Amino Acids in Dairy Nutrition – Where Do They Fit?

T. R. Overton and L. E. Chase
Department of Animal Science
Cornell University

As our understanding of the biology underlying specifics of protein nutrition for dairy cows has increased and systems utilized to formulate diets for dairy cows have become more sophisticated, more attention has been directed toward formulating diets on an amino acid basis. This makes sense because the tissues of the cow actually require amino acids for protein synthesis, rather than protein per se. The purpose of this paper is to provide some perspective to amino acid balancing together with the underlying biology supporting amino acid balancing and our current recommendations for amino acids in diets for dairy cattle.

Why balance for amino acids?

As mentioned above, the tissues of the cow utilize amino acids for protein synthesis and other functions in the body (Figure 1). In many situations, deficiencies of one or more amino acids actually may limit production of milk and milk protein. Furthermore, imbalances or large excesses of amino acids result in increased catabolism of amino acids by the liver and excretion of urea at an energy cost to the cow. Some researchers have utilized amino acid balancing to meet amino acid requirements while simultaneously decreasing the crude protein content of the diet. This obviously has advantages from an environmental standpoint. Nevertheless, it is important that we put amino acid balancing in context. Figure 2 indicates that there are numerous variables in nutritional management of dairy cows that must be under control in a herd before balancing for amino acids will yield satisfactory results for either the nutritionist or dairy producer.

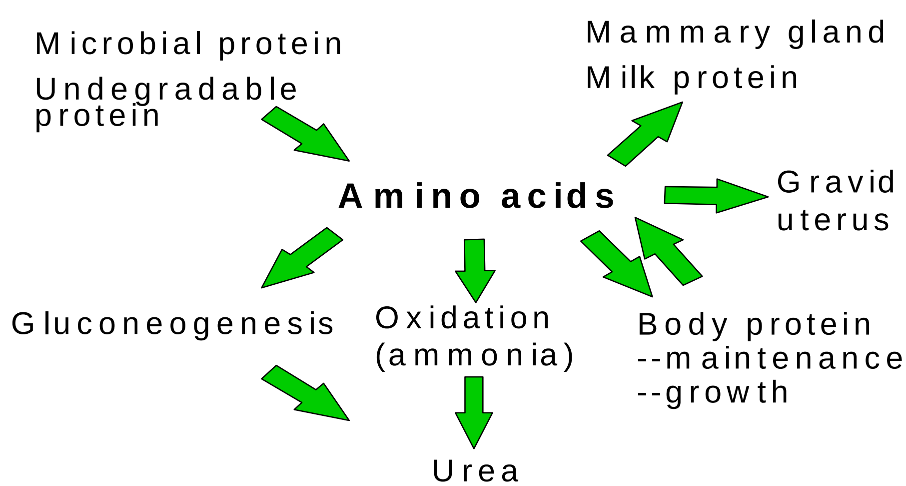

Figure 1. Schematic of amino acid utilization in the dairy cow.

