

# Environmental stewardship in the future: Nutrient management issues and options for beef cattle feeding operations

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## Abstract

Confinement feeding of beef cattle concentrates nutrient wastes, which could lead to environmental concerns. At present, public and legislative concern seems to be focused on excretion of N and P. Nutrient input should be a function of the animal's requirement for a given nutrient, with diets then formulated to meet the requirement given an expected or predicted feed intake. With N, however, estimates of animal requirements vary greatly between the two main systems used for calculation of requirements. Nitrogen requirements calculated with the factorial system are considerably lower than those calculated with the metabolizable protein system. Current industry formulation practices and some recent research data agree more closely with requirements calculated by the metabolizable protein system. Nitrogen and P excretion could be decreased by applying a phase-feeding approach in which diet formulas are changed with time on feed to reflect decreasing requirements for these nutrients. In addition, applying restricted or programmed feeding approaches that simply decrease feed intake to some percentage of ad libitum or fix intake to yield a specific rate of gain should decrease nutrient input and ultimately decrease nutrient output. When high-grain diets are fed to finishing beef cattle, limited data suggest little benefit from providing supplemental P. If further research supports these limited data, removal of supplemental P from high-grain beef cattle finishing diets might be an important environmental management option. Accurate estimates of nutrient requirements are vital to both animal well-being and nutrient management issues, and regular revisions of standards set by the National Research Council should be supported by the beef cattle feeding industry.

*Key Words: Beef Cattle, Nitrogen, Phosphorus, Excretion, Nutrient Requirements*

## Introduction

Confinement feeding of livestock leads to concentration of feed nutrients in a small area, which has led to public and legislative concern about odors, water and air quality, and manure-borne diseases (Meyer and Mullinax, 1999). For confined cattle, accumulation of N and P in waste is of particular interest because the animal retains a relatively small fraction of the total dietary N and P intakes. Excreted N could runoff to surface water, percolate through soil to ground water, or be volatilized as ammonia or nitrous oxide (Cole, 1998). Likewise, excreted P could accumulate in soil, potentially increasing the concentration of P in soluble forms that move with surface runoff water or with eroded soil particles (Nelson, 1999).

Increasing regulatory pressure on the livestock feeding industry necessitates careful evaluation of feeding practices and management techniques with respect to their effects on nutrient excretion. Meyer and Mullinax (1999) summarized existing and proposed regulations related to nutrient excretion from livestock feeding operations. Their article was part of two excellent symposia at the 1998 Joint Meetings of the American Society of Animal Science and the American Dairy Science Association, from which five articles were published (Koelsch and Lesoing, 1999; Kuipers et al., 1999; Meyer and Mullinax, 1999; Nelson, 1999; St-Pierre and Thraen, 1999). These articles provide a thorough treatment of comprehensive (whole-farm) nutrient management issues. The present article is more narrowly focused on nutrient input

issues, particularly the potential effects of dietary formulation practices on nutrient excretion and possible practices by which nutrient excretion might be more effectively managed in beef cattle feeding operations.

## Current Beef Cattle Feedlot Diet Formulations

Galyean (1996b) assessed formulation practices in the feedlot industry by surveying six consulting nutritionists (designated as A, B, C, D, E, and F in Table 1) regarding general management and formulation practices and specific practices with respect to percentages of CP and urea used in beef cattle finishing diets. The six consultants serviced feedlots in Arizona, Kansas, Oklahoma, Nebraska, and Texas. Four of those surveyed (A, B, D, and F) were independent consultants, providing services on a fee basis for commercial feedlots. The remaining two consultants (C and E) were employed by commercial cattle feeding businesses and consulted only for the feedlots owned by the corporation. In total, these six consultants were responsible for the nutrition program of approximately 3.6 million cattle per year. Results of the survey (Galyean, 1996b) are shown in Table 1.

