Is Methionine the First Limiting Amino Acid for Growing Cattle Fed Forages?

William E. Kunkle and Diane I. Hopkins
Department of Animal Science
University of Florida, Gainesville 32611

Introduction

In cow-calf and stocker production systems, a suggested strategy (Klopfenstein, 1993) has been to meet the rumen microbial nitrogen needs first, then feed additional undegraded (bypass or escape) feed proteins (UIP) to meet the metabolizable protein needs of the animal when the response is economical. Degraded protein requirements are usually met when the rumen degraded protein (DIP) is 9 to 13% of the dietary TDN (Lardy et al., 1998; NRC, 1996), diet TDN:CP ratio is 7 or lower (Moore and Kunkle, 1995) or the blood urea nitrogen is 10 mg/dl or higher (Hammond et al., 1994). Degraded protein needs can be met with high protein supplements containing non-protein nitrogen such as urea or with feedstuffs containing DIP.

After the DIP requirements are met then UIP can be supplemented if needed to meet the animal metabolizable protein requirements. A summary of eight experiments with growing beef cattle fed warm season perennial grass pastures and hays has shown that gains were usually improved when protein sources such as cottonseed meal, feather meal and blood meal are fed in molasses based liquid supplements (Kunkle et al., 1994). A summary of 24 evaluations showed an increase in gains ranging from .02 to .91 lb/d and with an average of .31 lb/d across several sources and levels of supplemental protein in situations where rumen degraded protein requirements were met (Figure 1). When increases in gain were high, the supplemental protein usually increased forage intake but when smaller increases in gain were reported, forage intakes were usually similar and an improved efficiency in the use of feed consumed was apparent. Feeding sources of undegraded protein to growing beef cattle improved performance and may be profitable in selected beef production systems.

Previous research established that forage-fed growing cattle offered molasses-based supplements had improved gains when UIP was added to the supplements. However, these trials did not answer questions about the optimum level for each UIP source or how to compare sources of UIP. Determining the amino acids limiting cattle performance offers the possibility of comparing sources of UIP and possibly improving the economic return since amino acid profiles of supplements vary considerably and rumen protected amino acids are one of the possible supplements.

Presented at the 10th Florida Ruminant Symposium, Gainesville, January 14-15th, 1999

