al. (2003) noted that the dietary crude protein (r = 0.71) and crude fiber (r = -0.73 to -0.82) content of dairy cattle diets were correlated to the subsequent mineral fertilizer equivalent value of slurry N. The plant availability of slurry N was correlated with the ammonium content (r^2 = 0.53) and negatively correlated to the slurry C:N ratio (r^2 = 0.67) and dry matter:N ratio (r^2 = 0.58).

Ebeling et al. (2002) noted that excessive addition of inorganic P to dairy diets (0.31 vs. 0.49%) produced manures with higher P concentrations (0.48 vs. 1.28% P). When applied at equal N application rates, total P runoff was 6 times greater and dissolved reactive P runoff was 10 times greater for the high-P manure than the low-P manure. When applied at equivalent P levels, total P runoff was 2 times greater and dissolved reactive P runoff was 6 times greater for the high-P than low-P manure.

Koelsch (2000) noted that decreasing dietary P concentration of beef finishing diets from 0.45 to 0.22% decreased the corn acres required for manure application by 60%. Powell et al. (2001; 2002) noted that decreasing dietary P concentration of dairy diets from the national average of 0.48% to a concentration of 0.38% (deemed to be adequate by several research studies), would decrease land required for manure application by 39%.

Composting of animal manures can decrease application costs, decrease mass and water content, suppress pathogens, destroy weed seeds and feed additives, and result in smaller and more uniform particle size, and decreased odor emissions. However, during composting there is a 30 to 50% decrease in mass due to losses of C (46 to 62%) and N (19 to 42%) (DeLuca and DeLuca, 1997; Eghball et al., 1997). This decreases the N:P ratio and increases the concentration of other nutrients, salts, and minerals.

Depending upon the type of housing and manure handling system, appreciable quantities of manure nutrients can end up in lagoons or retention ponds. Nutrient concentrations in retention ponds will vary depending upon rainfall, evaporation, changes in pond volume, and N volatilization. In general, the high concentrations of salt, P or other nutrients in many lagoons and retention ponds limit their use as fertilizer (Rhoades et al., 2003).

CONCLUSIONS

The general public is demanding that everyone - and that includes agriculture - be held accountable for their impact on the environment. This means that today, and in the future, we will need to balance animal production with environmental risks. "Safety margins" in diet formulation may have to be decreased. At the present time the biggest "cushion" available is probably toward the end of the feeding period and late in lactation - the time period when we can probably have the greatest effect on both nutrient excretion and ammonia emissions. The use of many technologies such as phase feeding and precision feeding is limited at the present time. Adding a "manure removal charge" to the cost of feed ingredients may be beneficial in limiting the use of feeds that may produce environmental problems. The major factor limiting use of manure nutrients is often farmers' preference for inorganic fertilizers; thus, to make manure more attractive as a fertilizer, livestock producers need to treat manures as a co-product, rather than as a waste to be disposed of at the cheapest price.

REFERENCES

Bundy, L. G. and S. J. Sturgul. 2001. A phosphorus budget for Wisconsin cropland. J. Soil Water Conserv. 56:243-249.

Chase. L. E. 2002. Animal management strategies – how will they change with environmental regulations? At: www.abc.Cornell.edu.

Cole, N. A. 2003. Precision nutrition –opportunities and limitations. Proc. Plains Nutr. Council Spring Conf. TAES Public # AREC 03-13: pg 1-19.

Cole, N. A. 2006. Update on recent protein research for finishing beef cattle. Proc. 21st Southwest Nutr. and Mgt. Conf., Feb. 23-24, 2006. Tempe, AZ. Pg 67-87.

Cole, N. A., R. N. Clark, R. W. Todd, C. R. Richardson, A. A. Gueye, L. W. Greene, and K. W. McBride. 2005. Influence of dietary crude protein on potential ammonia emissions from beef cattle manure. J. Anim. Sci. 83:722-731.

Cole, N. A., P. J. Defoor, M. L. Galyean, G. C. Duff, and J. F. Gleghorn. 2006. Effects of phase feeding crude protein on performance, carcass characteristics, serum urea nitrogen concentrations and manure nitrogen in finishing beef steers. J. Anim. Sci. (in review).

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordon. 2002. Effect of corn processing on degradable intake protein requirement of finishing cattle. J. Anim. Sci. 80:242-247.