The majority of the cattle in the feedlots represented by this survey were yearlings. Corn was the predominant grain fed, with milo second. Grain typically was processed, most commonly by steam flaking. Dry-rolled and high-moisture grains were not the sole grain in the diet, but were fed either in combination with each other or in combination with steam-flaked grain. Roughage concentrations varied among feedlots

within consultants, with a range of 3 to 11% of the dietary DM. The overall values for formulated percentage of CP (DM basis) in the finishing diet ranged from 12.5 to 14.4% (Table 1). A considerable portion of the total CP beyond that supplied by the dietary ingredients was derived from urea, which ranged from 0.5 to 1.5% of dietary DM. Feeding wheat or barley, which have higher CP contents than corn and sorghum, resulted in less supplemental protein (or NPN). In addition, urea levels typically were less with diets that contained high-moisture corn. None of the six consultants formulated for escape protein, generally believing that insufficient information was available to allow for such formulation. Unfortunately, P supplementation practices were not assessed in this survey; however, the high level of grain used in typical feedlot diets suggests that P concentrations were likely to be in excess of NRC (1984, 1996) requirements.

Results of the survey by Galyean (1996b) agreed with a similar survey of 12 consulting nutritionists conducted for the University of Nebraska in 1994 (personal communication, B. D. Dicke, Cattlemen's Consulting Service, Lincoln, NE). This Nebraska survey indicated that the range in CP concentrations used in finishing diets was 12.5 to 13.8% (average = 13.1%), with a range in urea levels of 0.8 to 1.5%.

These survey results suggest that CP concentrations used in practice are greater than would be required according to calculations based on the NRC (1984) factorial system. Moreover, the results suggest that urea typically contributes a significant portion of the supplemental CP in beef cattle feedlot diets. With medium-framed, yearling steers (initial and final shrunk BW of 340 and 567 kg, respectively) eating 9 kg/d of DM of a diet with 2.16 Mcal of NE<sub>m</sub> and 1.48 Mcal of NE<sub>g</sub> per kilogram of DM, the CP requirement predicted from NRC (1984) equations would be only 10.44%. If the NRC (1984) CP requirement is correct, the current formulation practices for CP seem excessive, and little or no urea would be needed. A reasonable question, however, is whether the NRC (1984) estimate of CP requirements is adequate for current dietary and management conditions (e.g., intensive bunk management, grain processing, and implant programs) in commercial beef feedlots. For example, performance benefits were noted when 0.88% urea was added to dry-rolled corn-based beef cattle finishing diets (Shain et al., 1998), presumably because the basal diet without urea was deficient in degraded intake protein (**DIP**) to meet the needs of ruminal microbes. Comparisons of the NRC (1984) factorial system with the NRC (1996) metabolizable protein (**MP**) system, which accounts for microbial N needs, will be considered in the next section.

### Formulation Practices vs Nutrient Requirements

**Nitrogen and Phosphorus.** A fairly low proportion of dietary N and P is retained in the tissues of finishing beef cattle (Cole, 1998). For the yearling steers described previously, calculations with the NRC (1984) factorial system suggest that approximately 20% of the dietary N and 31% of the dietary P would be retained in the tissues. The remainder would be excreted into the environment, primarily in feces

and urine. Hence, there is a high level of waste N and P built into the NRC (1984) requirements simply because of the high overhead (maintenance) costs for N and P. Why then are practicing nutritionists feeding levels of N, and often P, in the diet higher than those recommended by NRC (1984)? Feeding more N than recommended would be expected to add more waste N on top of an already high waste overhead. The most obvious reason for feeding levels of N (CP) higher than those recommended by NRC (1984) is that the recommended levels might be too low. Galyean (1996b) concluded that recent research, particularly with cattle given aggressive growth-promoting implants and fed highly processed grain diets, suggested benefits associated with feeding higher dietary CP levels than predicted by the NRC (1984) factorial system. Improved performance with higher CP levels seemed to be most evident when the additional CP was supplied by ruminally degraded sources (Galyean, 1996b). Perhaps the NRC (1984) factorial system of calculating CP requirements does not adequately describe the need for CP by feedlot cattle fed low-roughage diets that are composed mostly of highly processed grain.