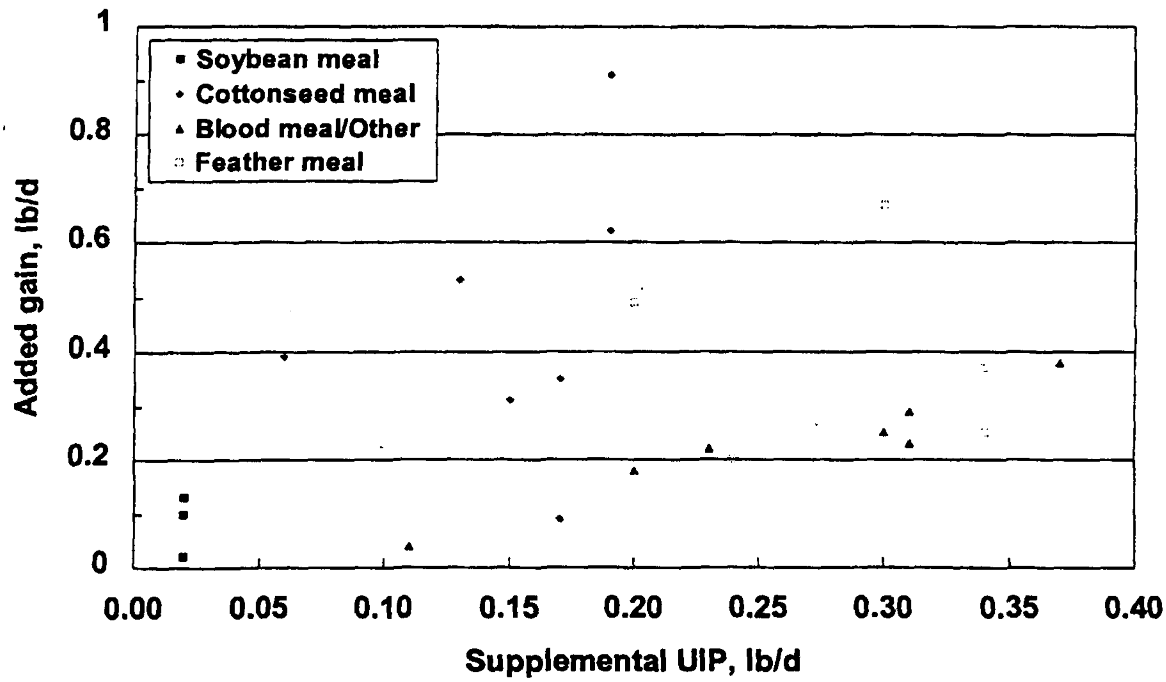

Figure 1. Effects of undegraded intake protein (UIP) on added gain in growing cattle fed molasses supplements and forages. Responses for eight studies conducted in Florida.

Previous Research

Microbial protein is a high quality protein with an essential amino acid pattern similar to lean body tissue but the essential amino acids are not perfectly balanced. Methionine has been shown to be the first limiting amino acid in rumen bacterial protein (Bergen et al., 1967). In cattle and sheep fed semi-purified diets or diets containing only small amounts of UIP, methionine and lysine have been shown to be the first and second limiting amino acids (Nimrick et al., 1970; Richardson and Hatfield, 1978; Storm and Orskov, 1984; Titgemeyer and Merchen, 1990). In these studies microbial and endogenous proteins supplied most of the absorbable amino acids and nitrogen retention and plasma amino acid concentrations were used to evaluate the response to infused amino acids. However, the amino acid balance in dietary UIP can alter the limiting amino acids. In diets containing 65% corn grain, lysine was the first limiting amino acid in growing steers (Burris et al., 1976; Hill et al., 1980). Corn protein contains over 50% UIP and it is considered adequate in methionine and deficient in lysine.

Merchen and Titgemeyer (1992) reviewed amino acid supplementation research in growing ruminants and stated that amino acid supply to the small intestine was dictated largely by microbial protein. They concluded total sulfur amino acids (methionine + cystine), lysine, histidine, and other amino acids were colimiting in many situations. This suggests that several amino acids avoiding rumen degradation may need to be supplemented for a significant improvement in performance.

The performance limiting amino acids of growing cattle and the beef cow fed forage based diets have not been well defined. Veira et al., 1991 supplemented a mixture of rumen protected lysine (8.2 g/d) and methionine (2.6 g/d) to growing steers (600 lb initial weight) fed grass silage. The silages contained 13 to 18% crude protein which should have been provided adequate DIP. Rumen protected lysine and methionine improved steer gains .33 lb/d and both treatments had similar dry matter intake. The authors noted the improvement in gain was similar to previous trials where 300 g/d of fishmeal was supplemented. Lusby (1993) fed 5 g of rumen stable methionine product (3.5 g methionine) to light weight calves (375 lb initial weight) grazing native tall grass pasture in Oklahoma during the summer. Calves supplemented with methionine gained .16 lb/d more than controls and the improvement in gain was higher early in the trial when calves were lighter and pasture quality and calf gain was higher.

Ellis (personal communication) evaluated supplements containing increasing levels of rumen protected methionine (0 to 8 gm/d product containing 75% rumen stable methionine) and methionine plus lysine fed to growing steers grazing ryegrass and bermudagrass pastures. Rumen protected amino acids did not improve the performance of 670 lb crossbred yearling steers grazing high quality ryegrass pasture (3.3 lb/d gain). In contrast, the gains of 320 lb Brahman-dairy crossbred heifers grazing bermudagrass pastures during the summer was improved by .29 lb/d (1.56 vs 1.85 lb/d) when 4 g/d of rumen stable methionine product (3 g of methionine) was fed. The response to the methionine plus lysine was similar and closely related to the methionine provided. A corn gluten-fish meal supplement providing 236 g of protein also improved gains by .38 lb/d in this study. When higher levels of either product was fed the performance improvement was reduced indicating that either over or under feeding the rumen protected methionine may result in less than optimal performance.

Considering the encouraging but limited data on supplementing rumen protected amino acids to cattle fed forage diets, research was initiated to: 1) determine the effects of rumen protected methionine on performance of growing cattle fed forage based diets supplemented with molasses based supplements, and 2) evaluate if the performance response to protein supplements is explained by the total sulfur amino acids in the UIP.

