
PRACTICAL CONSIDERATIONS FOR BALANCING RUMINANT DIETS FOR AMINO ACIDS

L'ÉQUILIBRE EN ACIDES AMINÉS DES RATIONS POUR RUMINANTS : CONSIDÉRATIONS PRATIQUES

Essi Evans, PhD

Essi Evans Technical Advisory Services Inc., 64 Scugog St.

Bowmanville, ON L1C 3J1 Canada

essievans@sympatico.ca

ABSTRACT

Although it has been possible for quite some time to balance diets for ruminants for amino acids, formulating on that basis is not widely practiced in the industry. Formulators frequently have a lack of confidence in amino acid technology. Where such formulations been mastered, the benefits include more consistent production performance along with an improved potential to reduce nitrogen wastage.

Amino acid nutrition for ruminants is somewhat more complicated than for monogastrics, due to the involvement of rumen microbes in the degradation of protein and the variable contribution that they make to the protein supply. However, the system can be readily understood if broken down into two categories: factors that influence demands for amino acids, and factors that contribute to the supply of amino acids. This paper provides an appreciation of the amino acid nutrition of cows and a practical view to solving these needs.

RÉSUMÉ

Bien qu'il soit possible depuis un certain temps déjà d'équilibrer des rations pour ruminants en fonction des acides aminés, la formulation sur cette base n'est pas une pratique largement répandue dans l'industrie. Souvent, les concepteurs de rations n'ont pas totalement confiance dans la technologie des acides aminés. Ceux qui maîtrisent ce type de formulation ont obtenu, entre autres avantages, une performance de production plus constante et des conditions plus favorables pour réduire les rejets d'azote dans l'environnement.

La gestion des acides aminés dans l'alimentation des ruminants est un peu plus compliquée que chez les monogastriques, considérant le rôle des microorganismes du rumen dans la dégradation des protéines et leur contribution variable à l'apport protéique. Cependant, le système devient très facile à comprendre lorsqu'on le divise en deux volets : les facteurs qui influencent la demande d'acides aminés et les facteurs qui contribuent à l'apport d'acides aminés. Dans cet article, l'auteur dresse le portrait des besoins en acides aminés de la vache et traite des solutions envisagées en pratique pour les combler.

Introduction

There is a pressing need to optimize protein and amino acid use in farm livestock. Excess nitrogen (N), produced by poorly formulating or over formulating the protein portion of the diet, is a burden to both the environment and to the animal. Many livestock producers must now follow environmental guidelines that limit manure application. At the same time, there is pressure to reduce the use of animal byproduct feeds, often resulting in the need to increase ration protein. On the other side of the equation, animals, particularly high producing dairy cows, must utilize additional energy when converting excess N and

amino acids to urea for elimination, reducing the amount of energy available for productive purposes. Diets need to be formulated to reduce oxidation of amino acids to the extent possible, by feeding the correct amounts of amino acids whenever possible and whenever economical.

Another consideration for using available amino acid technology revolves around animal health. Amino acids are key components of proteins required for the production of enzymes, immunoglobins, some hormones, muscle and milk. Amino acids contribute to the formation of glucose, acting as a buffer when other precursors are in short supply. When the feed fails to supply sufficient amino acids, net catabolism of tissues occurs in order to supply amino acids for the most critical functions. Insuring that the correct amounts of amino acids are available contributes to productive performance by supporting wellness.

Although the benefits of using amino acids is well understood, many feed formulators are lost in the apparent controversy over products and programs available. The purpose of this paper is to remove some of the mystic surrounding this technology, and to clear the path for greater application.

Assessing the Needs of Animals for Amino Acids

In order to determine the amino acid needs of an animal, a description is required. There must be an awareness of the performance potential to serve as a target, as well as knowledge of factors that impact this target. There must further be a procedure to assess temporary or long-term responses to shortages. Then, diets can be formulated to permit the animal to attain its performance potential. While this may seem mysterious, it is easy to visualize amino acid usage by compartments: maintenance, gain, lactation and reproduction. . O'Connor et al. (1993) and Evans and Patterson (1985) provided estimates of needs for maintenance, growth and production based upon the efficiencies by which absorbed amino acids are used. Analogous systems have been adopted by NRC (NRC, 2000; NRC, 2001)

Feedlot cattle and require sufficient amino acids to maximize protein gain. Similarly growing replacement animals need to be able to deposit sufficient protein for an acceptable rate of maturation. Equations predicting the rate of protein deposition are readily available (NRC, 2000; NRC, 2001; DiContango, 1996) as are equations included in formulation programs such as the CNCPS or the CPM model, as well as some proprietary software.