Galyean (1996b) compared CP requirements calculated by the NRC (1984) factorial system and those calculated by the NRC (1996) MP system. Requirements calculated by the MP system agreed more closely with CP levels used by practicing nutritionists in the survey by Galyean (1996b). The NRC (1996) MP system divides requirements into CP needed to meet the MP (absorbable amino acid) requirements of the animal and CP needed to meet the degraded N requirements of ruminal microbes. Total feed CP is described in terms of its degradability, with DIP used for microbial protein synthesis in the rumen, and undegraded intake protein (**UIP**) plus synthesized microbial CP meeting the MP needs of the animal.

With the yearling steers described previously, for which the NRC (1984) CP requirement would be 10.44%, the NRC (1996) CP requirement would be 12.23%. However, the value of 12.23% CP assumes that the diet is perfectly balanced for DIP and UIP, a situation that seldom exists in practice because cereal grains are relatively high in UIP and relatively low in DIP. Indeed, with a typical finishing diet based on steam-flaked corn, it is likely that the yearling cattle in this example would be deficient in DIP by approximately 200 g/d. This deficiency could be met by providing approximately 70 g of urea (200/2.87) or 0.78% of the dietary DM, with a DMI of 9 kg/d. The addition of urea at this level would bring the total dietary CP level to 13.3%, but the UIP supplied by such a diet would be approximately 96 g in excess of needs (13.3–12.23% = 1.07% of 9,000 g/d). Presumably, this excess N in the form of UIP would simply become waste N that is excreted into the environment.

One problem with the NRC (1996) MP system for calculating protein requirements is that in Level 1 of the system no net recycling of N is assumed to occur. Hence, the quantity of DIP needed in the diet equals the potential quantity of microbial CP that can be synthesized. However, in the animal system, net recycling most likely does occur. Indeed, if net recycling is assumed to be 10% of DIP intake, then the DIP

requirement would be decreased by 10%. With the previous yearling steer example, assuming 10% net DIP recycling would decrease the need for urea to 0.5% of the diet and thereby decrease the overall CP level to 12.54% of the 9 kg/d DMI. Perhaps future revisions of the NRC (1996) MP system will include adjustments for N recycling.

Some caution should be exercised in generally applying the calculations from the yearling steer example described above. These calculations are based on the average shrunk BW for the feeding period (453.5 kg in this example), which would result in too little CP being provided up to the point that the cattle reach the average BW and too much CP thereafter. The concept of changing requirements and diet formulas with time on feed (phase feeding) will be addressed in a subsequent section. In addition, calculated CP requirements in both the NRC (1984) and NRC (1996) systems are very sensitive to DMI. Hence, accurate estimates of DMI by cattle are essential for effective application of either system, and such estimates are ultimately required for the development of nutrient input:output relationships to use in comprehensive nutrient management programs.

Whether current formulation practices are environmentally sound with respect to N is a difficult question to answer because the research database is incomplete. For example, one could argue that CP levels greater than those suggested by NRC (1984) merely flood the environment with additional N. However, if DMI is less with a deficiency of DIP, and increasing DIP to meet microbial needs increases DMI and energy yield from ruminal fermentation, daily gain should be increased, and increased tissue N retention should partially offset increased N intake. The route of N excreted also might be influenced by dietary CP level. When DIP is imbalanced, with more supplied than needed to meet microbial needs, more N might be excreted in the urine and volatilized to the atmosphere. Balancing DIP to meet microbial needs, however, might result in more N excreted in the feces, greater retention of N in the manure for subsequent land application, decreased runoff and leaching of N, and decreased atmospheric N. Unfortunately, data are not available to predict how changes in N formulation practices alter N excretion patterns. Bierman et al. (1999) conducted N mass balance measurements in cattle fed an all-concentrate diet, a diet with 7.5% roughage (corn silage and alfalfa hay), and 7.5% roughage with 41.5% wet corn gluten feed. The dietary CP and DIP levels were equal among the three diets. Percentage of dietary N excreted in the feces was greatest with the wet corn gluten feed diet, but percentage of N excreted in the urine was greatest with the all-concentrate diet and least with the wet corn gluten feed diet. Despite a greater percentage of N excreted in the urine, excreted N volatilized was less for the all-concentrate diet (57.1%) than for the 7.5% roughage (65.3%) and wet corn gluten feed (66.8%) diets. Additional research is needed to determine effects of N formulation practices on N excretion patterns in beef feedlots.

