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Metabolizable Amino Acid Requirements of Feedlot Calves

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Abstract

One hundred ninety-two crossbred steers (229 kg) were used to evaluate the influence of metabolizable amino acid intake on growth performance and health during the initial 42-d receiving period. Treatments consisted of four levels of metabolizable lysine (23, 24, 25 and 26 g/kg diet DM). Morbidity averaged 36%, and was not affected ($P > 0.20$) by treatments. No steers died during the study. Increasing the metabolizable lysine supply increased DMI, ADG, gain efficiency, and dietary NE (linear effect, $P < 0.01$). Metabolizable amino acid supply of the basal diet was determined using 6 steers (214 kg) with cannulas in the rumen and proximal duodenum. Metabolizable amino acid supply of the diet was in close agreement with expected ($R^2 = 0.99$; $P < 0.0001$) based on NRC (2000) [12] Level 1 model. The metabolizable amino acid supplies for treatments in Trial 1 were estimated by adding tabular metabolizable amino acid values for the respective supplemental proteins (cottonseed meal and fish meal) to the observed metabolizable amino acid supply of the basal diet. Treatment effects on metabolizable lysine supply explained 99% of the variation ($P < 0.01$) in ADG, and 91% of the variation in observed versus expected dietary NE. The biological value for the intestinal chyme was determined based on chemical score technique, using bovine tissue as the reference protein. Accordingly, methionine and lysine were closely co-limiting amino acids having ratios of 77% and 79%, respectively. We conclude that current NRC standards reliably predict both requirements and supplies of metabolizable amino acids for feedlot calves. Diet formulations that do not meet the metabolizable amino acid requirements may depress both ADG and the partial efficiency of utilization of metabolizable energy for maintenance and gain.

Keywords

Amino Acid, Protein, Metabolism, Steer, Feedlot

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1. Introduction

Formulating diets to meet protein requirements of feedlot cattle enhance ADG and energetic efficiency [1]-[3]. Zinn and Shen (1998) observed that NRC (2000) provided reliable estimates of amino acid supply to the small intestine based on diet formulation as well as metabolizable amino acid requirements of feedlot calves. However, very little research has been conducted which validates the practicality of such diet formulations for lightweight calves during the initial receiving period. The objective of this study was to further evaluate the practicality of current standards (NRC, 2000) in making diet formulations to meet metabolizable amino acid requirements. The study specifically addresses two important issues: 1) reliability of current standards for estimation of amino acid supply to the small intestine of feedlot steers fed a conventional receiving diet; and 2) the relationship between limiting amino acid supply and growth performance responses (metabolizable amino acid requirements) during the initial receiving period.

2. Materials and Methods

Trial 1. One hundred ninety-two crossbred steers (229 kg) were used in 42-d receiving trial to evaluate the influence of metabolizable amino acid intake on health and performance. Steers were blocked by weight and randomly allocated to 24 pens (8 steers/pen). Pens were 43 m^2 with 22 m^2 overhead shade, equipped with automatic waterers and fence-line feed bunks. Processing on arrival includes branding, ear-tagging, castration (elastration), vaccination for IBR-PI_3 (TSV-2, Zoetis Inc., Kalamazoo, MI), Clostridials/Haemophilus (Ultrabac, TSV-2, Zoetis Inc., Kalamazoo, MI), treatment for internal and external parasites (Ivomec plus, Merck, Rahway, NJ), and injection with 1 mL vitamin A & D (Vita-jec A & D, Agripharm, Greely, CO). Horns, if present, were tipped. Calves visually diagnosed as sick received medication until rectal temperature remained below 39.4˚C for two consecutive days. Composition of experimental diets is shown in **Table 1**. Treatments consisted of a steam-flaked corn-based receiving diet formulated based on NRC (2000, level 1) to provide four levels of metabolizable lysine (23, 24, 25 and 26 g/kg diet DM) using combinations of fish meal and cottonseed meal. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed ad libitum access to their experimental diets. Fresh feed was provided twice daily. Steers were implanted with Synovex-S® (Zoetis Inc., Kalamazoo, MI). For calculating steer performance, initial is the off truck arrival weight. Final BW was reduced 4% to account for digestive tract fill. Estimates of steers' performance were based on pen means. Energy gain (**EG**) was calculated by the equation: $EG = ADG^{1.097} \times 0.0557W^{0.75}$, where EG is the daily energy deposited (Mcal/d) and W is the mean shrunk body weight [4]. Maintenance energy (**EM**) was calculated by the equation: $EM = 0.077W^{0.75}$ [4]. The NE_m and NE_g value of the diets were obtained by means of the quadratic formula: $(-b \pm (b^2 - 4ac)^{0.5})/2a$, where $a = -0.41EM$, $b = 0.877EM + 0.41DMI + EG$, $c = -0.877DMI$, and $NE_g = 0.877NE_m - 0.41$ [1]. The experimental data were analyzed as a randomized complete block design according to the following statistical model: $Y_{ij} = \mu + B_i + T_j + \varepsilon_{ij}$, where μ is the common experimental effect; B_i represents blocks (df = 5); T_j represents dietary treatment effect (df = 3); and ε_{ij} represents the residual error (df = 15). Treatments effects were tested by means of orthogonal polynomials (Statistix-10, Analytical Software, Tallahassee, FL).