In many models, the amino acid profile used for maintenance is similar to that used for growth. Some allowances have been made for the extrahepatic use of the branched chain amino acids (Evans and Patterson, 1985), which lowers the efficiency of use of the branched chain amino acids for maintenance. The relative relationship between maintenance and growth only needs to be considered when it is suspected that leucine, isoleucine or valine are only marginally available. The amino acid composition of tissue (Table 1) can be used as template for the amino acid profile that needs to be supplied via the duodenum.

Table 1. Amino Acid Profiles of Selected Items (g/100g amino acids)

Amino Acid	Rumen Bacteria ^a	Rumen Protozoa ^a	Soybean Meal ^b	Distillers Grains ^b	Gluten Meal ^b	Casein ^b	Tissue ^c
Arginine	4.8	4.6	7.3	3.7	3.0	3.7	3.3
Histidine	2.1	1.8	2.6	2.2	1.9	3.1	2.5
Isoleucine	5.2	6.0	4.5	3.5	3.9	5.2	2.8
Leucine	8.2	8.1	7.6	10.4	16.0	9.6	6.7
Lysine	7.1	10.2	6.0	2.3	1.6	8.1	6.4
Methionine	2.0	1.7	1.3	1.8	2.4	3	2.9
Phenylalanine	5.5	5.5	5.1	4.6	6.1	5.2	3.5
Threonine	5.8	5.6	3.6	3.5	5.3	4.2	3.9
Valine	5.6	5.3	4.8	4.8	4.4	6.6	4.0

^a Korhonen et al., 2002

^b Degussa corporation, 2001

^c NRC, 2000

Lactating cow needs amino acids for maintenance, growth and reproduction, as well as for milk production. During lactation, amino acid usage for milk is overwhelmingly the largest component.

Studies of amino acid uptake to output ratios dating back as far as 1975 (Clark, 1975) have shown that total uptake by the mammary gland are consistently higher than output into milk for arginine, lysine and the branch chained amino acids. On the other hand, the mammary uptake of the non-essential amino acids glutamate, aspartate, are proline considerably less than the quantities in milk. Evans (1999) demonstrated that the uptake of total amino acids is similar to output, indicating that these particular essential amino acids are needed to synthesize the non-essential amino acids found in milk. Because of this, the pattern of amino acids needed for milk is different than the composition of milk (Table 2).

Table 2. Uptake of Amino Acids by the Mammary Gland as Compared to Output in Milk
(g/100g amino acids)^a

Amino Acid	Total Uptake	Mammary Output
Arginine	8.53	3.40
Histidine	3.29	2.74
Isoleucine	8.80	5.79
Leucine	13.04	9.18
Lysine	9.14	3.40
Methionine	2.82	2.71
Phenylalanine	4.51	4.75
Threonine	4.76	3.72
Valine	10.01	5.89

^a Evans, 1999

Amino acid ratios. There is a certain amount of resilience built into the supply and demand within the udder. Practical formulation systems allow needs to be met to the extent possible, without elevating costs. Maintaining lysine and methionine in a narrow range relative to each other- especially without concern for the remaining essential amino acids- has the potential to elevate costs, and provides no proven benefit. Although efficiency may be higher when a ratio is maintained between all amino acids, the ability to supply them in a particular ratio may pose difficulties, and artificially elevate costs. As a result, one or more amino acids will be over supplied. Furthermore, if one of the amino acids found to be in excess happens to be lysine or methionine, then in order to maintain a constant ratio, more of the other amino acid would be required. If needs are met, then further maintaining of a constant ratio will only result in additional wastage.