**Other Nutrients.** Trace minerals are often added to finishing diets in excess of established requirements. Galyean (1996a) reported that supplemental Zn in beef cattle feedlot diets recommended by five consulting nutritionists ranged

from a low of 24 to 30 mg/kg of added Zn to a high of 300 mg/kg. These values essentially equate to approximately the NRC (1996) requirement on the low end and 10 times the requirement on the high end. Galyean (1996a) noted that in response to increased Zn supplementation, these consulting nutritionists recommended that Cu supplementation be increased to two to four times the NRC (1996) requirements.

Adding high levels of Zn and Cu to diets of newly weaned pigs for relatively short periods seems to be an increasingly popular practice in the swine industry. In a large-scale regional study, Hill et al. (2000) reported that either 3,000 mg/kg of added Zn from ZnO or 250 mg/kg of added Cu from CuSO<sub>4</sub> fed to weaning pigs for 28 d improved daily gain and gain:feed. No advantage was noted to adding both Zn and Cu at high levels.

The extent to which adding higher-than-recommended levels of trace minerals such as Zn and Cu to livestock diets can be justified environmentally is unclear. Few data are available to assess the environmental impact of such practices. Although N and P are the key elements of current regulatory efforts, output of other nutrients will certainly be scrutinized as the regulatory process evolves. Thus, formulation practices that avoid unnecessary excesses of any nutrient seem prudent.

### Options for Management of Nitrogen and Phosphorus Excretion

When law requires nutrient management, regardless of the validity of the science behind the law, what avenues will producers and nutritionists use to meet regulatory guidelines? Nutrient management issues, particularly in a regulatory context, have not been the focus of ruminant nutrition research during the last several decades. Nonetheless, a good deal of the research related to nutrient requirements of ruminants can be applied to nutrient management issues. Based on previous research, several options for management of N and P excretion by beef cattle feeding operations will be discussed in the following sections.

**Protein Withdrawal and(or) Phase-Feeding of Protein.** Body weight and rate of protein deposition are the primary factors that drive protein requirements, so requirements change over the course of a feeding period as cattle approach physiological maturity. Requirements are higher during the initial part of the feeding period when rates of protein deposition are high and diminish during the later stages of finishing when fat deposition rates are high. Feeding a constant level of CP in finishing cattle diets is a common industry practice, but changing diet formulations to match changing protein needs over time should offer one means of managing nutrient excretion. Two basic approaches have been evaluated in previous research to achieve this end: 1) complete withdrawal of supplemental CP from the diet at some point during the finishing period or 2) phase-feeding of CP, which would involve changing the CP level of the diet to match decreasing CP requirements as cattle increase in BW.

Protein withdrawal experiments with feedlot cattle that were conducted before 1980 were reviewed by Preston

(1982). He concluded that 1) supplemental CP levels can be decreased with time on feed with little overall effect on performance and carcass characteristics; 2) decreased protein levels (withdrawal) should not be initiated until after the first 28 to 56 d of the feeding period; 3) after the first 28 to 56 d, dietary CP can be decreased steadily as cattle increase in BW, with a suggested value of 8.5% CP in the dietary DM for 431-kg cattle (estimated to be 95% of the BW at Choice grade); 4) ingredients should be analyzed for CP when protein withdrawal is practiced rather than relying of tabular values; and 5) feed intake should be checked closely to ensure that CP intake is  $\geq 870$  g/d. Although many experiments reviewed by Preston (1982) showed virtually no effect of protein withdrawal on ADG, DMI, and feed conversion, not all experiments yielded positive results. For trials in which negative results were reported (e.g., Thomas et al., 1976), CP intakes were typically less than the minimum value of 870 g/d suggested by Preston (1982).