DeLuca, T. H. and D. K. DeLuca. 1997. Composting for feedlot manure management and soil quality. J. Prod. Agric. 10:235-241.

Dou, Z., J. D. Ferguson, J. Fiorini, et al. 2003. Phosphorus feeding levels and critical control points on dairy farms. J. Dairy Sci. 86:3787-3795..

Ebeling, A. E., L. D. Bundy, J. M. Powell, and T. W. Andraski. 2002. Dairy diet phosphorus effects on phosphorus losses in runoff from land-applied manure. Soil Sci. Soc. Amer. J. 66:284-291.

Eghball, B., J. F. Power, J. E. Gilley, and J. W. Doran. 1997. Nutrient, carbon, and mass loss of beef cattle feedlot manure during composting. J. Environ. Qual. 26:189-193.

Eng, K. S., R. Bectel, and D. P. Hutcheson. 2003. Adding potassium clinoptilolite zeolites and yucca extract to feedlot diets to reduce nitrogen losses from manure. J. Anim Sci. 81 (Suppl. 1): 77.

Erickson, G. E., J. R. Adams, T.B. Farran, C. B. Wilson, C.N. Macken, and T. J. Klopfenstein. 2003. Impact of cleaning frequency of pens and carbon to nitrogen (C: N) ratio as influenced by the diet or pen management on N losses from outdoor beef feedlots. Proc Ninth International Symposium on Animal, Agricultural and Food Processing Wastes. Raleigh, NC. Oct 12-15, 2003. Amer. Soc. Agric. Engin. St. Joseph, MI. pg 397-404.

Erickson, G., T. Klopfenstein, and C. T. Milton., D. Hanson, and C. Calkins. 1999. Effect of dietary phosphorus on finishing steer performance, bone status, and carcass maturity. J. Anim. Sci. 77:2832-2836.

Erickson, G., T. Klopfenstein, and C. T. Milton. 2000. Dietary protein effects on nitrogen excretion and volatilization in open-dirt feedlots. Pp 297-304. Proc. 8th Inter Symp. on Animals, Agriculture, and Food Processing Wastes. ASAE Press, St Joseph, MI.

Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: Industry application, university research and systems results. J. Anim. Sci. 74:2860-2870.

Galyean, M. L. 1998. Phase-feeding of finishing cattle: Are there potential benefits for efficiency and environmental nutrient management. Proc. 1998 Plains Nutrition Council Spring Conf. Publ. # AREC98-24, Texas A & M Research and Extension Center, Amarillo. Pp 62-67.

Galyean, M. L. and J. F. Gleghorn. 2002. Summary of the 2000 Texas Tech University consulting nutritionist survey. Proc. Plains Nutr. Council. TAMU Publ. AREC 02-20 San Antonio, TX, April 25-16, 2002. Pg 1-10.

Gilley, J. E., and L. M. Risse. 2000. Runoff and soil loss as affected by the application of manure. Trans. ASAE 43:1583-1588.

Gleghorn, J. F., N. A. Elam, M. L. Galyean, G. C. Duff, N. A. Cole, and J. D. Rivera. 2004. Effects of crude protein concentration and degradability on performance, carcass characteristics and serum urea nitrogen concentrations in finishing beef steers. J. Anim. Sci. 82:2705-2717.

Greene, L. W. and N. A. Cole. 2003. Feedlot nutrient management impacts efficiency and environmental quality. The Performance Edge. ADM Alliance Nutrition 5: 2-3.

Greene, L. W., F. T. McCollum, N. K. Chirase, and T. M. Montgomery. 2001. Performance and conservation of phosphorus in growing cattle. J. Anim. Sci. 79 (Suppl. 1):293.

Gueye, A. C. R. Richardson, J. H. Mikus, G. A. Nunnery, N. A. Cole, and L. W. Greene. 2003. The effects of dietary crude protein concentration on nitrogen absorption and retention by feedlot steers. J. Anim. Sci. 81 (Suppl. 1): 209 .

Jones, F. T. 2001. Quality control in feed manufacturing. Feedstuffs Reference Issue and Buyers Guide. July 11, 2001. Vol. 79, No. 29: 78-82.

Kellogg, R. L., C. H. Lander, D. E. Moffitt, and N. Gollehon. 2000. Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: Spacial and temporal trends for the United States. Publ. No. NPS 00-0579. USDA-NRCS and ERS, Washington, DC. (Available: http://www.nrcs.usda.gov/technical/land/pubs/). (Accessed 2/24/2004).

