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Effects of a Dietary Mixture of Meat and Bone Meal, Feather Meal, Blood Meal, and Fish Meal on Nitrogen Utilization in Finishing Holstein Steers¹

W. F. Knaus*, D. H. Beermann†, T. F. Robinson†, D. G. Fox†, and K. D. Finnerty†

*Department of Animal Science, University of Agriculture, Forestry and Renewable Natural Resources, A-1180 Vienna, Austria and †Department of Animal Science, Cornell University, Ithaca, NY 14853

ABSTRACT: Our objective was to determine to what extent rate and efficiency of protein gain in finishing cattle can be enhanced by feeding an amino acid-balanced mixture of undegraded intake proteins. The Cornell Net Carbohydrate and Protein System (CNCPS) model was used to formulate a corn-based diet that would meet the rumen requirements for 410-kg large-framed steers with an estrogen implant and fed an ionophore. The CNCPS model was also used to formulate a highly undegradable intake protein (UIP) mixture from meat and bone meal, blood meal, fish meal, and hydrolyzed feather meal to provide the amino acids needed to supplement those derived from microbial protein to better meet amino acid requirements for growth. Four Holstein steers weighing 407 kg were offered a 90:10 concentrate-forage diet at hourly intervals at 95% of ad libitum intake. The steers were injected with 500 µg of estradiol-17β at 12-h intervals to mimic the effects of an estrogenic implant. Treatments planned consisted of inclusion of the UIP mixture at 0, 2.5, 5, and 7.5%

of the diet DM. Dry matter intake was fixed at 6.4 kg/d, and DM digestibility was not significantly affected by varying the amount of UIP addition. Apparent digestibility of N increased ($P = .011$) from 63.8 to 65.8, 70.7, and 71.5%, the amount of N absorbed increased ($P = .001$) from 73 to 84, 100, and 106 g/d, and N balance increased ($P = .003$) from 20 to 30, 33, and 39 g/d when UIP was fed at 0, 2.6, 5.2, and 7.8% of diet DM, respectively. The efficiency of N use increased 39.7%, and biological value increased 31.6% when the UIP mixture was added to the diet. Circulating concentrations of plasma urea N (PUN) were increased ($P = .017$) from 4.5 for the control diet to 5.7, 6.2, and 6.1 mg/dL when the UIP mixture was added at 2.6, 5.2, and 7.8%, respectively. Corresponding IGF-I concentrations were also increased from 491 to 558 and 624 ng/mL with 2.6 and 5.2% levels of UIP addition. Plasma glucose, NEFA, and insulin concentrations were not affected by feeding the UIP mix. The rate and efficiency of N use for growth improved with addition of an amino acid-balanced UIP mixture to the diet.

Key Words: Cattle, Amino Acids, Nitrogen Metabolism

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Introduction

Animal by-products are useful feedstuffs for protein supplementation, improving the efficiency of dietary N utilization, and recycling "waste-nutrients" in ruminant diets. It is difficult to meet the specific amino acid requirements of growing-finishing cattle with conventional cereal-based diets. A shortage of specific amino acids may result because the mixture of amino acids delivered to the site of absorption is of insufficient quantity and/or quality to meet performance capabilities under some conditions (Richardson and Hatfield, 1978; Houseknecht et al., 1992). Supplementing diets with proteins that are resistant to ruminal degradation can increase the amount and/or alter the pattern of amino acids entering the small

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intestine (Zinn et al., 1981; Titgemeyer et al., 1989) and increase nitrogen retention (Cecava and Hancock, 1994). Quantitative estimates of the optimum combination and level of dietary undegraded intake proteins for growing cattle are lacking. The Cornell Net Carbohydrate and Protein System (CNCPS) model uses measured rates of rumen degradability and amino acid composition of protein sources to formulate diets that match mass and balance of amino acids at the site of absorption to tissue requirements of growing cattle. Previous experiments have demonstrated significant improvement in rates and efficiency of N use for growth in young Holstein steers fed a supplemental protein mixture formulated with the CNCPS model (Robinson et al., 1996). Use of anabolics may increase protein requirements, especially for large-framed cattle (Trenkle, 1993). This experiment was conducted to evaluate the effects of feeding four dietary levels of an "amino acid-balanced" combination of meat and bone meal (MBM), fish meal (FM), hydrolyzed feather meal (FtM) and blood meal (BM) on nitrogen metabolism and plasma metabolite and metabolic hormone concentrations in finishing Holstein steers.