Based on the survey of Galyean (1996b), diets, management, and cattle have changed substantially since the 1970s. Do these changes affect the usefulness of the protein withdrawal/phase-feeding concept as it applies to protein? Two experiments might shed some light on the potential for protein withdrawal and(or) phase-feeding to be applied in today's feedlot industry. Bartle and Preston (1994) fed steam-flaked milo-based diets to crossbred steers (initial BW = 312 kg) to compare effects of no implant or an estradiol + trenbolone acetate implant in diets with 11.8, 13.5, or 15.3% CP. Supplemental CP in these diets was derived from a combination of urea, blood meal, and corn gluten meal. A 13.5% CP diet with all supplemental CP from urea also was included, as was a phase-feeding CP treatment (15.3, 13.5, and 11.8% CP for 35 d at each level, with CP withdrawal on d 106). Implanting significantly increased gain and gain efficiency. Gain and gain efficiency were greater with the 13.5 and 15.3% CP diets than with the 11.8% CP diet for implanted cattle, but CP level had little effect on performance by unimplanted cattle. Performance was similar with the urea-based diet and the protein-blend diet. Through 105 d, the phase-fed CP cattle had the highest gain and second-highest gain efficiency, but when CP was withdrawn, performance decreased in the phase-fed group relative to groups fed 11.8% or greater CP.

Erickson et al. (1998) conducted one trial with yearlings and one trial with calves to test application of the NRC (1996) MP and P requirements. In the yearling trial, crossbred steers (initial BW = 297.5 kg) were fed either a standard control diet (dry-rolled corn-based; 13.6% CP and .34% P with all supplemental CP from urea) for a 147-d feeding period or a balanced diet based on high-moisture corn, in which the CP and P levels were changed throughout the feeding period to match NRC (1996) requirements. The CP levels for the balanced diet ranged from 11.2 to 11.9% during the feeding period, with P ranging from 0.22 to 0.24%. Daily gain for the overall trial did not differ between the control (1.84 kg/d) and balanced diets (1.82 kg/d). Dry matter intake was slightly less (11.34 kg/d) by cattle fed the balanced diet than by those fed the control diet (11.88 kg/d), and feed:gain

was 6.45 and 6.21 for the control and balanced diets, respectively. A similar treatment structure was used in the 193-d calf trial, with a control diet that contained 13.4% CP and .35% P vs a balanced diet with CP ranging from 12.7 to 10.8% CP and 0.26 to 0.21% P for the first 98 d of the feeding period and a 10.9% CP, 0.20% P diet for the last 95 d. Daily gain did not differ between the control and balanced diets (average of 1.66 kg/d) nor did DMI (average of 9.32 kg/d), resulting in similar feed efficiency between the two treatments. The authors concluded that a phase-feeding approach using the NRC (1996) requirements for MP and P was as effective as feeding a standard diet for the entire feeding period.

The results of these two experiments suggest that withdrawal of all supplemental CP from finishing diets is not advisable; however, as expected, phase-feeding of CP for growing/finishing beef cattle seems to have merit. Phase-feeding approaches also have been used successfully with lactating dairy cows. Wu and Satter (2000a) suggested that cows fed diets based on high-moisture ear corn, alfalfa silage, and corn silage needed approximately 17.5% CP in the dietary DM during first 30 wk of lactation, but that CP could be decreased to approximately 16% thereafter.

With respect to P, the data of Erickson et al. (1998) suggest that P levels could be decreased significantly, with little impact on performance. As further support, Erickson et al. (1999) compared P levels ranging from 0.14 to 0.34% with either 0.35 or 0.70% dietary Ca in finishing diets for yearling steers. No differences in performance were evident across P levels, and P level did not interact with Ca level. Recent research with dairy cattle also suggests that P levels can be decreased from a typical level of 0.48% of DM to as low as 0.38% of DM, with limited effects on reproduction and lactation performance (Wu and Satter, 2000b; Wu et al., 2000).