Experimental Approach

Supplements were formulated to provide 1, 2, 3, 4, or 5 g/d of total sulfur amino acids in the supplement UIP from blood-feather meal (BFM, 50:50), corn gluten meal (CGM) and rumen protected methionine (MET, Smartamine M®). Total sulfur amino acids (TSAA) is the sum of methionine plus cystine. Methionine is an essential amino acid for animal protein synthesis but cystine is not. Cystine is needed for animal protein synthesis but it can be supplied from absorbed cystine or synthesized from methionir if not enough cystine is available. However, cystine can not be converted to methionine. From the dietary perspective, methionine can supply the TSAA requirement but cystine can spare methionine up to the need for cystine for animal protein synthesis. Swine (NRC, 1998) and poultry (NRC, 1984) research suggests tl up to 50% of the TSAA requirement can be met with cystine. Limited research in catt (Ahmed and Bergen, 1983) suggests as much as 58% of the TSAA requirement can I met with cystine. Most feeds contain more methionine than cystine but feather meal contains five times as much cystine as methionine. The TSAA supplied by the blood-feather meal supplement in this trial was credited for cystine in UIP up to 50% of the TSAA supplied by the blood-feather meal supplement.

A control supplement containing the basal level of methionine in UIP was compared to the three sources of methionine fed at 5 levels (Table 1). Molasses and molasses urea supplements comprised 84% of the slurry supplement with corn added to increase supplement consumption and stabilize the proportion of dry ingredients in the molasses slurry supplement. Molasses urea was added to provide adequate DIP for the cattle fed the supplement plus bermudagrass hay adlibitum. Fourteen pens (6 head/pen) of crossbred steers and 14 pens of crossbred heifers were assigned to the 16 treatments in 1996-97. Fifteen pens (5 head/pen) of crossbred steers and 15 pens of crossbred heifers were assigned to the 16 treatments in 1997-98. Each pen was a two acre pasture and most grass was grazed off at the start of the trial but warm weather allowed some grass growth during February and March each year. The calve: averaged 530 lb and most calves were body condition score 5 at the start of the trials. Bermudagrass hay was offered adlibitum in hay rings outside (no shelter) and molasse: slurries were limit fed at 6 lb/d to growing cattle during the 105 to 120 day trials (December thru March). Hay not consumed was collected, weighed, sampled (dry matter analyzed), and removed from the pens every 3 to 4 weeks during the trials.

The molasses slurries were fed twice each week and a 3 or 4 day supply was offered at each feeding. Each feed ingredient was weighed and the slurry mixed by hand in the trough at each feeding. The MET was preweighed in the laboratory and hand mixed to avoid damage to the coating protecting the methionine from rumen degradation. Supplement consumption, hay consumption, full weight, shrunk weight (beginning and end only), height, body condition, and blood urea (2 calves/pen) were measured at 28 day intervals during the trials. Animal data were averaged for each pen and the experimental unit for statistical analysis was pen. Data for both years was analyzed and reported.

Results and Discussion

Cattle were offered (6 lb/d) of the assigned molasses slurry supplement and all slurry offered was consumed after the first week. Hay dry matter offered but not consumed (collected and weighed plus visually estimated waste) averaged 7.8% the first year and 11.7% the second year. More rainfall the second year (over 20 inches during trial) probably contributed to the increase in non-consumed hay during the second year.

Cattle gains increased linearly ($P < .0001$) as the bypass TSAA level was increased up to 5 g/d (Figure 2). Each gram of bypass TSAA increased gain .06 lb/d. All sources of methionine gave similar ($P = .53$) results suggesting that the TSAA concentration of the BFM and CGM supplements was the limiting nutrient that was improving performance. The gains in the first year were .17 lb/d higher than in second year but the response to increasing bypass TSAA levels was similar. Both steers and heifers had similar gains. Cattle height increased 3.1 inches and cattle body condition score increased .27 units during the trials but bypass TSAA level and source did not change ($P > .25$) these performance measures. Dry matter intake averaged 12.8 lb/day and bypass TSAA level and source did not change it ($P > .35$).

