

NEED FOR RUMINALLY DEGRADED NITROGEN BY FINISHING CATTLE FED PROCESSED GRAINS

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ABSTRACT

Assuring an adequate supply of ruminally degraded N in diets for feedlot cattle is important to maximize ruminal organic matter fermentation and microbial CP production. Growth performance data predominantly from studies using urea as the sole supplemental N source were reviewed to assess the influence of grain processing method and the influence of inclusion of co-products on the need for ruminally degraded N to support optimum performance. Dietary ruminally degraded intake protein (DIP) needs are provided on a 'standardized' basis assuming that corn grain contains 9.5% CP and that barley grain contains 11.5% CP. Growth performance was optimum for cattle fed diets based on dry-rolled corn without co-product inclusion when DIP was approximately 6.5% of diet dry matter. Thus, the optimal percentage of urea in the diet would vary inversely with the ruminally degraded N content of other ingredients fed. Limited data suggest that optimum growth performance by cattle fed a high-moisture corn diet without a co-product occurs with DIP between 8.5 and 9.8% of dry matter. For diets based on steam-flaked corn without a co-product, optimum growth performance was evident when the diet contained approximately 8.25% of dry matter as DIP; the optimum for steam-flaked barley occurred at 9.5% of diet dry matter. Finishing diets containing 20 to 40% wet corn gluten feed supported optimum growth performance when DIP was approximately 9.5% of diet dry matter. Further research is needed to characterize the influence of fractions of DIP on growth performance and to explore the DIP need of cattle fed diets containing distiller's grains.

INTRODUCTION

The metabolizable protein needs of feedlot cattle are influenced by a variety of factors including growth potential, relative feed intake and body weight, and ration energy concentration. The protein profile presented to the small intestine for digestion and absorption directly reflects the undegraded feed protein and microbial CP produced. For a typical steer weighing 1025 lb (800 lb initial weight, 1250 lb shrunk final weight) and consuming 21.5 lb of a 90% concentrate diet based on steam-flaked corn (assuming 0.78 Mcal of NEg/lb of steam-flaked corn; level 1 diet NE adjustment = 92%), predicted (NRC, 1996) microbial CP supply (13% of TDN with eNDF adjustment) alone would provide only 63% of the MP needed to achieve the rate of gain possible based on dietary ME. Thus, microbial protein alone is insufficient to meet protein requirement of this steer. The calculated diet TDN was 90% and diet eNDF was 8%. Thus, the 1142 g of MCP 'possible' ends up as 799 g with the eNDF adjustment or equal to 512 g of MP from bacteria. A deficiency in ruminally degraded N also will limit microbial CP production and in addition may limit ruminal organic matter fermentation and energy supply to the host. Moreover, providing ruminally

degraded N in excess of that required for maximum microbial CP production can improve growth performance.

Corn grain is the most common cereal fed in the feedlot industry in the U.S., although barley, wheat, and sorghum often are more cost-effective ingredients than corn in certain regions. Ruminal N needs can be altered by grain type and the processing method employed to improve starch utilization. Coproducts of the grain milling and ethanol industries such as corn gluten feed (wet and dry) and distiller's grains (wet and dry) are being used widely, particularly in the Northern Plains and the Midwest. The objective of this paper is to review the influence of grain processing and level of coproduct inclusion on the need for ruminally degraded N, particularly NPN, for optimum growth performance. Data evaluated were derived from studies encompassing the entire feeding period to slaughter.

RUMINALLY DEGRADED N IN DIETS BASED ON DRY-ROLLED CORN

Milton et al. (1997) conducted two performance studies with diets based on dry-rolled corn (44.7% DIP; NRC, 1996). In Exp. 1, yearling steers with an initial weight of 732 lb were fed diets containing 10% prairie