Table 2 was prepared using data obtained from a feeding trial with yearling cattle to illustrate the changes in CP and P requirements at 28-d intervals during a feeding period. Crude protein and P requirements and resulting deficiencies or excesses were computed from equations of both NRC (1984) and NRC (1996). It was assumed that a 90% concentrate diet containing 13.5% CP and 0.35% P was fed for the duration of the 140-d feeding period. Results suggest that, except for the first 28 d of the feeding period, CP was in excess. The magnitude of excess CP depended on the system used for calculations, with greater excesses noted with the factorial system of NRC (1984) than with the MP system of the NRC (1996). Allowing for a margin of safety, however, even with the NRC (1996) requirements, CP levels could likely be decreased after the first 56 to 84 d on feed. For P, results differed slightly between the NRC (1984) and NRC (1996) calculation methods, with a small deficiency in P noted for the first 28 d when requirements were calculated with the NRC (1996) equations, and excesses thereafter. Based on NRC (1984) equations, P was in excess for the entire feeding period when the diet was assumed to contain 0.35% P.

**Oscillating Protein Levels.** Increasing the retention of N would decrease excretion of N into the environment. Cole (1999) fed lambs 90% concentrate diets with CP levels of 10,

12.5, or 15%. In the first of two trials, supplemental CP was supplied by cottonseed meal, whereas a 50:50 mixture (CP basis) of cottonseed meal and urea was used in the second trial. In addition to diets with the three CP levels, the 10 and 15% CP diets were oscillated at 24- or 48-h intervals. In the first trial, when cottonseed meal was the source of supplemental CP, N retention was increased 38% by oscillating the 10 and 15% CP levels at 48-h intervals compared with the 12.5% CP diet; however, this effect of oscillation was not observed in the second trial. Oscillating the 10 and 15% CP levels did not affect the proportions of N excreted in the feces or urine compared with continuous feeding of a 12.5% CP diet in either trial. Cole (1999) suggested that oscillating CP levels might increase N utilization by ruminants fed high-concentrate diets and thereby affect the N content of feedlot waste. Further research is needed to verify these results in feedlot cattle.

**Restricted- or Programmed-Feeding Approaches.** Perhaps the simplest means of decreasing the output of N, P, or other nutrients in feedlot waste is to feed fewer nutrients. Feed intake management systems that involve either restricting the quantity of feed offered relative to ad libitum intake or involve feeding only the quantity needed to achieve a desired rate of gain have been used for several years by the cattle industry, particularly in growing programs (Galyean, 1999). These programs often improve feed efficiency relative to ad libitum feeding, but possible negative consequences include decreased carcass weight and quality grade (Galyean, 1999). The effectiveness of restriction depends on accurately predicting ad libitum intake, whereas the effectiveness of programming depends on accurately predicting potential rate of gain. To avoid problems associated with our inability to predict either feed intake or potential rate of gain accurately, a reasonable compromise is to limit or program cattle to a target BW and to provide ad libitum access to feed thereafter.

Loerch and Fluharty (1998) compared three programmed-feeding approaches for finishing steers (300 kg initial BW) fed 85% concentrate diets. Treatments consisted of 1) ad libitum access to feed; 2) programmed for increasing gains (1.13 kg/d, increased to 1.36 kg/d, followed by ad libitum intake); 3) programmed for decreasing gains (ad libitum intake, decreased to 1.36 kg/d, followed by 1.13 kg/d); or 4) programmed for constant gain (1.36 kg/d). For the overall experiment, daily gain did not differ among the four treatment groups, nor did carcass measurements or quality. Steers programmed for increasing gains had the best gain efficiency and consumed the least feed ( $P < 0.10$ ) among the four groups. A savings of 109 kg of feed/steer was realized by programming the steers for increasing gains, but steers programmed for decreasing or constant gains realized no feed savings relative to the ad libitum group. Further research with such approaches will be needed to determine the magnitude of change that might be expected in nutrient excretion with various restricted- or programmed-feeding strategies.