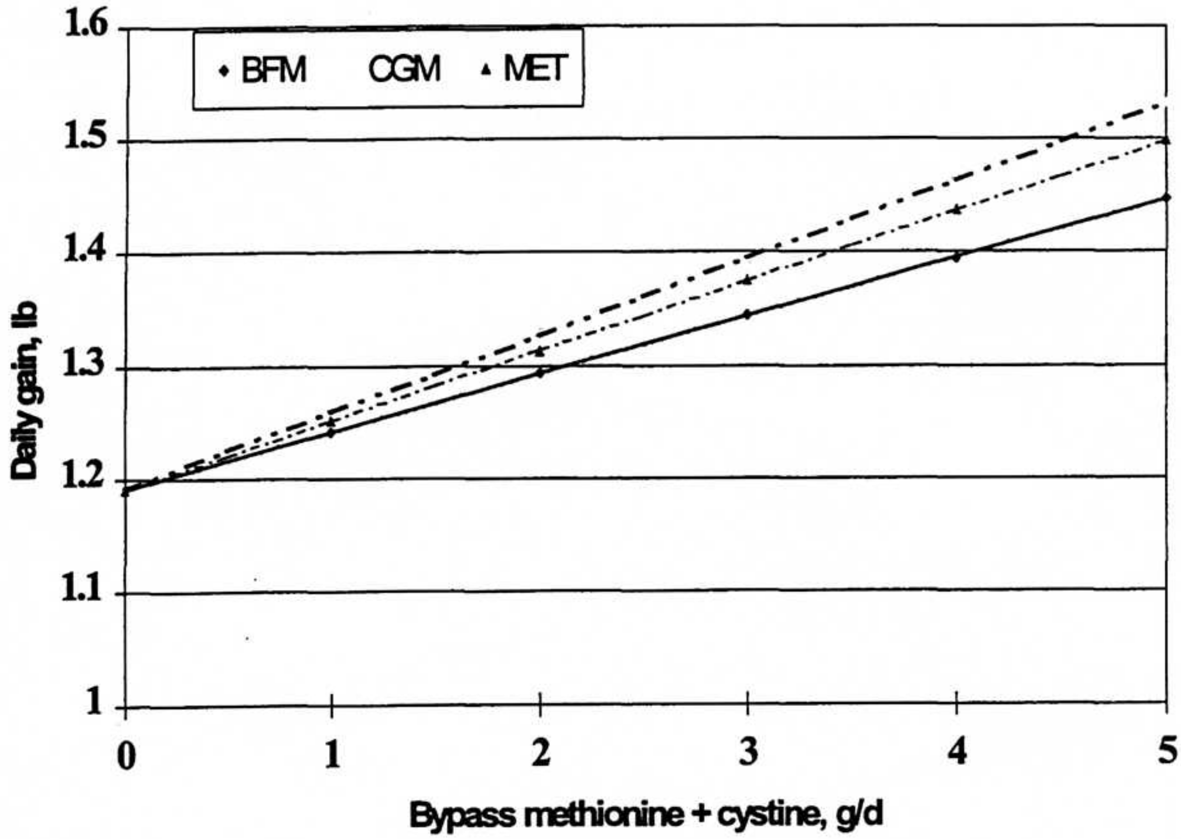

Figure 2. Bypass methionine + cystine (TSAA) effect on daily gain of growing cattle fed molasses supplements and bermudagrass hay. Sources of bypass TSAA provided in molasses supplements were blood-feather meal (BFM), corn gluten meal (CGM), and Smartamine M® (MET). All sources of bypass TSAA gave similar ($P = .53$) improvements in gain (.06 lb/d increase in gain/g bypass TSAA).