Trial 2. Six steers (214 kg) with cannulas in the rumen and proximal duodenum [5] were used to determine metabolizable amino acid supplies for the basal diet (treatment 1, 23 g lysine/kg, **Table 1**). Chromic oxide (0.4%) was added as a digesta marker. Steers were maintained in individual pens with access to water at all times. Diets were fed at 08:00 and 20:00 hours daily. Dry matter intake was restricted to 6.3 kg/d. Steers were given 10 d for diet adjustment and 4 d for collection. During collection, duodenal and fecal samples were taken twice daily as follows: d 1, 07:50 and 13:50 hours; d 2, 09:00 and 15:00 hours; d 3, 10:50 and 16:50 hours, and d 4, 12:00 and 18:00 hours. Upon completion of the trial, approximately 500 mL of ruminal fluid were obtained from each steer, composited across diets; bacteria were isolated via differential centrifugation [6]. The microbial isolates were prepared for analysis by oven drying at 70˚C and grinding with mortar and pestle. Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70˚C and grinding in a lab mill (Micro-Mill, Bel-Arts Products, Pequannock, NJ). Samples were oven dried at 105˚C until no further weight was lost and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analysis: ash, ammonia N, Kjeldahl N [7], chromic oxide [8]; and purines [9]. Microbial organic matter (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker [9]; and amino acids (hydrolysis under N in sealed ampules with 6 NHcl overnight at 110˚C. Organic matter fermented in the rumen was considered equal to

Table 1. Dry mater composition of experimental diets fed to steers in Trials 1[a] and 2.

	Metabolizable lysine, g/kg			
Item	23	24	25	26
Alfalfa hay	5.00	5.00	5.00	5.00
Sudangrass	30.00	30.00	30.00	30.00
Steam-flaked corn	53.55	51.55	51.55	49.55
Yellow grease	2.0	2.00	2.00	2.00
Molasses cane	7.00	7.00	7.00	7.00
Urea	0.80	0.80	0.80	0.80
Fishmeal			2.00	2.00
Limestone	1.00	1.00	1.00	1.00
Cottonseed meal		2.00		2.00
Magnesium Oxide	0.15	0.15	0.15	0.15
Salt[b]	0.50	0.50	0.50	0.50
Nutrient composition (DM basis)[c]				
NE, Mcal/kg				
Maintenance	1.93	1.92	1.92	1.91
Gain	1.28	1.27	1.27	1.26
Crude protein, %	11.4	12.2	12.6	13.4
UIP, %	33.3	33.7	35.8	36.0
DIP, %	66.7	66.3	64.2	64.0
Calcium, %	0.66	0.67	0.77	0.78
Phosphorus, %	0.28	0.28	0.33	0.34
DE, Mcal/kg	3.45	3.43	3.43	3.41
ME, Mcal/kg	2.86	2.84	2.84	2.83

[a]Chromic oxide added as a digesta marker in trial 2. [b]Trace mineral salt contained: $CuSO_4$, 0.068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07; KI, 0.52%; and NaCl, 92.96%. [c]Based on tabular values for individual feed ingredients (NRC, 2000) [12].

OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N, MN, and estimated endogenous N (0.195 g/kg BW0.75) [10]. The metabolizable amino acid supplies for the other three treatments were estimated by adding tabular metabolizable amino acid values for the supplemental proteins (fishmeal, cottonseed meal, and corn used in the replacements) to the observed metabolizable amino acid supply of the basal diet. The metabolizable amino acid supply for treatments in Trial 1 were obtained by multiplying respective metabolizable amino acid supply in Trial 2 by corresponding DMI for that treatment in Trial 1 and then dividing by 6.25.