hay (60% DIP; NRC, 1996) and either 0, 0.5, 1.0, or 1.5% urea. Steers were given Revalor-S on day 1 and fed for 131 days (3 pens/treatment). Dry matter intake tended ($P < 0.15$) to be higher for steers that did not receive supplemental N (24.5, 23.1, 24.0, and 23.6 lb/day for 0, 0.5, 1.0, and 1.5% urea diets, respectively). Steer ADG was greatest for steers fed 1.0% urea (quadratic; 3.64 lb/day). Feed efficiency was improved 10% by including 0.5% urea in the diet, but feed efficiency was not improved when additional urea was included in the diet (7.31, 6.54, 6.59, and 6.78 lb of feed/lb of gain, respectively). Rib fat thickness and average yield grade increased linearly as dietary urea increased. In Exp. 2, yearling steers with an initial weight of 765 lb were fed diets containing 10% alfalfa hay (82% DIP; NRC, 1996) and either 0, 0.35, 0.70, 1.05, or 1.40% urea. These steers also were given Revalor-S on day 1 and were fed for 141 days (4 pens/treatment). Dry matter intake was greatest for steers fed 1.05% urea and lowest for steers fed 1.4% urea (quadratic; 20.1, 19.9, 20.5, 20.9, and 19.3 lb/day for 0, 0.35, 0.70, 1.05, and 1.40% urea, respectively). Steer ADG also responded quadratically, being greatest for steers fed either 0.35 or 0.70% urea (2.67, 2.80, 2.82, 2.69, and 2.36 lb/d, respectively). Feed efficiency was optimum when the diet contained 0.35% urea (quadratic). Regression analysis of performance data predicted an optimum dietary urea concentration of 0.5% for the diets containing alfalfa hay (second trial) and 0.9% for the diets containing prairie hay (first trial); these values are equal to a dietary DIP of 6.2 and 6.3% of DM, respectively, using tabular DIP values for ingredients (NRC, 1996).

Shain et al. (1998) pooled data from two finishing studies (8 pens/treatment) in which diets based on dry-rolled corn contained a blend of alfalfa hay (5% of DM; 82% DIP) and corn silage (5% of DM, 75% DIP; NRC, 1996). Diets were supplemented with 0, 0.88, 1.34, or 1.96% urea, resulting in dietary CP concentrations of 8.9, 11.1, 12.6, and 14.1% CP. Corresponding dietary DIP calculated from tabular values were 4.5, 7.1, 8.4, and 10.2% of DM. Steers weighed 791 lb initially and were fed an average of 87 days. Steers received either Compudose or Revalor-S on day 1 of the feeding period. Dry matter intake was not altered by treatment (25.5, 26.2, 25.7, and 26.0 lb/day, respectively). Steer ADG (3.15, 3.39, 3.31, and 3.42 lb/day, respectively) and feed efficiency (8.09, 7.73,

7.76, and 7.60 lb/lb, respectively) were improved by urea addition to the diet when one considers the average of all urea-supplemented diets to the unsupplemented control diet. Thus, the optimum dietary DIP presumably was between 4.5 and 7.1% of DM.

RUMINALLY DEGRADED N IN DIETS BASED ON HIGH-MOISTURE CORN

Surprisingly few data are available for high-moisture corn considering the changes in soluble N and the high extent of ruminal starch digestion with this processing method. Cooper et al. (2002) fed diets containing a blend of alfalfa hay (5% of DM) and cottonseed hulls (5% of DM, 50% DIP; NRC, 1996) and either 0, 0.4, 0.8, or 1.2% urea. Steers were given Synovex Plus on day 1 (initial weight = 835 lb) and were fed for 108 days. The high-moisture corn, harvested at 29% moisture, was rolled before ensiling. Diets were reported to contain 10.6, 11.8, 12.9, and 14.1% CP; corresponding DIP reported were 7.0, 8.2, 9.3, and 10.5% of DM. However, the high-moisture corn must have contained approximately 11.0% CP to match the dietary CP concentrations reported. To compare these data with that of other experiments compiled for this summary, dietary CP and degradable intake protein were calculated assuming that the high-moisture corn contained 9.5% CP (and 67.8% DIP; NRC, 1996). These adjusted values were 9.0, 10.2, 11.5, 12.5% dietary CP with 6.3, 7.4, 8.6, and 9.8% of dry matter as DIP. Dry matter intake was not altered by treatment (27.1, 26.7, 26.7, and 26.7 lb/day for 0, 0.4, 0.8, and 1.2% urea, respectively). However, steer ADG increased linearly as urea concentration increased (3.75, 3.79, 4.01, and 4.08 lb/d, respectively); the magnitude of the increase was much smaller beyond 0.8% urea. Feed efficiency data were evaluated only by regression against dietary urea; feed efficiency averaged 7.23, 7.04, 6.66, and 6.54 lb/lb, respectively. Carcass rib fat thickness increased linearly with dietary urea, but marbling score decreased linearly as dietary urea increased.