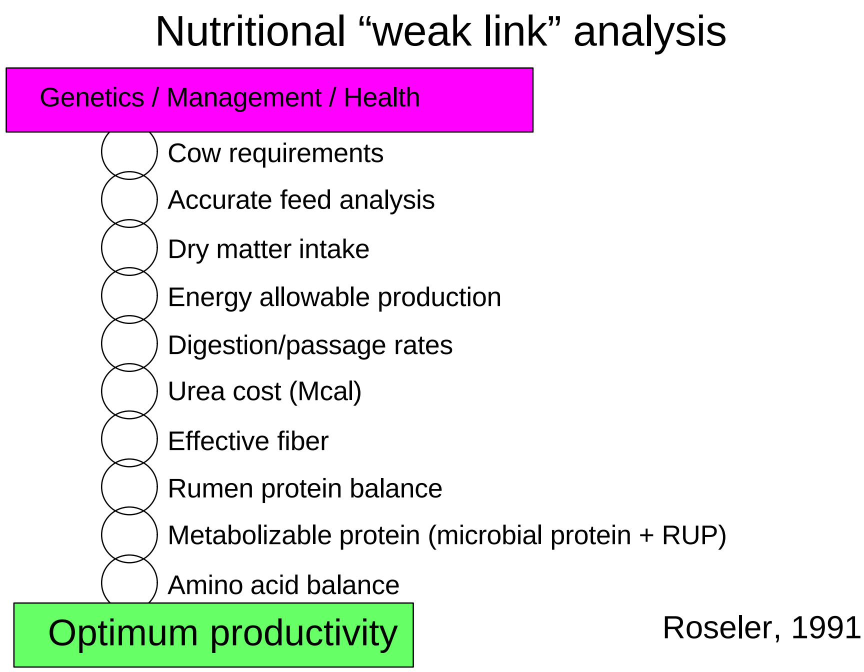

Figure 2. "Weak link" analysis of nutritional management (Roseler, 1991).

The basics of balancing for amino acids.

The concept underlying amino acid balancing is straightforward and is simply a comparison of amino acid flow to the small intestine compared with amino acid requirements for synthesis of milk and tissue. The amino acid makeup of tissue and milk protein is encoded in the genes present in the cow; therefore, the amino acid composition of tissue and milk protein is reasonably constant and characteristic of the types of proteins synthesized by any given tissue (Table 1). Flow of individual amino acids to the small intestine can be predicted from the amount of microbial protein flowing to the small intestine and the amount of insoluble feed protein that escapes ruminal fermentation, combined with the characteristic amino acid composition of each.

The "take-home" message from Table 1 is that the amino acid composition of microbial protein compares quite favorably with that of milk protein; therefore, it makes sense for us to formulate diets that result in synthesis of large amounts of microbial protein when fed to the cow. Some key dietary factors that influence synthesis and passage of microbial protein to the small intestine are feed intake, source and amount of carbohydrates and proteins, and feeding some types of rumen-active fats (Clark et al., 1992). For most high producing cows microbial protein will account for only 50 to 60% of amino acid requirements; therefore, we must also pay attention to the ruminally undegradable protein sources included in the diet. Unlike microbial protein, all sources of ruminally undegradable proteins typically fed to dairy cows have one or more "weaknesses" in their amino acid compositions when compared to the amino acid composition of milk protein. Table 1 indicates that corn protein sources such as corn gluten meal are particularly weak in terms of supplying lysine whereas blood meal is weak in supplying methionine and isoleucine. Therefore, it makes sense that we formulate diets using ruminally undegradable protein sources that have complementary amino acid compositions to more closely match the amino acid composition of milk protein. A second factor that we must consider when evaluating sources of ruminally undegradable proteins is their intestinal digestibility. Figure 3 demonstrates that there are marked differences in intestinal digestibility of various ruminally undegradable protein sources.

Amino acid composition of tissue, milk, microbes, and selected feed proteins (g/100g protein)

AA	Tissue	Milk	Microbes	CGM	Blood
Met	2.0	2.71	2.60	2.09	1.07
Lys	6.4	7.62	7.90	1.24	9.34
His	2.5	2.74	2.00	2.45	6.45
Phe	3.5	4.75	5.10	6.48	7.86
Trp	.6	1.51	- - -	- - -	- - -
Thr	3.9	3.72	5.80	2.93	4.73
Leu	6.7	9.18	8.10	16.22	13.40
Ile	2.8	5.79	5.70	4.34	.88
Val	4.0	5.89	6.20	5.04	9.08
Arg	6.6	3.40	5.10	3.17	5.01

O'Connor et al., 1993

Table 1. Amino acid composition of tissue, milk, microbes, and selected feed proteins (O'Connor et al., 1993).