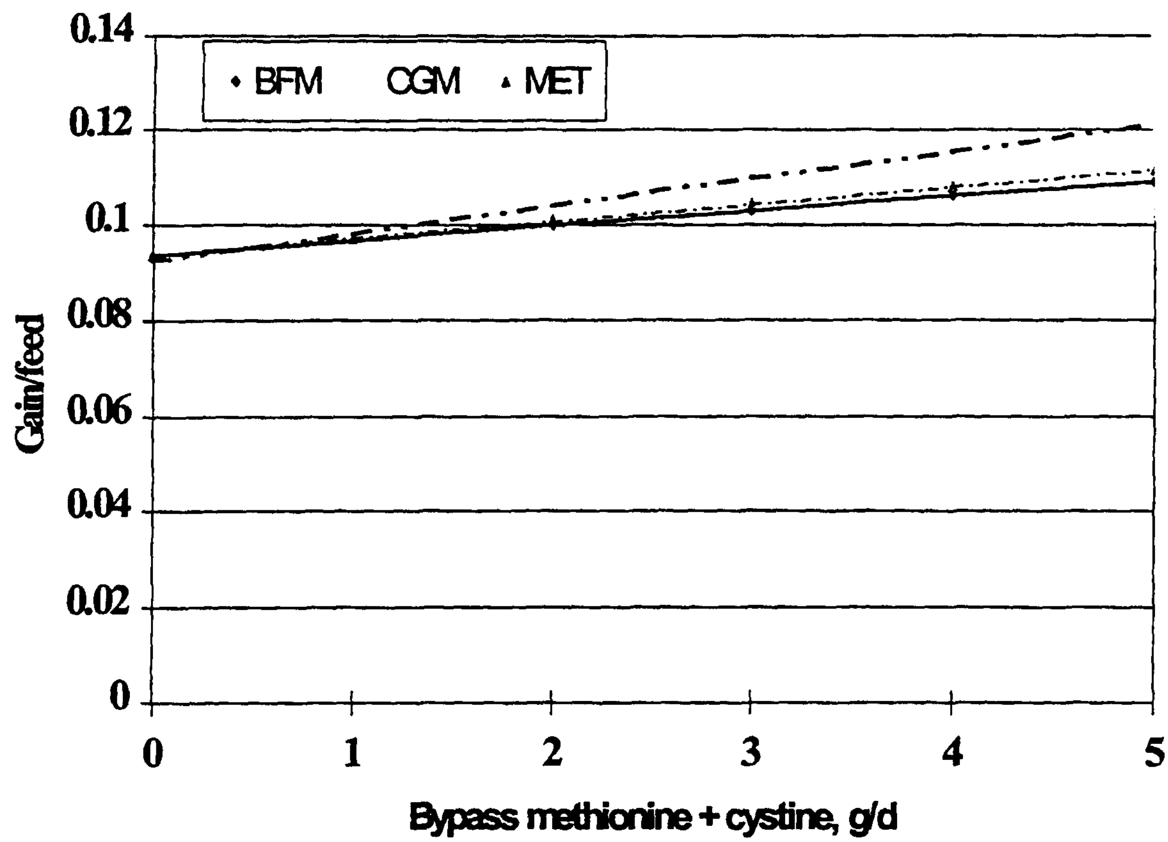

Figure 3. Bypass methionine + cystine (TSAA) effect on gain/feed of cattle fed molasses supplements and bermudagrass hay. Sources of bypass TSAA provided in molasses supplements were blood-feather meal (BFM), corn gluten meal (CGM), and Smartamine M® (MET). All sources of bypass TSAA gave similar (P = .38) improvements in gain/feed (.003 units increase in gain/feed per gram of bypass TSAA).

Gain/feed was improved .003 units (linear, P = .03) for each gram of bypass TSAA up to the 5 g/d (Figure 3). All sources of bypass TSAA gave similar results (P = .38). Blood urea nitrogen (BUN) concentration was measured the day after feeding every 28 days during the trials then averaged across dates for analysis. Cattle fed BFM and CGM supplements had increased BUN as the bypass TSAA level increased but cattle fed increasing levels of MET supplement had similar BUN (Figure 4). This was expected since the crude protein intake of the supplements and total crude protein intake was increased with higher levels of bypass TSAA. Only a portion of the additional nitrogen intake was retained in the added gain and the extra nitrogen consumed would be metabolized to urea and be expected to increase BUN.