Materials and Methods

Animals and Diets

Four Holstein steers with an average initial weight of 407 kg were purchased from a commercial feedlot

and transported to the Cornell University Large Animal Research and Teaching Unit. They were housed in individual metabolism stalls under environmentally controlled thermoneutral conditions and acclimated for 3 wk before the onset of treatment. The metabolism stalls were constructed of galvanized pipe (3.8 cm diameter) over rubber-padded concrete flooring and a metal grate for fecal collections. Stalls were approximately 2.3 m long \times 1.1 m wide. Procedures involving the steers used in this study were approved by the Cornell University Institutional Animal Care and Use Committee.

The CNCPS (Fox et al., 1992; Russell et al., 1992; Sniffen et al., 1992; Ainslie et al., 1993; O'Connor et al., 1993) was used to formulate a corn-based control diet that would meet the ruminal requirements for 410-kg large-framed steers supplied with an estrogen implant and fed an ionophore. The CNCPS analysis predicted that rumen N balance and rumen peptide balance were positive for the control diet and each diet containing the UIP by-product mixture. Fresh control diet was offered twice daily to provide an excess of daily intake for 2 wk to determine ad libitum intake for each animal. Orts were weighed daily. The steers were in good health throughout the experiment. The CNCPS model was also used to formulate a highly undegradable intake protein (UIP) mixture of MBM, FM, FtM, and BM that provided the amino acids needed to supplement those derived from microbial protein. An ionophore (Rumensin[®] Elanco, Indianapolis, IN; 33 mg/kg feed) was added to the diets to

Table 1. Ingredients and chemical compositions of diets fed to Holstein steers^a

Item	UIP, % ^b			
	0	2.6	5.2	7.8
	% of DM			
Ingredient				
Grass hay	9.2	9.2	9.2	9.2
Ground corn	81.8	80.2	78.6	77.0
Soybean meal	6.0	4.5	3.0	1.5
Meat and bone meal	0	1.0	2.0	3.0
Fish meal	0	.6	1.2	1.8
Hydrolyzed feather meal	0	.5	1.0	1.5
Blood meal	0	.5	1.0	1.5
Beef tallow	0	.5	1.0	1.5
Vegetable oil	1.0	1.0	1.0	1.0
Salt and trace minerals	1.0	1.0	1.0	1.0
Dicalcium	1.0	1.0	1.0	1.0
Chemical composition				
OM, %	97.0	96.6	95.9	95.3
CP, %	11.3	12.5	13.8	14.9
NE, Mcal/kg				
Maintenance	2.05	2.02	2.02	2.04
Gain	1.56	1.55	1.55	1.56
NDF, %	19.5	18.9	20.4	21.6
ADF, %	5.6	5.7	6.2	4.9

^aDM basis.

^bLevels represent the portion of UIP expressed as a percentage of diet DM.

facilitate control of acidosis and a steady flow of microbial protein to the small intestine.

