Amino Acid Nutrition of Feedlot Calves

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Introduction

In 1996 the Subcommittee on Beef Cattle Nutrition of the National Research Council (NRC) released the seventh revised edition of the 'Nutrient Requirements of Beef Cattle' (subsequently updated as NRC, 2000). Among the more dramatic changes with this revision was the enhanced characterization of feedstuffs with respect to composition and degradation rates of N and carbohydrate fractions, with the bold intent of factorializing them into estimates of metabolizable protein supply to the small intestine. It had been recognized for many years that net protein supply to the small intestine was a function of undegradable intake protein (UIP) content of the diet and ruminal microbial protein synthesis. However, at the time the sixth revised edition was released (NRC, 1984) the factors involved in predicting protein supply were poorly understood, and mathematical manipulations were sufficiently complicated to make calculations impractical for most nutritionist. Subsequent advances in ruminant protein nutrition and computer technology led to this first attempt (NRC, 2000) at expressing requirements on the basis of metabolizable protein (MP) and amino acid supplies. Estimates of supply are derived at two levels of abstraction. "Level 1" (L1) combines tabular measures of dietary UIP with estimates of microbial N yield based on dietary TDN (20.8 g/kg of TDN), adjusted for effective neutral detergent fiber (eNDF) [microbial N = (0.0208TDN) * (1- ((20 - eNDF) * 0.025), where TDN is expressed in kg/d, and eNDF as a percentage of DM intake]. "Level 2" (L2), on the other hand, combines estimates of degradation rates and passage rates of dietary carbohydrate and protein fractions to calculate UIP and MP.

Requirements for metabolizable protein and amino acids (NRC, 2000)

Metabolizable protein requirements are based on requirements for maintenance (3.8 g of MP per kg of Live Weight$^{0.75}$) plus gain [protein gain ÷ (0.83 - (0.00114LW) when LW is less than 300 kg, else protein gain/0.49], where protein gain = (ADG * (268 - (29.4 * (retained energy/ADG))), and retained energy = 0.0557 * (LW * (478/mature weight))$^{0.75}$ * ADG$^{1.097}$. The metabolizable amino acid requirements are then estimated based on the average amino acid composition of bovine tissue (metabolizable protein requirement × respective amino acid content of standard bovine tissue). During the early growing period, ADG and feed efficiency of feedlot calves are predictable functions of metabolizable amino acid supply with respect to requirements (Zinn, 1988; Zinn and Shen, 1998; Zinn et al 2007). Metabolizable amino acid requirements were derived by feeding diets that were first limiting in methionine (metabolizable methionine requirement = 1.565 + 0.0234ADG(268 - (29.4 * 0.0557BW$^{0.75}$ADG$^{1.097}$)/ADG) +

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$0.0896BW^{0.75}$). Requirements for the other essential amino acids were then estimated based on relationships between methionine and other amino acids in a standard reference protein (bovine muscle protein). Estimates of amino acid requirements derived in this manner (Zinn and Shen, 1998) were in close agreement with the more factorialized approach of NRC (2000), lending strong support to the metabolizable amino acid concept.

Metabolizable protein and amino acid supply

Microbial N

In a 35-trial evaluation, Zinn and Shen (1997) observed a close association (R^2 = .87) between L1 and L2 estimates of net microbial N flow to the small intestine. The L1 approach explained only 46% of the variation in observed net flow of microbial N, although the estimates were similar in magnitude to the observed. In contrast, the L2 explained 57% of the variation in net microbial N flow to the small intestine, but values were consistently overestimated. This overestimation may be due to a systematic overestimation of ruminal digestible OM. Growing finishing diets for feedlot cattle are characteristically high in starch. The L2 approach is not sensitive to differences in starch digestibility. Another cause for the overestimation may be the coefficient selected in L2 for deriving microbial N from estimates of microbial DM yield. In the case of observed values from the 35-trial summary, ruminal microbial isolates of steers consuming the experimental diets averaged 8% N, whereas NRC (2000) assumed microbial DM contains 9.92% N.