Knowlton, K. 2002. Reducing phosphorus losses through nutrition. At www.usjersey.com/reference/environment3.pdf.

Koelsch, R. 2000. Feed program impact on land requirements for managing manure nutrient from a feedlot. 2000 Nebraska Beef Report, pg 72-73.

Lander, C. H., D. Moffitt, and K. Alt. 1998. Nutrients available from livestock manure relative to crop growth requirements. Publ. No. RASPW 98-1. USDA-NRCS, Washington,DC. (Available:http://www.nrcs.usda.gov/technical/land/pubs/nlweb.html). (Accessed 2/24/2004).

Loecke, T.D., M. Liebman, C. A. Cambardella, and T. L. Richard. 2004. Corn response to composting and time of application of solid swine manure. Agron. J. 96:214-223.

McBride, K. W., L.W. Greene, N. A. Cole, F. T. McCollum, and M. L. Galyean. 2003. Nitrogen and phosphorus utilization by beef cattle fed three dietary protein levels with three levels of supplemental urea. J. Anim. Sci. 81 (Suppl. 1):73.

McCoy, R. A. 1994. Mixer Testing. In R. R. McEllhiney (Tech Ed.) Feed Manufacturing Technology IV/ Amer. Feed Industry Assoc, Inc. Arlington, VA.

Milton, C. T., R. T. Brandt, Jr., and E. C. Titgemeyer. 1997. Urea in dry-rolled corn diets: Finishing steer performance, nutrient digestion, and microbial protein production. J. Anim. Sci. 75:1415-1424.

NRC. 1984. Nutrient Requirements of Beef Cattle. 6th Revised Ed., National Academy Press, Washington, DC.

NRC. 1989. Nutrient Requirements of Dairy Cattle. 6th Revised Ed., National Academy Press, Washington, DC.

NRC. 2000. Nutrient Requirements of Beef Cattle: Update 2000. 7th Revised Ed., National Academy Press, Washington, DC.

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th Revised Ed., National Academy Press, Washington, DC.

NRC. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. National Academies Press, Washington, DC.

NRCS. 2000. Comprehensive Nutrient Management Planning Technical Guidance. USDA-NRCS. http://www.nhq.nrcs.usda.gov/Programs/ahcwpd/CNMPTG.pdf.

Powell, J. M., Z. Wu, and L. D. Satter. 2001. Dairy diet effects on phosphorus cycles of cropland. J. Soil and Water Conserv. 56:22-26.

Powell, J. M., D. B. Jackson-Smith, and L. D. Satter. 2002. Phosphorus feeding and manure nutrient recycling on Wisconsin dairy farms. Nutr. Cycling in Agroecosystems 62:277-286.

Rhoades, M. B., D. B. Parker, J. M. Sweeten, N. A. Cole, and M. S. Brown. 2003. Land application of beef feedyard effluent to forage sorghum and winter wheat. Pages 99-106 in Proc. 9th International Symp. On Animal, Agricultural and Food Processing Wastes. Am. Soc. Agric. Eng. St. Joseph, MI. .

Ribaudo, M. 2003. Manure management for water quality: costs to animal feeding operations of applying manure nutrients to land (AER824). ERS Information. USDA-ERS, June-July, 2003. Also at www.ers.usda.gov (Accessed 1/24/2004).

Satter, L. D. and Z. Wu. 1999. New strategies in ruminant nutrition: Getting ready for the next millennium. Proc. Southwest Nutr. and Mgt. Conf. Phoenix, AZ. p. 1.

Shain. D. H., R. A. Stock, T. J. Klopfenstein, and D. W. Herold. 1998. Effect of degradable intake protein level on finishing cattle performance and ruminal metabolism. J. Anim. Sci. 76:242-248.

Shi, Y., D. B. parker, N. A. Cole, B. W. Auvermann, and J. E. Mehlhorn. 2001. Surface amendments to minimize ammonia emissions from beef cattle feedlots. Trans. ASAE 44:677-682.

Sorenson, P., and J. A. Fernandez. 2003. Dietary effects on the composition of pig slurry and on the plant utilization of pig slurry nitrogen. J. Agric. Sci. 140:343-355.

Sorenson, P., M. R. Weisbjerg, and P. Lund. 2003. Dietary effects on the composition and plant utilization of nitrogen in dairy cattle manure. J. Agric. Sci. 141:79-91.