Steers were randomly assigned to treatments arranged factorially in a 4×4 Latin square design. Treatments consisted of addition of this mixture to the basal diet at 0, 2.6, 5.2, and 7.8% of the total mixed diet (90.8% concentrate, 9.2% chopped grass hay). The ingredients and chemical compositions of the diets are presented in Table 1. Diets were fed hourly in equal portions via automatic feeders for 14 d per treatment period. Daily intake was fixed at 95% of the measured ad libitum intakes for each steer and was maintained throughout the experiment. The first 7 d of each treatment period were allowed for adaptation to the diet, and N balance collections were conducted from d 8 to 14. Feed refusals were measured once daily. Water was freely available throughout the study. Body weight was determined for each treatment period to verify that growth was occurring during the study. Steers were injected s.c. twice daily with 500 μg of estradiol-17 β to mimic the effects of an anabolic implant starting 2 wk before initiation of dietary treatments. Commercial estrogenic implants are designed to deliver between 60 and 100 μg of estradiol per day for the first 2 to 3 wk and 30 to 60 $\mu\text{g}/\text{d}$ thereafter. The increase in circulating concentration achieved with s.c. injection is much shorter in duration compared with the more constant elevation achieved with an implant.

Sample Collection and Analysis

Feces, urine, and feed refusals were collected at 0900 daily during the nitrogen balance collection periods. Continuous suction of the urine from a rubber funnel system attached to the ventral portion of the abdomen allowed collection of urine into a plastic carboy. Urine acidity was reduced to $\text{pH} < 2$ by adding 200 mL of 9 mol/L H_2SO_4 to the collection reservoir. Daily urine volume and wet weight of feces were measured, and 10 % aliquots were collected for analysis. Subsamples of urine were stored at -18°C . Before subsampling, daily feces collections were homogenized in a blender with formaldehyde (370 mL/L solution, .25 mL/kg feces) to retard spoilage. The feed refusals and feces were dried at 65°C for 48 h and ground. Daily feed refusals and fecal and urine aliquots were composited for each collection period, and Kjeldahl N analysis was conducted on duplicate samples of each.

Each steer was surgically fitted with a jugular vein catheter between 0900 and 1200 on d 14 of each treatment. Venous blood samples were collected in heparinized tubes at 60-min intervals over a 6-h period beginning at 1300 and were immediately centrifuged at $3,000 \times g$ for 20 min. The plasma was harvested and frozen at -18°C . Blood sample collections encompassed six feed offerings to assess any feeding interval-related effects that might occur.

Nitrogen content of feed, feces, and urine was determined with Kjeldahl analyses (AOAC, 1990). Chemical composition of feedstuffs and total diets was determined in duplicate at the Northeast Dairy Herd Improvement Association Forage Testing Laboratory (Ithaca, NY). Amino acid (AA) concentrations were determined on hydrolyzed duplicate samples of the same as described by Krick et al. (1993).

Plasma glucose concentrations were measured with a Sigma kit (Procedure #510, Sigma Diagnostics, St. Louis, MO) for colorimetric determination. Plasma urea N (PUN) was measured with the method of Chaney and Marbach (1962). Plasma NEFA concentrations were determined with a modification of an enzymatic colorimetric kit (NEFA-C, Cat. No. 990-75401, Wako Pure Chemical Industries, Dallas, TX). Plasma insulin concentrations were determined in 100- μL sample volumes with the solid-phase Autopack RIA kit (Micromedic, Horsham, PA). Intraassay CV was 14.1%. Serum IGF-I concentrations were measured with a double antibody RIA as described by Beermann et al. (1991).

Statistical Analysis

All statistical analyses were conducted using Model 1 of the LSMLMW Analysis of Variance computer program (Harvey, 1990). Data were analyzed as a completely randomized 4×4 Latin Square design. The model sums of squares were partitioned into the main effects of animal, period, and treatment. Differences between diet least squares means were analyzed using the BONFERRONI-HOLM test procedure (Holm, 1979) when main effects were significant. All data are presented as least squares means. Differences were considered to be significant when $P < .05$.