RUMINALLY DEGRADED N IN DIETS BASED ON STEAM-FLAKED GRAINS

Data describing the NPN needs for optimum performance by cattle fed steam-flaked sorghum or wheat are not available, but one experiment involving steam-flaked barley and several involving steam-flaked corn have been conducted. Zinn et al. (2003) fed calves with an initial weight of 556 lb for 84 days. Calves were fed diets based on steam-flaked barley (66.9% DIP;

NRC, 1996), 10% forage (alfalfa hay + sudan hay [69% DIP; NRC, 1996]), and either 0, 0.4, 0.8, or 1.2% urea as the sole source of supplemental CP (5 pens/treatment). Diets contained 10.5, 11.5, 12.5 or 13.5% CP; corresponding DIP calculated from tabular values were 7.1, 8.3, 9.5, and 10.6% of DM. The barley was reported to have contained 11.8% CP. Steer calves were given Synovex-S on day 1. Dry matter intake was not altered by treatment (14.9, 15.4, 16.1, and 16.2 lb/day, respectively). Although ADG increased linearly (3.02, 3.15, 3.37, and 3.26 lb/day, respectively), ADG was not numerically improved when the diet contained above 0.8% urea. Feed efficiency also increased linearly as urea increased (4.93, 4.89, 4.78, and 4.97 lb/lb, respectively), but feed efficiency was numerically optimum with 0.8% dietary urea.

Cooper et al. (2002) fed diets based on steam-flaked corn (29 lb/bu, 43% DIP; NRC, 1996) that contained 5% alfalfa hay and 5% cottonseed hulls. Supplemental N was provided by including 0, 0.4, 0.8, 1.2, 1.6, or 2.0% urea (4 pens/treatment). Dietary CP ranged from 9.5 to 15.3%, whereas DIP concentrations were 4.7, 5.8, 7.0, 8.2, 9.3, and 10.5% of DM, respectively. Steers were given Synovex-C on day 1 (initial weight = 782 lb) and Revalor-S on day 47 of the 129-day feeding period. Dry matter intake, ADG, and feed efficiency responded quadratically; performance was optimized between 0.8 and 1.2% urea.

Healy et al. (1995) fed yearling steers (785 lb) diets based on steam-flaked corn. Steers were provided either no supplemental N, or blends of urea and soybean meal (N basis; 0:100, 33:67, 67:33, and 100:0) to attain 13% CP in the diet. Corresponding urea inclusion rates were 0, 0.6, 1.2, and 1.7% of DM, whereas soybean meal (65% DIP; NRC, 1996) inclusions were 10.8, 7.0, 3.3, and 0%. Dietary DIP values were not calculated because complete diet composition was not available. Growth performance was improved markedly by providing supplemental N; performance was optimized with a blend of 33% soybean meal and 67% urea. Steers fed the 33:67 soybean meal:urea produced carcasses with the greatest fat thickness.

Gleghorn et al. (2004) pooled data across two experiments in which steers were fed diets based on steam-flaked corn contained 11.5, 13.0, or 14.5% CP

provided by blends of urea and cottonseed meal (N basis; 100:0, 50:50, and 0:100). Cottonseed meal was assumed to contain 57% DIP (NRC, 1996). Corresponding DIP concentrations ranged from 6.1 to 9.7% of DM. Steers received Ralgro on day 1 and Revalor-S on day 56. Steers had an initial weight of 729 lb and were fed an average of 162 days (9 pens/treatment). No interaction of dietary CP and urea:cottonseed meal was detected for the performance data. Dry matter intake was not altered by either CP or urea:cottonseed meal. Adjusted ADG increased by 5% as dietary CP was increased from 11.5 to 13.0%. Adjusted ADG increased linearly and adjusted feed efficiency improved linearly as urea replaced cottonseed meal. Thus, the optimum performance occurred when the diet contained approximately 8.2% dietary DIP (1.0% urea).