A very difficult aspect of predicting microbial N flow to the small intestine is the estimation of ruminal microbial efficiency (g of microbial N / kg of OM truly fermented). Both L1 and L2 approaches failed to account for this variation (R^2 = 0). Predicted microbial efficiencies ranged within the relatively narrow limits of 25 to 34. In contrast, observed values ranged from 14 to 36. Even the exclusion of observations from the data base that were outside the limits of microbial efficiency predicted by the models (outside the range of 25 to 34) did little to enhance the models accuracy in predicting (R^2 < 0.10) microbial efficiency.

From the practical standpoint of diet formulation, one might consider that although there is a rather large animal to animal variation in ruminal OM digestion and ruminal microbial efficiency, the average microbial efficiency and hence, yield for a pen will be in good agreement with expected. As will be discussed later, it is more likely that diets for feedlot cattle will be deficient in metabolizable amino acids only during the initial receiving and early growing period. During this period feed intakes are low relative to genetic potential of the calf for growth, and therefore greater pressure is placed on UIP amino acids to satisfy requirements (microbial amino acids play an important yet lesser role). During the latter growing and finishing phases when feed intakes are greater, microbial amino acids will play a much more dominant role in satisfying requirements to the extent that the degradable intake protein (DIP) content of the diet may be the only significant formulation constraint with respect to protein nutrition.

Formulating to meet requirements for microbial growth

Net synthesis of microbial N is not enhanced when ruminal degradable feed N is greater than 11% of dietary TDN (Rihani et al., 1993; Koster et al., 2000; Zinn and Shen 1998) or 8% of dietary DM (Zinn and Shen, 1998). Although NRC (2000) provides tabular estimates for ruminal degradability of feed N, actual measures can be quite variable and may be influenced by ruminal conditions, particularly pH. Furthermore, most feed proteins are composite proteins. Thus, the amino acid profile of DIP and UIP may also vary considerably.

It is generally assumed that the amount of urea that should be added to the diet to optimize ruminal microbial growth, is equivalent to net microbial protein synthesis minus the degradable intake protein content of the basal diet divided by 2.8 (Burroughs et al., 1975). This approach, although conceptually appealing, has limited empirical support. Firstly, microbial N flow to the small intestine is not enhanced when ruminal degradable N exceeds 75% of net microbial synthesis (Zinn and Shen, 1998). But perhaps more importantly, there is considerable evidence (Lofgreen et al., 1968; Zinn et al., 1994; Milton et al., 1997; Zinn et al., 2003) that growth-performance of feedlot cattle may be enhanced by levels of urea supplementation in excess of that required to optimize microbial protein synthesis. The basis for this effect may be due to the alkalizing effects of urea as it is hydrolyzed within the rumen to form ammonium carbonate.

Numerous studies (Buchanan-Smith et al., 1974; Hatch et al., 1972; Jones et al., 1961; Thompson et al., 1967) have demonstrated negative associative effects between urea compared with intact protein as sources of supplemental N in growing-finishing diets for cattle. The bases for these earlier findings are not clear. However, in all cases, energy density of the diets were below 1.6 Mcal/kg of NE_m (DM basis). In a summary of 10 trials conducted at Oklahoma State University between 1976 and 1980 comparing SBM and urea in finishing diets for feedlot cattle, Martin et al (1980) observed that animals fed urea were superior to those fed SBM in ADG (5.0%) and DM conversion (1.1%) when fed with steam-flaked, whole shelled, and dry-rolled corn-based diets. Alternatively, animals fed SBM had superior ADG (5.2%) and DM conversion (5.1%) to those fed urea when fed high-moisture corn-based diets. Presumably, the greater solubility of protein in high-moisture corn was a factor influencing the effective utilization of supplemental urea.