3. Results and Discussion

Treatment effects on feedlot performance are shown in **Table 2**. Morbidity averaged 36%, and was not affected ($P > 0.20$) by treatments. No steers died during the study. Increasing the metabolizable lysine increased DMI, ADG (**Figure 1**), gain efficiency, and dietary NE (linear effect, $P < 0.01$). Similarly, [11] observed that supplementation with rumen-stable Lysine (RS-Lys) improved ($P < 0.01$) ADG in growing cattle.

Characteristics of digestion and metabolizable amino acid supply of treatment 1 (23 g lysine/kg; (**Table 1**) is shown in **Table 3**. Proportionately, observed and expected amino acid concentrations were in very close agreement ($r^2 = 0.99$; $P < 0.0001$). However, observed metabolizable amino acid supply was greater (16%) then predicted based on [12] Level 1 model.

Treatment effects on biological value of duodenal chyme for the four dietary treatments based on chemical score (amino acid in duodenal chyme × 100/amino acid in reference protein), using "ideal protein" for growing

Table 2. Effects of the treatment on 42-d performance of crossbred steers and net energy value of the receiving diet.

	Metabolizable lysine, g/kg					Contrast P-value		
Item	23	24	25	26	SEM	Linear	Quadratic	Cubic
Dayson test	42	42	42	42				
Pen replicates	6	6	6	6				
liveweight, KG								
Initial	231	232	228	234	3.94			
42 d	250	257	254	266	4.08	0.03	0.51	0.21
DMI,KG	4.45	4.78	4.63	4.84	0.11	0.56	0.64	0.12
ADG,KG	0.46	0.59	0.63	0.77	0.04	<0.01	0.94	0.38
DMI/ADG	0.10	0.12	0.14	0.16	0.01	<0.01	0.90	0.67
DIETARY NEM Mcal/kg NRC 1984								
NemMcal/kg	1.59	1.65	1.71	1.83	0.43	<0.01	0.5	0.82
NegMcal/kg	0.98	1.03	1.09	1.2	0.38	<0.01	0.5	0.82
OBS/EXP NEM Mcal/kg NRC 1984								
Maintenance	0.82	0.86	0.89	0.96	0.02	<0.01	0.49	0.75
Gain	0.76	0.81	0.86	0.95	0.02	<0.01	0.49	0.76
Sickdays	7.44	5.08	7.33	7.74	1.3	0.59	0.30	0.28
Morbidity, %	37.5	35.42	33.3	36.61	7.9	0.89	0.71	0.87

[a]Initial and final BW reduced 4% to account for fill. [b]Linear effect, $P < 0.05$. [c]Linear effect <0.001.

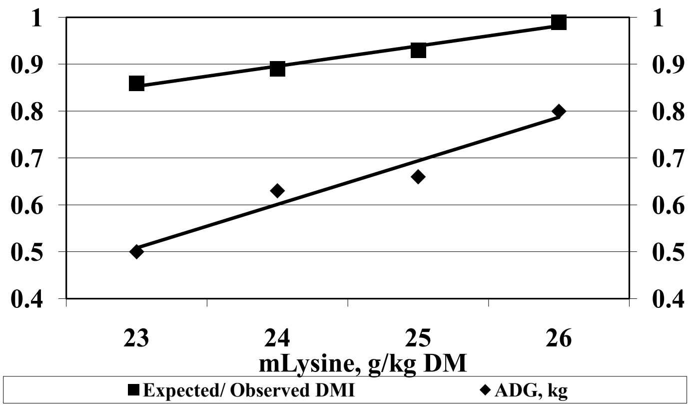

Figure 1. Relationship between metabolizable lysine intake (mLysine) and the ratio of expected/observed DMI and ADG.

swine [13], and bovine tissue [12], are shown in **Table 4**. Some researchers have suggested that amino acid requirements cannot be logically related to amino acid composition of deposited protein because amino acids are used for various functions in addition to deposition, and because protein turnover and recycling rates differ. However, research with non-ruminants does not support that contention. Indeed, amino acid requirements for non-ruminants are closely related to and have been extensively calculated from amino acid composition of deposited carcass tissue or of secreted milk protein [14]. Carcass amino acid composition served as one basis for developing the "ideal protein" concept, which is used extensively to calculate amino acid requirements of swine [13]. As has been shown previously using similar techniques [2] [14], histidine would appear to be the first

Table 3. Characteristics of ruminal and total tract digestion and observed vs expected metabolizable amino acid supply of treatment 1 (basal diet, **Table 1**; Trial 2).