RUMINALLY DEGRADED N IN DIETS CONTAINING MILLING AND ETHANOL CO-PRODUCTS

Block et al. (2005) compared performance of cattle fed a control diet based on steam-flaked corn formulated to contain 1.8% urea as the sole supplemental N source to provide 14% dietary CP (9.0% DIP of DM) with various diets containing wet corn gluten feed (Sweet Bran, 75% DIP; NRC, 1996). Diets containing 20% wet corn gluten feed were supplemented with 0.62, 0.87, or 1.13% urea (14.0, 14.7, and 15.4% dietary CP, respectively). Diets containing 30% wet corn gluten feed were supplemented with 0.15, 0.40, or 0.65% urea (14.3, 15.0, and 15.6% dietary CP, respectively), whereas diets containing 40% wet corn gluten feed were supplemented with 0 or 0.19% urea (15.4 or 16.0% dietary CP, respectively). The DIP of diets containing wet corn gluten feed ranged from 8.7 to 10.6% of DM. All diets contained 10% of DM as corn silage. Steer calves weighing 635 lb were implanted on day 1 with Synovex-S and received Revalor-S on day 70 of the 166-day feeding period (3 pens/treatment). Dry matter intake was highest with 30% wet corn gluten feed. Steer ADG and feed efficiency were optimized when the diet contained 20% wet corn gluten feed. Performance data indicated that optimum ADG and feed efficiency occurred when diets containing wet corn gluten feed contained a dietary CP concentration of 15.4% (20% wet corn gluten, 1.13% urea), 15.0% (30% wet corn gluten, 0.40% urea), and 15.4% CP (40% wet corn gluten, no added urea). The corresponding dietary DIP concentrations were 9.7 to 10.2% of DM, although the

authors reported that the regression-predicted optimum DIP was 9.6% of DM ($R^2 = 0.28$).

Macken et al. (2006) fed 679-lb steer calves diets containing 25% wet corn gluten feed (Sweet Bran) and 10% corn silage for 152 days. Treatments involved one of two dietary CP concentrations (14 or 15%) achieved by including 0.3 or 0.6% urea factored across five grain processing treatments that included dry-rolled corn, finely round corn, rolled high-moisture corn, ground high-moisture corn, and steam-flaked corn (4 pens/treatment). No interaction of dietary CP and grain processing was detected for growth performance data. Thus, the main effect of dietary CP was derived with 20 pens/treatment. Increasing dietary CP to 15% (9.8% of diet dry matter as DIP) did not influence growth performance or carcass characteristics beyond that achieved with 14% CP (8.8% of diet dry matter as degradable protein).

Richeson et al. (2006) implanted yearling steers (886 lb) on day 1 with Revalor-S and fed diets based on steam-flaked corn and 25% wet corn gluten feed (Sweet Bran) for 116 days. Treatments included diets formulated to contain 14% CP provided either by only urea (0.44% of DM; 9.4% of diet DM as DIP), 67:33 urea:cottonseed meal (N basis; 9.3% of diet DM as DIP), or 33:67 urea:cottonseed meal (9.2% of diet DM as DIP; 8 pens/treatment). The analyzed dietary CP concentrations were close to the expected values (13.5%), but the degradable protein content reported above was tabulated assuming that corn contained 9.5% CP. Dry matter intake was not influenced by source of supplemental N, but ADG increased linearly as the proportion of urea increased (4.19, 4.36, and 4.34 lb/day for 33, 66, and 100% urea, respectively). Feed efficiency tended to be

poorer when urea comprised only 33% of the supplemental N.