Results and Discussion

Results of the AA analysis of the grass hay, ground corn, SBM, MBM, FM, FtM, and BM, as well as of the animal protein mixture used in this study, are summarized in Table 2. Values are comparable to those of Mäntysaari et al. (1989), Gibb et al. (1992), and Palmquist and Weiss (1994). The CNCPS model recommended proportions of 39:23:19:19 for MBM:FM:FtM:BM, respectively. These protein sources were chosen based on availability and their complementary contributions to amino acids absorbed when growing cattle are fed a corn-based diet. The advantage of combining these animal by-products is to achieve a complementary effect of the different amino acid compositions and varying degradability of protein sources in the rumen. The hypothesis is that rate and(or) efficiency of nitrogen utilization can be enhanced in growing-finishing steers by feeding appropriate combinations and amounts of animal by-product mixes when conventional diets are fed and

Table 2. Amino acid concentrations of feedstuffs^a

Amino acid	Grass hay	Ground corn	Soybean meal	Meat and bone meal	Fish meal	Feather meal	Blood meal	Mix ^b
Arginine	.36	.38	4.29	2.92	3.87	6.34	4.75	3.98
Cystine	0	.01	.05	.13	.12	.66	.11	.09
Glycine	.48	.37	2.60	7.45	4.70	7.23	4.95	5.97
Histidine	.13	.25	1.53	.59	1.47	1.19	6.61	1.55
Isoleucine	.33	.29	2.83	1.02	3.02	4.80	1.18	2.08
Leucine	.68	1.07	4.68	2.27	5.14	8.29	14.82	5.42
Lysine	.31	.29	3.54	1.82	5.06	2.85	10.77	3.56
Methionine	.01	0	.02	.02	.04	.04	.01	.02
Phenylalanine	.38	.40	2.93	1.22	2.65	4.61	8.20	2.99
Threonine	.30	.37	2.51	1.21	3.72	4.82	7.06	2.84
Tryptophan	.15	.18	2.11	.71	2.09	2.74	3.89	1.93
Valine	.32	.34	2.73	1.58	3.24	7.30	10.45	4.43
TSAA ^c	.01	.01	.07	.15	.16	.70	.12	.12

^aExpressed as g/100 g DM.

^bMix = mixture of meat and bone meal, fish meal, feather meal, and blood meal used in diets.

^cTotal sulfur amino acids (methionine + cystine).

energy intake is adequate. Feeding several levels of the mixture allows assessment of the optimum level of supplementation for cattle of specified genotype, gender, and stage of growth.

No difference in DMI was observed as the dietary level of UIP increased from 0 to 7.8% (Table 3). Daily gain was not increased significantly but increased numerically from 770 g/d to 1,232 g/d on average with UIP supplementation. These data are presented to provide evidence that growth was observed throughout the experiment, rather than to estimate gains that might apply to a feedlot environment. Increased long-term growth rates were observed in studies conducted by Titgemeyer et al. (1989), Cecava et al. (1990), and Goedeken et al. (1990). Diets used in those studies were based on projected rates of amino acid disappearance from the small intestine and the expectation that

combining undegraded protein sources will provide greater improvement in amino acid composition than feeding a single source of undegraded intake protein to ruminants fed corn or corn-soy-based diets. In a previous study, Angus and Angus × Hereford steers averaging 280 kg were fed a basal diet of approximately 80% corn supplemented with MBM and BM to provide 11% dietary crude protein (Loerch and Berger, 1981). Observed gains were .11 and .08 kg/d higher, respectively, than those obtained with SBM as the only protein supplement. Beermann et al. (1986) reported significantly enhanced skeletal muscle growth in lambs fed for 10 wk an isonitrogenous corn-based diet that contained 3% FM plus SBM when compared with those fed SBM alone.