This research suggests that TSAA concentration in supplemental UIP is an important factor for growing cattle fed forage based diets. A recent cost of providing 5 g/d of supplemental bypass TSAA in this trial (gains improved .3 lb/day) was $.21 from

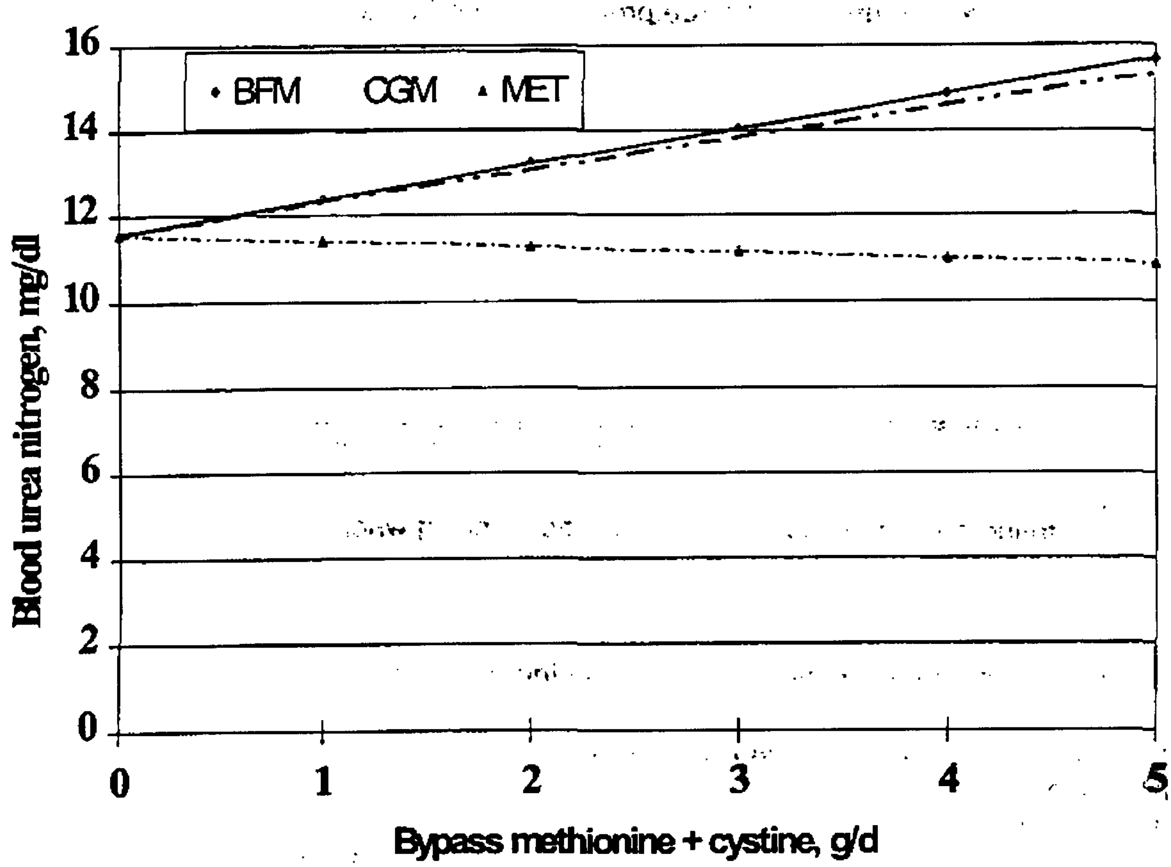

Figure 4. Bypass methionine + cystine (TSAA) effect on blood urea nitrogen of cattle fed molasses supplements and bermudagrass hay. Sources of bypass TSAA provided in molasses supplements were blood-feather meal (BFM), corn gluten meal (CGM), and Smartamine M® (MET). Cattle fed MET had lower blood urea nitrogen concentration than cattle fed BM/FM or CGM supplements.

BFM (.6 lb/d blood meal, $450/T; .6 lb/d feather meal, $240/T), $.15 from CGM (.9 lb, $320/T) and $.10 from Smartamine M® (7.4 g/d, $5.85/lb). The cost of added gain when adding Smartamine M® was $.33/lb. Other sources of rumen protected TSAA have also shown good results and cost less for each unit of bypass methionine.

This research is consistent with three other studies that have shown .16 to .33 lb/d increases in gain when growing cattle fed medium quality forages were supplemented with 2.6 to 5 g/d of rumen protected methionine. In two studies, dry matter intake was similar and gain/feed efficiency was improved. Ellis (personal communication) evaluated several levels of rumen protected methionine and improvements in gains were lost when levels above the optimum were fed indicating that future research needs to evaluate several levels.