GRAIN PROTEIN AND STARCH DIGESTION CHARACTERISTICS

Tabular values for ingredient DIP for processed corn (NRC, 1996; Table 1) were applied to all studies reviewed. However, actual DIP of ingredients will indeed be influenced by factors other than grain processing that drive extent of ruminal OM digestion and microbial yield such as feed intake, rate of passage, and ruminal pH patterns. In vivo data summarized in previous reviews clearly indicate that steam flaking and high-moisture ensiling increase the extent of ruminal starch digestion (Table 1). Using the NRC (1996) level 1 model, estimates of the predicted DIP deficiency of a basal diet (no supplemental protein included) based on corn that was dry-rolled, steam flaked, or in high-moisture form were derived. Microbial efficiency was assumed to be 13% of TDN with the appropriate eNDF adjustment for each diet. Alfalfa hay was used as the forage source at 5, 10, and 10% of diet DM for diets containing dry-rolled, steam flaked, and high-moisture corn, respectively, to approximate diet composition of studies reviewed here. Feed intake was assumed to be equal for the steam flaked and high-moisture diets (21.5 lb/d), and feed intake of the dry-rolled diet was assumed to be 110% of the former (23.65 lb/d). Assuming in this example that the DIP deficit (Table 1) is equivalent to the added urea needed, the diets would need to include 0.79% (dry-rolled), 1.06% (steam flaked) and 0.02% urea (DM basis). Thus, the DIP need for each of these diets follows the extent of ruminal starch digestion much more closely than ruminal protein digestion. Indeed, Cooper et al. (2002) reported a very close relationship ($r^2 = 1.0$) between ruminal starch digestion (dry-rolled, steam flaked, and high-moisture corn) and regression-predicted DIP need (based on feed efficiency) derived from a growth performance study.

Table 1. Estimates of degraded intake protein (DIP), ruminal starch digestion and model-predicted DIP deficit in diets based on processed corn without supplemental N

Item	Tabular DIP, % of crude protein	Ruminal starch digestion, % of Dry matter		Predicted DIP deficit, g/d
Dry-rolled	44.7	76.2	63.8	- 244
Steam flaked	43.0	84.8	86.5	- 296
High-moisture	67.8	89.8	84.1	- 7
Source	NRC, 1996	Huntington, 1997	Owens, 2005	NRC, 1996

SUMMARY

Dietary need for ruminally degraded intake protein (DIP) was calculated for the experiments reported assuming that corn contains 9.5% CP and that barley contains 11.5% CP. Growth performance was optimum for cattle fed diets based on dry-rolled corn without co-product inclusion when degraded intake protein was approximately 6.5% of diet dry matter. Thus, the optimum percentage of urea to be included in the diet would vary inversely with the ruminally degraded N content of the other dietary ingredients. Limited data suggest that optimum growth performance by cattle fed a high-moisture

corn diet with no added co-products occurs with DIP near 9.5% of dry matter. For diets based on steam-flaked corn with no added co-product, optimum growth performance was evident when the diet contained approximately 8.25% of dry matter as DIP; the optimum DIP for steam-flaked barley occurred at 9.5% of diet dry matter. Finishing diets containing 20 to 40% wet corn gluten feed supported optimum growth performance when DIP was approximately 9.5% of diet dry matter. Further research is needed to characterize the influence of DIP fractions on growth performance and to describe the DIP requirement for diets containing distiller's grains.

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QUESTIONS AND ANSWERS

Q: Thirty years ago, we had papers about soluble protein content of high moisture corn. Today we heard about soluble protein in reconstituted milo. What's it mean? Can we use it?

A: Soluble protein is likely to be degraded in the rumen. High-moisture and reconstituted grains have higher amounts of soluble and ruminally degraded protein. This should be considered when you decide how much non-protein nitrogen should be added to the ration. Soluble N content is reflective of DIP.

Additional Comment by Soderlund: There is a high correlation between soluble N content and ruminal starch digestion; both increase during storage. Recent Nebraska work and some of our work from about 10 years ago show that correlation.

Q: Mike, you omitted values for the dietary DIP value for rations with wheat. What is your estimate of dietary DIP on steam-flaked wheat rations?

A: I would anticipate that DIP for steam-flaked wheat would be similar to the DIP value for high-moisture corn.