Dry matter digestibility was not significantly affected, but apparent digestibility of N increased ($P =$

Table 3. Effects of increasing amounts of a dietary animal by-product protein mixture on apparent digestibility and nitrogen metabolism

Item	UIP, % ^a				Pooled SE	Significance (P)
	0	2.6	5.2	7.8		
No. of animals	4	4	4	4		
Average daily gain, g/d	770	1303	1078	1315	287	.212
Intake, kg of DM/d	6.40	6.42	6.43	6.42	.04	.844
Apparent digestibility, %						
Dry matter	75.3	76.2	77.2	77.8	2.0	.362
Nitrogen	63.8 ^b	65.8 ^{bc}	70.7 ^c	71.5 ^c	2.5	.011
N intake, g/d	114.2 ^b	127.5 ^c	141.4 ^d	151.4 ^e	2.8	<.001
Fecal N, g/d	41.4	43.6	41.5	45.1	2.6	.342
Urine N, g/d	53.7 ^b	53.5 ^b	66.7 ^c	67.2 ^c	3.7	.013
N retention, g/d	19.6 ^b	30.5 ^c	33.3 ^c	39.3 ^c	3.3	.003
N retention, % of N intake	17.4	23.9	23.3	25.7	2.7	.079
Biological value (N retention, % of N absorbed)	26.9	36.7	33.0	36.5	4.3	.149

^aLevels represent the portion of undegradable intake protein (UIP) expressed as a percentage of diet DM.

^{b,c,d,e}Means within a row with different superscripts differ ($P < .05$).

Table 4. Plasma urea nitrogen, glucose, NEFA, insulin, and IGF-I concentrations

Item	UIP, % ^a				Pooled SE	Significance (<i>P</i>)
	0	2.6	5.2	7.8		
No. of animals	4	4	4	4		
Plasma urea N, mg/dL	4.5 ^b	5.7 ^{bc}	6.2 ^c	6.1 ^c	.6	.018
Glucose mg/dL	92.0	90.6	89.1	91.9	3.6	.758
NEFA, μ mol/L	112.2	119.3	120.7	140.3	19.7	.310
Insulin, ng/mL	1.4	1.4	1.3	1.6	.2	.663
IGF-I, ng/mL	491.4	557.9	623.7	508.7	38.9	.047 ^d

^aLevels represent the portion of undegradable intake protein (UIP) expressed as a percentage of diet DM.

^{b,c}Means within a row with different superscripts differ ($P < .05$).

^dPairwise comparison using BONFERRONI-HOLM test procedure resulted in no significant ($P < .05$) difference.

.01) from 63.8 to 65.8, 70.7, and 71.5% when UIP was added to the diet at levels of 0, 2.6, 5.2, and 7.8%, respectively. The N disappearing from the small intestine can be considered the N fraction of greatest value for the animal (Titgemeyer et al., 1989); it is either stored as tissue N or excreted as urinary N (Nakamura et al., 1994). Urinary N excretion was higher ($P = .013$) at dietary UIP levels of 5.2 and 7.8%, but N retained, expressed as a percentage of total N intake, remained unchanged. Although N retained per day was not significantly different among the three levels of UIP addition, the two highest levels (5.2 and 7.8% UIP) produced increases of 9 and 29%, respectively, compared with the 2.6% level of UIP addition. If maximum or genetic capacity for N retention is considered appropriate for defining protein "requirements" for the animal, results suggest that protein and amino acid requirements were not being met at the lower levels of UIP addition. An 18% greater rate of N retention was observed with the 7.8% UIP diet compared with the 5.2% UIP diet.

Increased PUN concentrations were observed with the two highest levels of UIP addition. These increases were quite small, however, suggesting that requirements were being approached or approximated at the highest level of UIP addition. The increases in PUN cannot be attributed to poorer amino acid balance because biological value, expressed as N retained as a percentage of N absorbed, remained unchanged across the three levels of UIP addition.