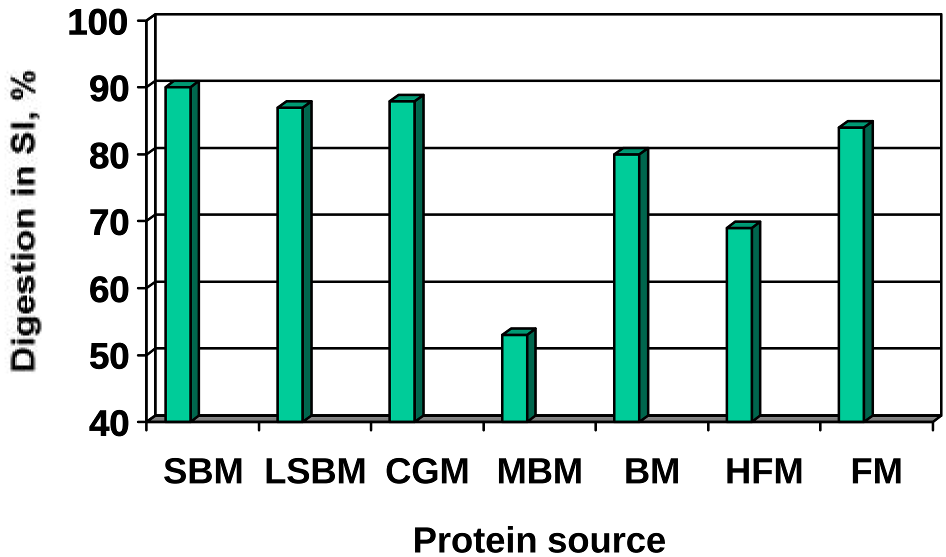

Figure 3. Estimates of intestinal digestibility of various protein sources (Calsamiglia and Stern, 1995).

Systems used to formulate diets for dairy cattle on an amino acid basis.

There are two principal systems used to formulate diets on an amino acid basis. One is the factorial system used in the Cornell Net Carbohydrate System and developed by O'Connor et al. (1993). The second is the ideal protein system – Dr. Chuck Schwab from the University of New Hampshire and Dr. Henri Rulquin from INRA in France have developed variations of this system that are used today.

The factorial system calculates amino acid requirements using the net amount of protein synthesized for each function in the cow (maintenance, growth, gestation, and lactation), its amino acid composition, and an efficiency factor for conversion of absorbed (metabolizable) amino acids to the net amino acid requirement (Table 2). Each of these steps has variance associated with it, and this system is particularly sensitive to the efficiency factors for the different physiological functions.

Table 2. Utilization of individual absorbed amino acids for physiological functions (g/g). From O'Connor et al., 1993.

Amino acid	Maintenance	Lactation
Methionine	.85	.98
Lysine	.85	.88
Histidine	.85	.90
Phenylalanine	.85	1.00
Tryptophan	.85	.85
Threonine	.85	.83
Leucine	.66	.72
Isoleucine	.66	.62
Valine	.66	.72
Arginine	.85	.42

The ideal protein system is based upon the concept that amino acids will be used for productive function in a characteristic proportion to each other; therefore, balancing on an ideal protein basis will maximize the efficiency of nitrogen use in the cow. At this time, methionine and lysine are the only amino acids defined in either the Schwab or Rulquin systems. The Schwab system expresses methionine and lysine as a percentage of essential amino acid flow to the small intestine, and the Rulquin system expresses methionine and lysine as a percentage of metabolizable protein flow to the small intestine. Requirements in both systems were determined by either infusing or feeding increasing amounts of the amino acid of interest until the response variable (usually milk protein yield) peaked (Figure 4). Table 3 contains the Schwab and Rulquin "requirements" and our practical targets for these in diets for lactating cows.

How do these systems compare? Schwab (1996) calculated requirements for amino acids using both the factorial system and his ideal protein system, and determined that the factorial system approximated his system when there were no excesses of the other essential amino acids (Table 4). Most diets will result in excesses of one or more amino acids when fed to dairy cattle; therefore, it is difficult to determine how sensitive these requirements are to changes in supplies of other amino acids to the dairy cow.