**Application of Approaches.** Practical application of phase-feeding and oscillation of CP levels is not without problems. First, only small changes in feed costs would likely occur if phase-feeding were practiced or if supplemental P

sources were removed from finishing diets. Hence, justifying such changes solely from an economic standpoint might be difficult for most producers. Second, if excess DIP has either ruminal or metabolic buffering effects (Galyean, 1996b) that might alter DMI or affect the incidence of metabolic disorders, decreased CP levels associated with phase-feeding or oscillation might have consequences on the overall cost of production that are not readily projected. Third, from a practical standpoint, problems with mill management and supplement inventory noted by Erickson et al. (1998) also would be a concern with protein phase-feeding or oscillating dietary CP levels. One simple means to implement a CP oscillation strategy might be to withdraw supplement from the diet. Nonetheless, supplements contain more than protein, and the physiological and legal effects of oscillating vitamins, other minerals, and feed additives would need to be considered before such an approach could be recommended. Whether potential decreases in feed cost per unit of gain and(or) environmental benefits outweigh increased management and(or) equipment inputs associated with these strategies needs careful review.

A greater margin of safety in dietary CP content relative to calculated requirements might be needed in commercial beef cattle feedlots, where variation in BW, frame size, and age is greater than in research settings. For phase-feeding approaches to be successful in commercial feedlots, grouping strategies that involve sorting cattle into multiple outcome groups might need to be employed. For example, sorting cattle based on BW and degree of fatness near the time of reimplanting should yield outcome groups that can be more accurately fed with respect to inputs of N, P, and other nutrients. The grouping strategy concept has been modeled in dairy production systems, and results indicate that fairly substantial decreases in N excretion might be possible by grouping (St-Pierre and Thraen, 1999). Caution needs to be exercised, however, because sorting cattle during the later stages of the finishing phase might decrease performance and(or) efficiency of feed utilization, thereby resulting in limited benefits on nutrient output.

Restricted or programmed feeding could be readily applied in practice. As long as restricted or programmed cattle did not overcompensate in DMI after restriction was removed, such feed intake management would be expected to decrease output of total N, P, and other nutrients in feedlot waste. Nonetheless, targeting the appropriate rate of gain or level of intake restriction to be used in such programs is a significant practical challenge.

Despite several potential drawbacks, research attention should be given to these and other possible strategies to manipulate N and P input:output by feedlot cattle. Change by the feedlot industry could be fairly rapid because any of the nutrient management options discussed above could be readily field-tested.

## Nutrient Requirements: A Critical Component in the Nutrient Management Process

Accurate estimates of nutrient requirements are vital not only to animal well-being, but also to management of nutrient inputs. For domestic livestock, nutrient requirements are established by subcommittees of the Committee on Animal Nutrition (CAN), a standing committee of the Board on Agriculture and Natural Resources of the National Research Council (NRC). The NRC nutrient requirement publications have long been valued as an unbiased source of information on nutrient requirements of livestock. The role of these publications in animal agriculture will no doubt increase as we move into the era of nutrient input:output management. Indeed, recent beef cattle (NRC, 1996) and swine (NRC, 1998) reports have included computer models that allow producers to more accurately define nutrient requirements for a given production setting. This move toward computer modeling vs a "one size fits all" approach to nutrient requirements should improve our ability to meet environmental constraints, while maintaining acceptable and profitable levels of production. Unfortunately, limited funding to support the activities of CAN subcommittees slows progress, often resulting in updates of livestock requirement publications less frequently than desired to meet the challenges of a rapidly changing production environment. Frequent revisions of these feeding standards should be wholeheartedly supported by the beef cattle feeding industry.

### Implications

Beef cattle feeding operations will be required to manage nutrient outputs, particularly of nitrogen and phosphorus. Nutrient inputs (e.g., diet formulas) should be based on calculated nutrient requirements, but, with nitrogen, the system of determining requirements markedly affects input decisions. More closely matching nitrogen inputs with requirements over the course of the feeding period (phase feeding) should decrease nitrogen output. Restricted or programmed feeding also might decrease nitrogen output. Based on currently available data, removal of supplemental phosphorus from high-grain beef cattle finishing diets might be possible, but further research is needed.