The highest level of UIP addition increased N retention by 100% ($P = .003$) compared with the control diet. Although N retention increased throughout all levels of UIP addition, the increase was not linear, as was the increase in total N intake. As N intake increased in a linear manner from 114 to 151 g/d, fecal N excretion increased only 4 g/d and urinary N excretion increased 13.5 g/d. The proportion of N retained was clearly increased with all levels of UIP addition. Biological value, which is an indicator for how well the digested AA composition meets tissue requirements, increased 32% on average across all three levels of UIP addition. Similarly, the partial efficiency of N utilization, calculated as N retained

divided by N intake, improved an average of 40% ($P = .08$) with inclusion of UIP in the diet. Therefore, although an increase in N digestibility explains part of increased efficiency, it appears that improved amino acid composition of the absorbed N is a significant factor as well.

Additional evidence to support this conclusion is provided by the PUN data. Concentrations of PUN were significantly increased only when the UIP supplement was fed at 5.2 and 7.8% of the diet, and these increases were small (Table 4). These results reflect the lack of proportional increase in N retention with each increase in total N intake above the 2.6% level of UIP addition. Because biological value of the absorbed N was similar at all levels of UIP addition to the diet, results support the conclusion that efficiency of N use can be improved and maintained, even when dietary changes cause increases in PUN concentrations (control vs UIP diets).

Beermann et al. (1991) and Houseknecht et al. (1992) also reported substantial increases in PUN concentrations in growing lambs and steers, respectively, when casein was abomasally infused, and efficiency of N use was enhanced. At the highest level of UIP feeding, PUN was only slightly higher (1.7 mg/dL) in association with the 37 g/d increase in N intake in the present study. A much larger increase in PUN was observed (5.1 mg/dL) when N intake was increased only 21 g/d by abomasal infusion of casein in similar steers (Houseknecht et al., 1992). Feeding the UIP supplement at 7.8% of the diet increased N absorbed by 33 g/d, whereas the casein infusion increased N absorbed by only 21 g/d. The complementary effect of the UIP to improve amino acid composition to better match tissue requirements could account for the lesser increase in PUN observed, albeit total N absorbed was increased by a greater amount.

Results demonstrate that even with improved composition of absorbed AA, efficiency of N use for growth declines with increasing maturity. Biological values were less in these heavier steers (.36, .33, and .36) than in lighter steers of similar genotype (.45 to .49) fed the same protein supplement mixture at similar levels (Robinson et al., 1996).

By studying the effects of abomasally infused AA on N retention and plasma AA levels, methionine, lysine, and threonine were recognized to be deficient in the microbial protein for growing cattle (Richardson and Hatfield, 1978). The use of ruminally protected AA in growth studies has been generally disappointing. Because the supply of several amino acids (co-limiting amino acids) may limit performance when typical diets are fed, feeding individual ruminally protected amino acids seems to have limited potential (Merchen and Titgemeyer, 1992). Wright and Loerch (1988) observed no improvement in DM digestibility, N digestibility, and N balance in lambs fed ground corn-soybean hull diets supplemented with urea and rumen-protected methionine added at up to .12% of the diet. Responses to postruminal infusions of whole proteins and(or) mixtures of AA often indicate that no single AA is responsible for limiting the postruminal protein supply, and that maximal growth is achieved when whole proteins are provided postruminally rather than when one or two AA are supplied (Merchen and Titgemeyer, 1992; Robinson et al., 1996).

Improving rates of total amino acid absorption also seems to be important for improving rates of protein accretion in growing ruminants. Results from a study conducted by Beermann et al. (1991) demonstrate that enhancing the mass of absorbed N through abomasal casein infusion increased N balance 43% ($P < .001$) in wether lambs fed a corn-soy-based diet. Similar responses to abomasal casein infusions in steers were reported by Houseknecht et al. (1992). Cecava and Hancock (1994) observed the phenomenon that, as FtM replaced SBM in corn silage and high-moisture corn diets for steers weighing 308 kg, apparent N digestibility decreased linearly ($P < .05$), but biological value of absorbed N was enhanced ($P < .05$) in a linear manner. This implies that FtM N is less digestible than SBM N, but FtM probably supplies greater quantities or a better AA composition to the small intestine.