McGuire (1998) established that the mammary could alter the extent of extraction of nutrients based upon the relationship between supply and need. This means that if there is an overage of one amino acid, there is no advantage to over formulating for another. Lacasse et al (1996) demonstrated that secretory epithelial cells in proximity to arterioles produce nitric oxide from arginine. Nitric oxide is a vasorelaxant, increasing local blood flow. The mammary gland appears to have the flexibility to regulate its own supply of nutrients through a combination of altering blood flow rates and altering percentage extraction to meet the target requirement (Maas et al., 1998).

Non-essential amino acids. Although systems, however crude, have been established to predict the utilization of essential amino acids, little regard has been given to the use of non- essential amino acids, and how they may impact the need for essential amino acids. It must be borne in mind that, if nonessential amino acids are not available, they will be synthesized from essential amino acids, much as occurs in the mammary gland. As well, Krebs's cycle intermediates contribute to the formation of nonessential amino acids.

The availability of non-essential amino acids may therefore be important in insuring the adequacy of the essential amino acid supply. Lobley et al. (2001) indicated that glutamine protects against methionine oxidation, and that this amino acid can alter the need for methionine. As another example, glutamate is preferred over glucose as an energy substrate for mucosa cells. Stoll et al. (1999) determined that 94% of the enteral glutamate but only 6% of the enteral glucose was utilized by the gut mucosa. The gut requirement for glutamate may result in withdrawal of this amino acid from somatic tissues, and the need to synthesize glutamate from arginine and proline.

Ruminant tissues have the capability of synthesizing non-essential amino acids. However, it is important not to forget that the roles of these amino acids can be essential and that as such it may influence the supply of essential amino acids. It is advisable to provide total amino acids in at levels that approximate the quantity needed for protein synthesis.

Sources of Amino Acids

In order to meet the animal's need for amino acids, there must be an understanding of not just how amino acids are consumed, but also the supply and availability of amino acids. The principle sources of amino acids are: microbial protein, escape feed protein, and protected amino acids.

Microbial protein. Microbial protein is by far the most important source of protein available to the ruminant. The amino acid composition of microbial protein has a profile that more closely approximates that of casein, which represents about 85% of the protein in milk, and body tissue than many of the vegetable protein sources commonly used (Table 1). It is advisable to maximize the production of microbial protein, as it is generally the cheapest source of protein available.

The rumen provides roughly 100 to 150g of microbial protein/ kg of dry matter consumed (Verbic, 2002). The higher levels are attainable when sufficient nutrients are supplied to support the growth of the microbes. Much like cows, rumen microbes are sensitive to the nutrient supply available to them. Microbial production is influenced by the availability of fermentable carbohydrate (Ahvenjarvi et al., 2002), nitrogen (Verbic, 2002) and minerals (Broudiscou et al, 1999).

Most systems for predicting microbial protein utilize some measurement of energy to predict the amount of protein that can be produced in the rumen (INRA 1988, AFRC 1992, NRC 2001). However, microbial protein cannot be readily predicted from the amount of energy or fermentable carbohydrate supplied (Orskov, 1994; Dijkstra et al., 1998), except at sub-optimal input levels. Growth will be proportionately increased when supply to the rumen is below optimum. However, an over supply does not result in extra growth any more than it does in the cow. In the cow, over supplying feed simply results in greater bunk losses and increased cost. This may explain why microbial efficiency (microbes produced/ carbohydrate assumed to be fermented) is often reduced with high grain diets.

Microbial growth and microbial efficiency is improved at higher turnover rates. Turnover rate has long been known to be dependent upon feed intake (Evans, 1981) and high growth rate results in the dilution of microbial maintenance and improved efficiency (Meng et al., 1999). Therefore insuring that intake is maximized is an ideal system for reducing the need for escape protein from ingredients and gaining the most from the rumen.

The nutritional requirements of rumen microbes may differ from that of the host, particularly in the area of intermediary metabolism. Microbial production may be enhanced or reduced with the addition of minerals such as sulfur (Carneiro et al, 2000) or phosphorus (Broudiscou et al, 1999) as examples. The addition of unprotected fat, particularly if the fat is unsaturated, can inhibit protozoa growth and fiber digestion (Oldick and Firkins, 2000). If energy levels are marginal, microbial protein may further be impaired, since unsaturated fats can lower cell wall digestibility.