Most of the absorbed amino acids are derived from microbial protein in cattle fed forage diets. The contribution of forge protein to absorbed amino acids is unknown and needs to be quantitated. The Beef Nutrient Requirements (NRC, 1996) shows the amino acid composition in UIP of several forages but the concentrations are similar for many forages leaving one to wonder if these are based on analytical analyses for the individual forage or if all forage have the same amino acid composition of UIP. Molasses used in these trials was analyzed for amino acids and essential amino acids ranged from .5% to .8% of molasses dry matter with only .01 to .02% methionine in dry matter. Most of these amino acids in molasses probably are degraded by the rumen microbes.

The amino acid nutrition of lactating dairy cattle has been researched more than growing beef cattle and this research has been summarized in several reviews (Rulquin et al., 1993; Schwab, 1996a; Schwab, 1996b). Schwab (1996a) states that lysine is first limiting amino acid when corn or corn product feeds provide all or most of the UIP for the lactating dairy cow, but methionine is first limiting when smaller amounts of corn are fed and most of UIP is provided by oilseed or animal-derived proteins. It is interesting to note that most dairy research tends to measure and report only methionine, but cystine and/or total sulfur amino acids is not addressed. The concept that cystine is a nonessential amino acid and the requirement can be met via synthesis from methionine seems to be widely accepted. However, some variation of cystine concentration in feeds could lead to under or over valuing these feeds for balancing the UIP amino acids. Although we initiated this research with the primary objective to establish if methionine would give a performance response, it is gratifying and promising to note that the rumen protected source of methionine had an economic advantage in improving performance and application to production systems offers potential.

Summary

Research suggests that methionine is the first limiting amino acid in microbial protein for growth of cattle. A summary of 4 studies indicates that supplementing 2.6 to 5 g/d of rumen protected methionine will increase gains .16 to .33 lb/d in growing cattle fed medium quality forages. Supplementing rumen protected methionine appears to offer economical improvements in gain in selected situations.

References

Ahmed, B.M., and W.G. Bergen. 1983. Methionine-cyst(e)ine relationship in steers. J. Anim. Sci. 57 (Suppl. 1) :110 (Abstr.)

Bergen, W.G., D.B. Purser, and J.H. Cline. 1967. Enzymatic determination of the protein quality of individual rumen bacteria. J. Nutr. 92:357-364.

Burris, W.R., J.A. Boling, N.W. Bradley, and A.W. Young. 1976. Abomasal lysine infusion in steers fed a urea supplemented diet. J. Anim. Sci. 42:699-705.

Hammond, A.C., E.J. Bowers, W.E. Kunkle, P.C. Genho, S.A. Moore, C.E. Crosby and K.H. Ramsay. 1994. Use of blood urea nitrogen concentration to determine time and level of protein supplementation in wintering cows. Prof. Anim. Sci. 10:24-31.

Hill, G.M., J.A. Boling, and N.W. Bradley. 1980. Postruminal lysine and methionine infusion in steers fed a urea-supplemented diet adequate in sulfur. J. Dairy Sci. 63:1242-1247.

Klopfenstein, T. J. 1993. Strategies for predicting the first limiting nutrient for grazing cattle. *In:* Proc. 4th Annual Florida Ruminant Nutrition Symposium, pp 112-126, Univ. of Florida, Gainesville, FL.

Kunkle, W.E., D.A. Stateler, D.B. Bates, L.M. Rutter, W.F. Brown, and F.M. Pate. 1994. Protein levels and sources in molasses for growing cattle. In: Proc. 5th Annual Florida Ruminant Nutrition Symposium, pp 89-103, Univ. of Florida, Gainesville, FL.

Lardy, G., D. Adams, T. Klopfenstein, and D. Brink. 1998. Use of the NRC model for evaluating nutrient balances of grazing beef cattle. Nebraska Beef Cattle Report MP 69-A, pp 7-11, Univ. of Nebraska, Lincoln, NE.

Lusby, K.S. 1993. Rumen-stable methionine improves performance of lightweight cattle. *Feedstuffs 65:14 (# 52, December 20, 1993).*

Merchen, N.R., and E.C. Titgemeyer. 1992. Manipulation of amino acid supply to the growing ruminant. J. Anim. Sci. 70:3238-3247.