Plasma glucose, insulin, and NEFA concentrations were not affected by the inclusion of UIP in the diet, although plasma NEFA concentrations were 25% higher at the highest UIP level. Beermann et al. (1991) observed no change in plasma glucose and insulin concentrations when growing lambs received abomasal casein infusion. Plasma NEFA concentrations were significantly lower when lambs received abomasal casein infusion (Beermann et al., 1991). There is no apparent explanation for the enhanced plasma NEFA values observed at the highest level of UIP addition.

Increasing levels of UIP from 0 to 5.2% of diet DM increased plasma IGF-I concentrations in a linear manner ($P = .047$). Houseknecht et al. (1992) observed no increase in serum IGF-I concentrations in steers that were abomasally infused with casein.

Elsasser et al. (1989) reported that serum IGF-I concentrations in unrestricted steers exhibited a linear positive response to increased dietary protein concentrations when the steers were fed a high-energy diet. The elevation of IGF-I concentrations is consistent with responses observed when N balance was increased from 23 to 52 g/d with abomasal casein infusion in studies previously conducted in our laboratory (Moloney et al., 1995). High-concentrate diets, being high in readily available energy, are particularly suited for efficient urea utilization (Braman et al., 1973). This also applies to dietary protein sources mostly undegradable in the rumen. The intestinal AA profile can be altered via protein source selection (Merchen and Titgemeyer, 1992). According to Titgemeyer et al. (1989), combinations of protein sources may be best to supply optimal quantities and profiles of AA, because large differences exist among protein sources in the extent to which they escape ruminal microbial degradation. Also, protein sources vary to an even greater extent in the quantities of individual AA that they supply for absorption from the small intestine. In a growth study with steers Goedecken et al. (1990) observed that protein efficiency tended to be greater for the combination of BM + FtM than when BM or FtM was fed alone. Stock et al. (1981) also observed that feeding combinations of protein sources that had complementary AA profiles improves efficiency of protein utilization. Blasi et al. (1991) expressed the importance of meeting the growing ruminant's AA requirements, not so much by supplementing total protein per se, but rather by supplying proper proportions in accordance with limiting AA phenomena encountered when feeding growing ruminants. Contrary to most reports in the literature, results from a growth trial with calves weighing 230 kg indicated that there was no complementary response between MBM and BM or FtM (Gibb et al., 1992). Pate et al. (1995) pointed out the possibility that ruminal degradation characteristics of animal protein sources, as well as processing and rendering conditions, may influence any complementary effects of these protein sources on animal performance. We did not attempt to characterize differences between the commercial sources of by-product proteins used in this study with others.

The efficiency of N utilization by growing cattle receiving anabolic steroids can be enhanced when ruminally degradable and undegradable protein sources are fed in the correct proportions (Cecava and Hancock, 1994). Therefore, it should be noted that feeding this protein mixture could also be efficacious under practical conditions, when protein deposition rate is stimulated by administration of growth-enhancing agents, such as the commercial anabolic steroid implants (simulated in this study by s.c. injections of 500 μg of estradiol-17 β administered twice daily), or when genotypes are used that exhibit superior rates of protein accretion and deposition.

Implications

Feeding a balanced mix of undegraded intake protein (UIP) sources seems to improve nitrogen (N) digestibility, N balance, and efficiency of N utilization in growing-finishing cattle. Future research on use of dietary animal by-product blends for growing-finishing cattle should focus on identifying the appropriate combination and proper dietary amount of UIP, taking into account animal maturity and genotype and management strategies used. Determination of the amino acid (AA) quantity and corresponding AA profile needed at the site of absorption for maximum rates of protein synthesis and deposition is required. Investigation of the expected decrease in efficiency of use of absorbed AA with level of protein feeding and the quality of supplemental protein reaching the duodenum is also needed. Ultimately, it is the efficiency with which dietary N is used for protein accretion and the related rates of N excretion that are of greatest practical importance.

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