Under certain conditions, microbial growth has been shown to be greater than anticipated. This may largely reflect the lack of understanding of the needs of rumen microbes. Miller- Webster et al. (2002) showed that yeast culture improves the digestion capacity of mixed rumen microbes. Ehjalberta et al

(1999) found improvements in ammonia uptake at some times after feeding, likely associated with increased microbial production. Likewise other fermentation products, such as Fermenten, have been shown to result in enhanced microbial performance (Hoover et al., 2001) and greater microbial protein synthesis.

To insure that microbes get enough soluble nitrogen to support growth, they need at least as much as what is incorporated into microbial protein, plus some extra to account for material that escapes from the rumen before it is converted to microbial protein. The amount lost will increase with rumen turnover rate. If there is not enough nitrogen in the rumen to support microbes, then feed will not be digested properly. Often the manure will appear stiff and fibrous. Bear in mind that there are other causes for this to occur. Results of experiments where the flow of nitrogenous components have been measured suggest that there is a general overage of ammonia nitrogen emanating from the rumen (Blouin et al., 1995). Saliva also contributes N to the rumen to assist in the support of microbial protein synthesis. Blood urea nitrogen is sometimes used as an indicator of excess soluble nitrogen. However, blood urea nitrogen levels can be high when there is also too much total protein in the diet. Excess escape protein will be deaminated, with urea the result. Therefore using the potential for microbial protein synthesis based upon intake and considering positive and negative modifiers is a useful guideline to evaluating the adequacy of the soluble nitrogen available.

The amino acid compositions of rumen bacteria and rumen protozoa are fairly consistent. In spite of considerable changes in diet and sampling time Martin et al. (1996) found no differences in the amino acid composition of bacteria and protozoa measured at various times post feeding. Prestlokken and Harstad (2001) reported no effects of diet upon the composition of bacteria and protozoa. Likewise, Rodriguez et al. (2000) found no differences in the profiles of bacteria that could be associated with level of intake. The composition of bacteria is, however, different than protozoa (Martin et al, 1996; Korhonen et al., 2002).

Of the microbial protein produced, approximately 70% will be in the form of amino acids (Korhonen et al, 2002). In other words, if 100g of microbial protein are synthesized/kg of feed dry matter, then 70 grams will be in the amino acid form. Evans and Patterson (1985) used a mixture of bacteria and protozoa (80:20) to derive an average amino acid pattern for rumen microbes. The proportion was based upon older data suggesting that of the microbial protein entering the gut in dairy cows consuming high grain diets, 20-25% originated from protozoa and 75-80% from bacteria. The origin of the profile used in the popular CPM model (O'Connor et al., 1993) is based upon the pattern found for bacteria.

There are two ways of providing results of amino acid analyses. Some laboratories report results from amino acid analyses on a molar, rather than a weight basis. It is important to be able to distinguish the difference. Convention for feed ingredients is to express amino acid percent on a weight and not a molar basis.

Escape protein. Escape protein is the portion of the total feed protein that is not fermented in the rumen. Because each protein source is made up of several proteins with differing solubilities, the amino acid profile of the escape portion of the protein will differ somewhat from the native protein. Therefore, it is useful to be able to predict the profile for the escape portion. A good source of information is Dr. Peter Robinson's' home page: <http://animalscience.ucdavis.edu/faculty/robinson/default.htm>

Protected amino acids. Protected amino acids have been available to the dairy industry for a considerable length of time. However, the addition of a protected amino acid will only be of benefit if it happens to be limiting. The value of adding protected amino acids can be determined with the use of a ration formulating program specifically designed to address the issue of the amino acid needs of the dairy cow. Several amino acid products are readily available on the North American market (Table 2). A complete description of most of these has been provided by Lapierre et al. (2002) The potential advantage of being able to target amino acids is to meet a specific need and lower overage.