Moore, J.E., and W.E. Kunkle. 1995. Improving forage supplementation programs for beef cattle. *In:* Proc. 6th Annual Florida Ruminant Nutrition Symposium, pp 65-74, Univ. of Florida, Gainesville, FL.

Nimrick, K., E.E. Hatfield, J. Kaminski, and F.N. Owens. 1970. Qualitative assessment of supplemental amino acid needs for growing lambs fed urea as the sole nitrogen source. J. Nutr. 100:1293-1300.

NRC. 1984. Nutrient requirements of poultry (8th Revised Ed.). National Academy Press, Washington, DC.

NRC. 1996. Nutrient requirements of beef cattle (7th Revised Ed.). National Academy Press, Washington, DC.

NRC. 1998. Nutrient requirements of swine (10th Revised Ed.). National Academy Press, Washington, DC.

Rulquin, H., P.M. Pisulewski, R. Verite, and J. Guinard. 1993. Milk production and composition as a function of postruminal lysine and methionine supply: a nutrient-response approach. Livestock Prod. Sci. 37:69-90.

Richardson, C.R., and E.E. Hatfield. 1978. The limiting amino acids in growing cattl J. Anim. Sci. 46:740-745.

Schwab, C.G. 1996a. Rumen protected amino acids for dairy cattle: Progress towai determining lysine and methionine requirements. Anim. Feed Sci. Tech. 59:87-101.

Schwab, C.G. 1996b. Amino acids and their application in formulating diets for cattl *In:* Proc. 7th Annual Florida Ruminant Nutrition Symposium, pp 82-103, Univ. of Florida, Gainesville, FL.

Storm, E., and E.R. Orskov. 1984. The nutritive value of rumen micro-organisms in ruminants. 4. The limiting amino acids of microbial protein in growing sheep determin by a new approach. Br. J. of Nutr. 52:613-620.

Titgemeyer, E.C., and N.R. Merchen. 1990. The effect of abomasal methionine supplementation of nitrogen retention of growing steers postruminally infused with casein or nonsulfur-containing amino acids. J. Anim. Sci. 68:750-757.

Veira, D.M., J.R. Seoane, and J.G. Proulx. 1991. Utilization of grass silage by growin cattle: Effect of a supplement containing ruminally protected amino acids. J. Anim. Ac 69:4703-4709.

Table 1. Composition of molasses-based supplements containing different sources and levels of total sulfur amino acids in undegraded intake protein.								
		Concentration in supplement,% as fed						
Total sulfur amino acids[a] g/d	Source	MOL-UREA[b]	MOL[c]	Ground corn	Blood meal	Feather meal	Corn gluten meal	MET[d] g/d
.45	Corn	60	24	16	0	0	0	0
1.45	BFM	60	24	11.66	2.17	2.17	0	0
2.45	BFM	60	24	7.66	4.17	4.17	0	0
3.45	BFM	60	24	3.66	6.17	6.17	0	0
4.45	BFM	59.8	23.9	0	8.17	8.17	0	0
5.45	BFM	57.2	22.8	0	10	10	0	0
1.45	CGM	60	24	13	0	0	3	0
2.45	CGM	60	24	10	0	0	6	0
3.45	CGM	60	24	7	0	0	9	0
4.45	CGM	60	24	4	0	0	12	0
5.45	CGM	60	24	1	0	0	15	0
1.45	MET	60	24	16	0	0	0	1.47
2.45	MET	60	24	16	0	0	0	2.94
3.45	MET	60	24	16	0	0	0	4.41
4.45	MET	60	24	16	0	0	0	5.88
5.45	MET	60	24	16	0	0	0	7.35

[a]Methionine and cystine (TSAA) contained in undegraded intake protein when supplement fed at 6 lb/head/day. Cystine concentration credited to up to 50% of the TSAA concentration in the BFM supplement.
[b]78.6% dry matter, 22% crude protein, fortified with .5% P, .0005% Cu, .00001% I, .0025% Zn, and vitamins A, E, and D.
[c] 79.3% dry matter, 10.3% crude protein, fortified with .5% P, .0005% Cu, .00001% I, .0025% Zn, and vitamins A, E, and D.
[d]Smartamine M®, Rhone-Poulenc Animal Nutrition, rumen protected methionine calculated using 75% methionine in product and 90% of methionine rumen protected.