Item	Basal diet	SEM	NRC[a]
Steers wt. Kg	253		
Intake, g/d			
DM	5,557	21	
OM	5,150	19	
N	97.4	0.4	
Flow to duodenum, g/d			
OM	2,572	95	
Microbial N	66.1	1.5	
Nonammonia N	108.1	2.4	
Feed N	31.1	0.7	
MN efficiency	21.4	0.8	
Metabolizable amino acids, g/d			
Arginine	19.8	0.6	16.9
Threonine	24.1	0.8	19.7
Valine	26.4	0.9	22.1
Methionine	10.2	0.4	8.4
Isoleucine	24.1	0.8	19.3
Leucine	41.1	1.3	34.9
Phenylalanine	22.2	0.7	18.9
Lysine	29.5	0.9	24.3
Histidine	7.6	0.2	7.9
Ruminal digestion, %			
OM	62.5	1.4	
Feed N	68.1	1.8	
Total-tract digestion, %			
OM	73.5	1	
N	62	0.9	

[a]Expected, (NRC, 2000) [12] Level 1 model.

limiting amino acid. No research has been reported that directly evaluates the histidinerequiermentsof cattle. In light of this fact, and the fact that supplementation with individual amino acids such as lysine and methionine enhanced growth performance [2] reasoned that it is more likely that current standards overestimate the histidine requirements. More research is needed in this area.

Methionine and lysine were closely co-limiting amino acids. Indeed, metabolizable lysine supply explains 99% of the variation ($P < 0.01$) in ADG (**Table 5**). Metabolizable lysine also explained 91% of the variation in ($P < 0.01$) in dietary NE. This finding is consistent with [2] who observed that changes in dietary NE with protein supplementation are a very sensitive indicator metabolizable amino acid adequacy.

Table 4. Biological value of duodenal chyme based on chemical score using bovine tissue and "ideal protein".

	Metabolizable lysine g/kg			
Biological value	23	24	25	26
Arginine				
Ideal protein	127.6	132.8	133.0	139.5
Bovine tissue	103.2	107.4	107.4	112.8
Threonine				
Ideal protein	98.3	98.3	98.3	97.5
Bovine tissue	105.4	105.4	105.4	104.5
Valine				
Ideal protein	102.4	103.2	101.6	102.4
Bovine tissue	112.3	113.5	111.4	112.3
Methionine				
Ideal protein	89.1	89.1	92.7	91
Bovine tissue	75.4	75.4	78.5	76.9
Isoleucine				
Ideal protein	110	106.4	106.4	105.5
Bovine tissue	153.2	148.1	148.1	146.8
Leucine				
Ideal protein	109.3	108.2	107.1	106
Bovine tissue	153.2	103.7	102.6	101.6
Phenylalanine				
Ideal protein	117.4	118.5	116.3	117.4
Bovine tissue	110.2	111.2	109.2	110.2
Lysine				
Ideal protein	78.1	78.1	79.8	78.7
Bovine tissue	78.6	78.6	80.2	79.1
Histidine				
Ideal protein	63.8	65.5	63.8	65.5
Bovine tissue	52.1	53.5	52.1	53.5

Table 5. Metabolizable protein and amino acids supply versus requirements (Trial 1).

	Metabolizable protein and amino acids, g/d									
Items	Protein	Arg	Thr	Val	Met	Ile	Leu	Phe	Lys	His
Supply, g/d										
mLys diet										
23	399	15.8	19.3	21	8.2	19.8	32.8	17.7	23.5	6.1
24	434	18.1	20.9	23	8.7	20.9	35.3	19.5	25.5	6.7
25	433	18	20.9	22.6	9	20.8	34.9	19.1	26	6.6
26	461	20.1	22	24.3	9.5	22.1	36.8	20.5	27.4	7.2
Requirements, NRC (2000)										
mLys diet										
23	388	17	19.9	22.3	8.5	19.5	35.2	19.1	24.5	8
24	430	19.5	21.5	24.3	9.1	21.2	38	21	26.5	8.9
25	436	19.4	21.3	24	9.5	21.1	37.5	20.5	27	8.8
26	483	21.6	22.6	25.6	9.9	22.5	39.6	22.1	28.6	9.5

4. Conclusion

It is concluded that the Level 1 model [12] is a reliable tool for predicting both requirements and supplies of metabolizable amino acids for feedlot calves during the receiving period. Diet formulations that do not meet metabolizable amino acid requirements may depress both ADG and the partial efficiency of energy utilization.

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