Table 3. Companies Providing Protected Amino Acids or Amino acid Analogs in North America

Company	Amino Acid Provided
Adisseo	Methionine, methionine analog
Church and Dwight Co. Inc	Methionine analog
Degussa Corporation	Methionine
Jefo Nutrition Inc	Methionine, lysine
Nisso Inc.	Methionine
Novus International Inc	Methionine analog

Conclusion

Cow have amino acid requirements, and respond to a change in supply. Both the supply of amino acids and the needs for amino acids can be estimated with reasonable confidence with the information currently available. Although predictions may be less than completely accurate, using them should improve formulation accuracy over simply resolving diets on the basis of amino acids. An additional benefit of using amino acid programs is tighter formulas and whole farm nutrient management considerations.

References

- AFRC, 1992. Nutritional requirements of ruminant animals. Protein Nutr. Abst. Rev. Series B 62: 787-835.
- Ahvenjarvi, S., A. Vanhatalo and P. Huhtanen. 2002. Supplementing barley or rapeseed meal to dairy cows fed grass-red clover silage. 1. Rumen degradability and microbial flow. J. Anim. Sci. 80: 2176-2187.
- Blouin, J. P., J. F. Bernier, G. E. Loble, C.K. Reynolds, P. Debreuil and Helene Lapeirre. 1995. Effects of protein degradability on protein metabolism in dairy cows. J. Dairy Sci 78 (Suppl 1): 213.
- Broudiscou, L-P., Y. Papon and A. F. Broudiscou. 1999. Effects of minerals on feed degradation and protein synthesis by rumen microbes in a dual effluent fermenter. Reprod. Nutr. Dev. 39: 1999.
- Carneiro, H., R. Puchala, F. N. Owens, T. Sahlu, K. Qi and A. L. Goetsch. 2000. Effects of dietary sulfur level on amino acid concentrations in ruminal bacteria of goats. Small Rum. Res. 37:151-157.
- Clark, J. H. 1975. Lactational responses to post-ruminal administration of proteins and amino acids. J. Dairy Sci 58:1178-1197.
- Degussa Corporation. 2001. AminoDat 2.0. Interactive Software. Degussa AG. Hanau-Wolfgang, Germany.
- DiContanzo, A. 1996. Protein Requirements of Feedlot Cattle. Minnesota Cattle Feeders Report b-432.
- Dijkstra, Jan, J. France and D. R. Davies. 1998. Different mathematical approaches to estimating microbial protein supply in ruminants. J. Dairy Sci 81:3370
- Enjalberta, F., J.E. Garrett, R. Moncoulonc, C. Bayourthec, and P. Chicoteaud . 1999. Effects of yeast culture (*Saccharomyces cerevisiae*) on ruminal digestion in non-lactating dairy cows. Anim. Feed Sci Technol. 76:195-206
- Evans, Essi 1982. A dynamic model of crude protein digestion and utilization in ruminants. J. Anim. Sci. 55 (Suppl. 1): 419.
- Evans, Essi. 1981. An evaluation of the relationships between dietary parameters and rumen solid turnover rate. Can J. Anim. Sci. 61:91-96.