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### Notes

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**Table 1.** Results of a survey of consulting nutritionists regarding general management practices and percentages of crude protein and urea in beef cattle finishing diets (from Galylean, 1996b)

Consultant	No. of cattle <sup>a</sup>	C:Y <sup>b</sup>	Grains fed <sup>c</sup>	Grain proc. <sup>d</sup>	Rough. level, % <sup>e</sup>	Bunk mgmt. <sup>f</sup>	Iono. <sup>g</sup>	Implant prog. <sup>h</sup>	CP level, % <sup>i</sup>	Urea level, % <sup>j</sup>	Escape form. <sup>k</sup>
A	550	40:60	C,M,W,B	SF	8–11	Clean	Yes	Aggr.	13.8–14.4	1.25-1.4	No
B	1,100	33:67	C,M,W,B	HM,DR,SF	4–9	Clean	Yes	Aggr.	13–13.7	0.9-1.2	No
C	150	50:50	C,M	SF,DR	3–8	Clean	Yes	Mod.	12.5–13	0.7-0.9	No
D	900	20:80	C,M,W	SF,DR	7–10	Clean	Yes	Aggr.	13–14	0.8-1.3	No
E	400	30:70	C,M	SF,HM	9–10	Clean	Yes	Aggr.	13.5–14	1-1.5	No
F	500	50:50	C,M,W,B	SF	10	Clean	Yes	Aggr.	13–14	0.5-1	No

<sup>a</sup>Values are  $\times 10^3$ /yr.

<sup>b</sup>C:Y = approximate ratio of calves (C; cattle on feed for approximately 180 d or greater) to yearlings (Y; cattle on feed for approximately 110 to 180 d).

<sup>c</sup>Grains fed, ranked from left to right by order of use. C = corn; M = milo; W = wheat; B = barley.

<sup>d</sup>Grain processing methods used, ranked from left to right by order of use. SF = steam-flaked; HM = high-moisture harvested and stored; DR = dry-rolled.

<sup>e</sup>Range in roughage levels in finishing diets on a DM basis.

<sup>f</sup>Bunk management approach. In “clean” bunk management, the objective is for the feed bunk to be empty or “slick” within a daily feeding cycle.

<sup>g</sup>Ionophore used in finishing diet.

<sup>h</sup>Implant program. Aggr. = aggressive, which for yearling steers is defined as an estrogen implant initially and an estrogen + trenbolone acetate implant within 80 to 90 d of slaughter. Mod = moderate, which for yearling steers is defined as two estrogen implants during the feeding period.

<sup>i</sup>Range in percentage of CP in the finishing diet on a DM basis.

<sup>j</sup>Range in percentage of urea in the finishing diet on a DM basis.

<sup>k</sup>Formulation for escape protein.

**Table 2.** Crude protein and phosphorus requirements of finishing beef cattle calculated by the NRC (1984) and NRC (1996) methods compared with the supply of crude protein and phosphorus from a typical diet

Days on feed	BW at end of period, kg <sup>a</sup>	DMI, kg/d	Supply from typical diet, g/d <sup>a</sup>		Requirement, g/d				Excess or deficiency, g/d			
					NRC (1984)		NRC (1996)		NRC (1984)		NRC (1996)	
			CP	P	CP	P	CP	P	CP	P	CP	P
0 to 28	383.1	9.07	1,224.5	31.8	1,223.8	28.3	1,406.9	32.4	+0.7	+3.5	-182.4	-0.7
29 to 56	437.6	9.57	1,291.8	33.5	1,025.0	23.9	1,181.1	24.6	+266.8	+9.6	+110.7	+8.9
57 to 84	487.2	9.66	1,304.1	33.8	975.3	23.9	1,130.5	23.4	+328.8	+9.9	+173.6	+10.4
85 to 112	528.1	9.61	1,298.0	33.7	860.7	22.2	986.6	19.8	+437.3	+11.5	+311.4	+13.8
113 to 140	565.6	9.12	1,230.6	31.9	835.9	23.5	1,004.6	20.7	+394.8	+8.5	+226.0	+11.2

<sup>a</sup>Shrunk BW (unshrunk BW × 0.96).

<sup>b</sup>Assumes a diet with 13.5% CP, 0.35% P, 51% degradation of CP (DIP), 10% effective NDF, 2.24 Mcal of NE<sub>m</sub>/kg of DM, and 1.56 Mcal of NE<sub>g</sub>/kg of DM. The initial BW was 314.8 kg.