Research has provided a means for satisfying amino acid requirements at any stage of growth during the growing-finishing period. However, due to practical management constraints for feed preparation (feed mill operation) and feed delivery, most feedlots are not able to efficiently handle more than four different diet formulations. Therefore, given the great diversity of genetics, background, and weight of feedlot cattle, diets are typically formulated to meet "requirements" for feeding phases rather than target weight and expected rate of gain. These phases generally include receiving, transition, finishing, and pre-slaughter (the pre-slaughter phase is a newer phenomenon related to the addition of beta-agonists and vitamin E). Thus, in most cases all feedlot

cattle, whether large or small, will be fed the same receiving diet. Transition diets are intended to aid the digestive adaptation from a higher forage receiving diet to the lower forage finishing diet, and thus are typically fed for a brief period (one to two weeks). In some cases, nutritionists have sought to make the transition diet a transition/growing diet by increasing the MP density. Accordingly, the diet is fed for a varying length of time depending on established criterion of minimum live weight (i.e. 280 kg) prior to the finishing phase. However, the validity of this approach has not been justified empirically. Indeed, the only area where greater protein supplementation of feedlot cattle has consistently enhanced growth-performance has been during the receiving period (Fluharty and Loerch, 1995; Barajas and Zinn, 1998; Rossi et al., 2001). Thus, it seems more customary at the present time for feedlot cattle to be fed a receiving diet that is high in MP density until cattle are in a "full-feed" condition (DM intake is ≥ 2.5% of live weight). This receiving period may vary from as little as 7 days in yearling cattle to 28 or even 56 days in lighter-weight calves. In the special case of calf-fed Holsteins, this initial phase may extend until calves reach a live weight of about 275 kg (first 112 to 140 days in the feedlot; Ainslie et al., 1993; Ludden et al., 1995; Zinn and Shen, 1998; Klemesrud et al., 2000; Zinn et al., 2000; Zinn et al. 2007).

Receiving diets for feedlot cattle of diverse initial weights and backgrounds should be formulated to provide a minimum of 2.1 and 7.0 g/kg dietary DM intake of metabolizable methionine and lysine, respectively. However, achieving these constraints can be challenging. Corn and corn co-product feedstuffs are poor sources of ruminal escape lysine, and conventional supplemental proteins (soybean meal, canola meal, and cottonseed meal) are relatively poor sources of metabolizable methionine. Fishmeal is an excellent source of metabolizable methionine and lysine. However, due to negative effects on diet acceptability, its inclusion rate should not exceed 3% of dietary DM (and, it is has become very expensive). Alternatively, there remains considerable interest in balancing dietary metabolizable amino acid constraints for feedlot calves using protected amino acids, particularly methionine and lysine (Hussein and Berger, 1995; Klemesrud et al., 2000).

Conclusions

Factors involved in predicting metabolizable protein requirements and supply are sufficiently understood and demonstrated to be of practical significance in diet formulations for feedlot cattle. Most of the variation in prediction of metabolizable protein supply revolves around the estimation of the microbial contribution. This is due to a rather large animal-to-animal variation in ruminal OM digestion and microbial efficiency. Net ruminal synthesis of microbial protein is optimal when DIP is 11% of TDN or 8% of dietary DM. However, growth-performance of feedlot cattle may be enhanced by levels of urea supplementation in excess of that required to optimize microbial protein synthesis. Due to practical management constraints of feed mill operation and feed delivery, most feedlots are not able to efficiently handle more than four different dietary formulations. Thus, diets are formulated to meet "requirements" for feeding phases rather than target weight and expected rate of gain. These phases are: receiving, transition, finishing, and pre-slaughter. In most cases all feedlot cattle,

whether large or small, will be fed the same receiving diet. Methionine is expected to be the first limiting amino acid when feed intakes are low (as during the receiving period). Receiving and early growing diets should be formulated to provide 2.1 and 7.0 g/kg dietary DM of metabolizable methionine and lysine, respectively.

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