- Evans, Essi. 1999. Criteria for assessing amino acid utilization for milk protein synthesis. Proc. Eastern Nutr. Conf., p. 113-123.
- Evans, Essi and R. J. Patterson. 1985. Use of dynamic modelling seen as good way to formulate crude protein, amino acid requirements for cattle diets. Feedstuffs 57(42): 24-25.
- Evans, Essi, S .A. Yorston, and Dirk Van Binnendyk. 1993. Numerous factors affect milk protein percentage. Feedstuffs 65 (10): 14-17.
- INRA, 1988. Alimentation de bovins, ovins et caprins. INRA, Paris.
- Hoover, W.H., T.M. Miller, J. E. Nocek and W.E. Julian. 2001. Interaction between Fermenten or soybean meal and fermentability of carbohydrate source on microbial yield and efficiency in continuous culture. J. Dairy Sci 84(suppl. 1):80(Abstract0
- Korhonen M., S. Ahvenjarvi, A. Vanhatalo and P. Huhtanen. 2002. Supplementing barley or rapeseed meal to dairy cows fed grass-red clover silage. II. Amino acid profile of microbial fractions. J. Anim. Sci 80:2188-2196.
- Lacasse, P. V. C. Farr, S. R. Davis and C. G. Prosser. 1996. Local secretion of nitric oxide and the control of mammary blood flow. J. Dairy Sci. 79: 1369-1374.
- Lapierre, Helene, R. Berthiaume and L. Doepel. 2002. Rumen protected amino acids: Why, what and When? Proc.Maryland Nutr. Conf. p. 86-94.
- Lobley, G.E., S.O. Hoskins and C. J. McNeil. 2001. Glutamine in animal science and production. Brit. J. Nutr. 131:2525S-2531S.
- Maas, J. A., J. France and B.W. McBride. 1998. Towards a mechanistic model of amino acid uptake and metabolism by the mammary gland of the lactating cow. A literature review. J. Anim. Feed Sci. 7: 105-129.
- Martin, C., L. Bernard and B. Michalet-Doreau. 1996. Influence of sampling time and diet on amino acid composition of protozoal and bacterial fractions from bovine ruminal contents. J. Anim. Sci. 74: 1157-1163.
- McGuire, M.A. 1998. The potential to enhance milk protein. Proc. Pacific NW Anim. Nutr. Conf. P. 157
- Meng, Q., M. S. Kerley, P.A. Ludden and R. L. Belyea. 1999. Fermentation substrate and dilution rate interact to affect microbial growth and efficiency. J. Anim. Sci 77:206-214.
- Miller-Webster, T, W. H. Hoover, M. Holt, and J. E. Nocek. 2002. Influence of yeast culture on ruminal microbial metabolism in continuous culture J. Dairy Sci 85:2009-2014.
- NRC. 1994. Metabolic Modifiers: Effect on Nutrient Requirements of Food Producing animals. National Academy Press, Washington, DC
- NRC 2000. Nutrient Requirements of Beef Cattle: Seventh Revised Edition: Update 2000. National Academies Press, Washington, DC.
- NRC. 2001. Nutrient Requirements of Dairy Cattle. Seventh Revised Edition. National Academies Press. Washington, DC
- Oldick, B. S. and J. L. Firkins. 2000. Effects of degree of fat saturation on fiber digestion and microbial protein synthesis when diets are fed 12 times daily. J. Anim. Sci 78:2412-2420.

O'Connor, J. D., C. J. Sniffen, D. G. Fox and W. Chalupa. 1993. A net carbohydrate and protein system for evaluating cattle diets. IV. Predicting amino acid adequacy. *J. Anim. Sci*, 71: 1298-1311.

Orskov, E.R. 1994. Recent advances in understanding of microbial transformations in ruminants. *Livestock Prod. Sci* 39:53-60.

Parker, David. 2001. Amino Acid Nutrition in beef cattle. *Proc. S. Afr. Anim. Feed Industry Forum* p. 197.

Prestlokken, Egil and O. M. Harstad. 2001. Effects of expanded-treating a barley based concentrate on ruminal fermentation, bacterial N synthesis, escape of dietary N and performance of dairy cows. *Anim. Feed Sci Technol.* 90: 227-246.

Rodriguez, C. A. , J. Gonzalez, M. R. Alvir, J. L. Repetto, C. Centeno and F. Lamrani. 2000. Composition of bacteria harvested from liquid and solid fractions of the rumen of sheep as influenced by feed intake. *Br. J. Nutr.* 84:369-376.

Stoll, B., D.G. Burrin, J. Henry, H. Yu, F. Jahoor, and P.J. Reeds. 1999 Substrate oxidation by the portal drained viscera of fed piglets. *Am. J.Physiol.* 277: E168-E175.

Van Soest, P. J., C. J. Sniffen, D. R. Mertens, D. G. Fox, P. H. Robinson and U. Krishnamoorthy. 1982. A net protein system for cattle:the rumen submodel for nitrogen. Page 265 in *Protein Requirements for Cattle: Proceedings of an international Symposium* (F.N. Owens, Ed.) Oklahoma State Publ. MP-109, Oklahoma State University.

Verbic, J. 2002. Factors affecting microbial protein synthesis in the rumen with emphasis on diets containing forages. Bericht 29. *Viehwirtschaftliche Factgang, BAL, Gumpenstein* April 24-25, pages 1-6.