Todd, R. W., N. A. Cole, L. A. Harper, T. K. Flesch, and B. H. Baek. 2005. Ammonia and gaseous nitrogen emissions from a commercial beef cattle feedyard estimated using the flux-gradient method and N:P ratio analysis. Proc. Symp. State of the Science: Animal manure and waste management. www.cals.ncsu.edu:8050/wast_mgt/natlcenter/sanantonio (Accessed, Dec. 2005)

Todd, R. W., N. A. Cole, and R. N. Clark. 2006. Reducing crude protein in beef cattle diet reduces ammonia emissions from artificial feedyard surfaces. J. Environ.Qual. 35:404-411.

Tylutki, T. P., D. G. Fox, and M. McMahon. 2004. Implementation of nutrient management planning on a dairy farm. Prof. Anim. Sci. 20:58-65.

USEPA. 2003a. National Pollutant Discharge Eliminations System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFO2); Final Rule. 40CFR Parts 9, 122, 123, and 412

USEPA. 2003b. Producers' Compliance Guide for CAFOs: Revised Clean Water Act Regulation for Concentrated Animal Feeding Operations. EPA 821-R-03-010. Available http://www.epa.gov/npdes/cafo/producersguide. Accessed March 12, 2004

Van Horn. H. H., A. C. Wilkie, W. J. Powers, and R. A. Nordstedt. 1994. Components of dairy manure management systems. J. Dairy Sci. 77:2008-2030.

Vasconcelos, J. T., L. W. Greene, N. A. Cole, and F. T. McCollum. 2006. Effects of phase feeding of protein on performance, blood urea nitrogen, manure N: P ratio, and carcass characteristics of feedlot cattle. J. Anim. Sci (in press).

White, S. L., R. E. Sheffield, S. P. Washburn, L. D. King, and J. T. Green. 2001. Spatial and time distribution of dairy cattle excreta in an intensive pasture system. J. Environ.Qual. 30:2180-2187

Withers, P.J.A., S. Peel, R.M. Mansbridge, A. C. Chalmers, and S. J. Lane. 1999. Transfers of phosphorus within three dairy farming systems receiving varying inputs in feeds and fertilizers. Nutr. Cycling in Agroeco. 55:63-75.

Wu., Z., L. D. Satter, A.J. Blohowiak, R. H. Stauffacher, and J. H. Wilson. 2001. Milk production, estimated phosphorus excretion and bone characteristics of dairy cows fed different amounts of phosphorus for two or three years. J. Dairy Sci. 84:1738-1748.

Wu, Z., L. D. Satter, and R. Sojo. 2000. Milk production, reproductive performance, and fecal excretion of phosphorus by dairy cows fed three amounts of phosphorus. J. Dairy Sci. 83:1028-1041.

Table 1. Calculated effects of feeding to meet the CP requirements of 50%, 84%, 100%, or of precision feeding on steer performance and N excretion: 100 head of 880 lb., large frame steers (NRC, 1984)

Item	50%	84%	100%	Precision
Ration cost, $ / ton	108	110	112	109
N intake, lb/d	34.8	39.8	45.1	37.4
N excreted, lb/d	27.9	31.9	36.1	29.9
ADG, lb	2.73	3.39	3.52	3.52
Feed/gain	8.00	6.49	6.25	6.25
Cost of gain, $/cwt	43.20	35.70	35.00	34.06
Days to 1,280 lb	146	118	114	114
N excreted, lb/100 steers	4,073	3,764	4,115	3,409

Table 2. Variation in composition (% DM) of sorghum, corn, and complete diets at a commercial feedyard over 8 years (diet formulated to contain 13.5% CP; no supplemental P was added) (Cole, 2003).

Item	Crude protein,%			P,%		
	Sorghum	Corn	Diet	Sorghum	Corn	Diet
Number of samples	69	32	110	68	32	110
Mean	11.15	9.25	13.74	0.28	0.25	0.36
Std. Dev.	1.05	1.14	0.92	0.05	0.04	0.07
Maximum	13.29	12.31	16.34	0.45	0.39	0.64
90%	12.40	10.51	14.96	0.33	0.28	0.42
75% quartile	11.80	9.58	14.33	0.31	0.26	0.39
Median	11.32	9.06	13.68	0.26	0.24	0.35
25% quartile	10.73	8.55	13.13	0.24	0.23	0.32
10%	9.49	8.30	12.75	0.23	0.21	0.30
Minimum	8.29	6.84	11.13	0.19	0.20	0.18
Skewness	-0.63	1.08	0.16	1.11	2.12	1.37
Kurtosis	0.22	2.05	0.54	1.38	6.94	4.58
NRC, 2000	12.6	9.8	--	0.34	0.32	--

Table 3. Variation in crude protein analysis of five feedlot diet samples obtained at unloading from a feed truck (diets formulated to contain 13.5% CP) (Cole 2003).

Sample #	Lab 1	Lab 2	Lab 3	Mean	Std dev
1	14.3	14.2	14.1	14.2	0.10
2	13.4	14.0	13.0	13.5	0.50
3	13.2	14.5	13.0	13.6	0.81
4	13.6	14.4	12.7	13.6	0.85
5	13.5	13.9	12.8	13.4	0.56
Average	13.6	14.2	13.1	13.7	--
Std dev.	0.42	0.25	0.56	0.61	--
CV,%	3.1	1.8	4.3	4.45	--

Table 4. Effects of P bioavailability on dietary needs and P excretion of a 1,000 lb beef cow on native range and 1,500 lb dairy cow in dry lot.

Item	Defluor. Rock Phosphate	Dicalcium Phosphate	Monocalcium Phosphate	Phosphoric acid
% P in source	18.0	18.5	21.0	25.0
Absorption coefficient	65%	75%	75%	90%
Cost, $/ton	370	350	360	262
Beef Cow				
P excreted, g/d	3.33	2.06	2.06	0.69
P source needed, g/d	52.81	44.53	39.23	27.46
Fecal P from supplement, lb per 100 cows per yr	267.5	165.6	165.6	55.2
Cost, $/100 cows per yr	785.41	626.5	607.1	289.2
Dairy cow				
P excreted, g/d	3.63	2.25	2.25	0.75
P source needed, g/d	57.6	48.6	42.8	30.0
Fecal P from supplement, Lb/100 cows per year	291.7	180.6	180.6	60.2
Cost $/100 cows per yr	856.51	683.20	662.06	315.38

Assumes beef cow requires 6.2 g of absorbable P /d in supplement and dairy cow requires 6.7 g/d.

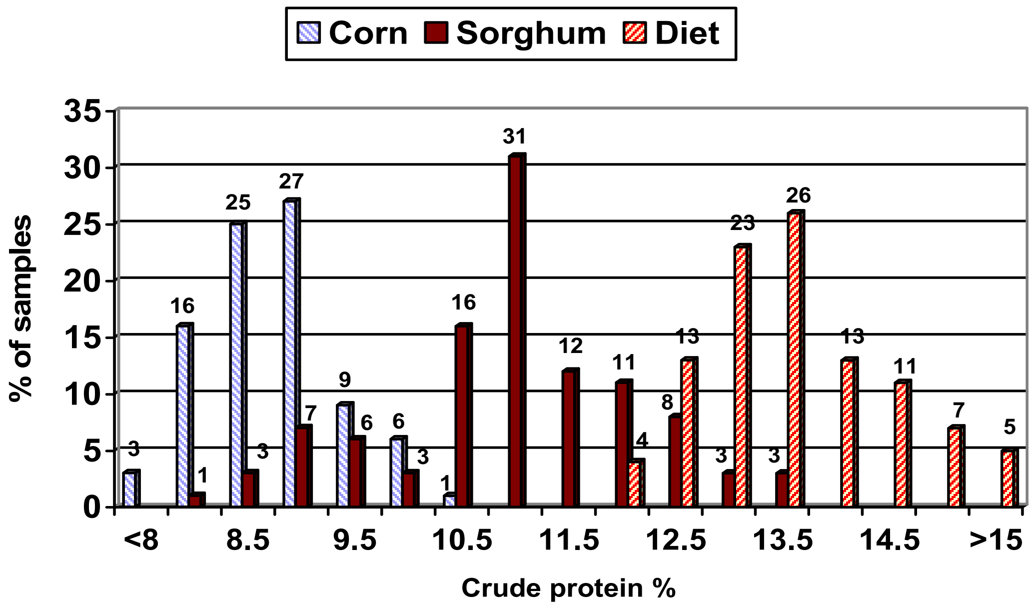

Figure 1. Distribution of crude protein concentrations in feed grain and diet samples (% of samples with designated CP concentration - rounded to nearest 0.5%). Diet formulated for 13.5%CP.