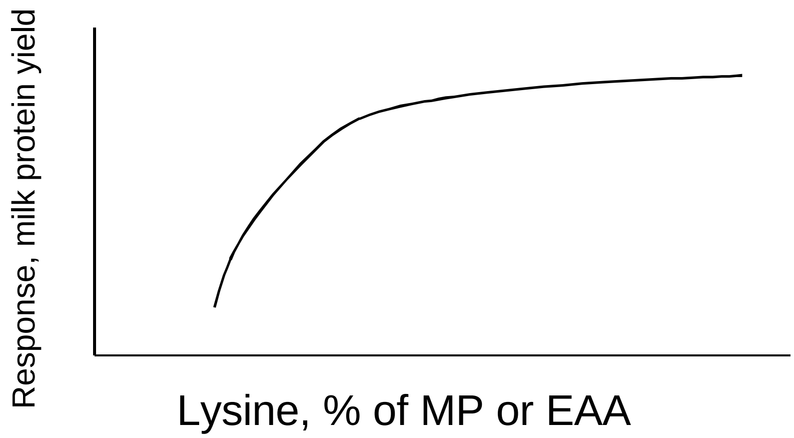

Figure 4. Schematic of determination of requirement for lysine in the Rulquin and Schwab systems.

Table 3. Requirements and practical targets for methionine and lysine in the Schwab and Rulquin systems.

System	AA	"Requirement"	"Practical target"
		--------------- % of EAA	---------------
Schwab	Met	5.0	4.7 to 4.8
	Lys	15.0	14.5 to 14.7
		--------------- % of MP	---------------
Rulquin	Met	2.5	2.1 to 2.2
	Lys	7.3	6.7 to 6.8

Table 4. Requirements of Holstein cows for absorbed EAA at three levels of milk production as determined using the CNCPS

	60 lb/d		100 lb/d		140 lb/d	
EAA	g/d	(% of EAA)	g/d	(% of EAA)	g/d	(% of EAA)
Arg	67	(10.5)	88	(9.6)	111	(9.1)
His	37	(5.9)	54	(5.8)	70	(5.8)
Ile	76	(11.8)	116	(12.5)	156	(12.8)
Leu	112	(17.5)	162	(17.5)	212	(17.5)
Lys	104	(16.3)	151	(16.3)	198	(16.3)
Met	33	(5.1)	48	(5.2)	63	(5.2)
Phe	58	(9.0)	84	(9.0)	110	(9.1)
Thr	56	(8.8)	80	(8.7)	104	(8.6)
Trp	17	(2.7)	27	(2.9)	36	(3.0)
Val	79	(12.3)	117	(12.6)	154	(12.7)

Schwab, 1996

Use of rumen-protected amino acids in diets for dairy cattle.

There are several sources of methionine or analogs of methionine currently on the market. At present time, there is no rumen-protected source of lysine on the market. Our philosophy on these methionine products is to utilize them in diets when you are seeking to add a single amino acid, and it is more economical to provide the methionine using a synthetic source as opposed to adding it through a feed ingredient such as corn gluten meal. Characteristics of each product, as provided by the manufacturers, are available in CPM Dairy.

Amino acid balancing for transition cows.

It is attractive to apply the concept of amino acid balancing to the most important phase of the lactation cycle. Unfortunately, the systems described above are most effective when milk protein synthesis is the primary fate of amino acids absorbed from the small intestine. Results of supplementing protected methionine or lysine during the transition period have been mixed, perhaps as a result of the large amount of variation in performance of cows during early lactation and inadequate numbers of cows used in these experiments. Recent data suggest that there are alternative roles of amino acids during the transition period, namely an increase in use of amino acids for glucose synthesis in the liver and specialized roles of both methionine and lysine in metabolism of nonesterified fatty acids by liver. Although balancing amino acids during the transition period has the potential to optimize health and production, more research must be conducted before requirements for individual amino acids can be determined accurately.

Conclusions

Balancing for amino acids offers opportunities to decrease the amount of protein fed to the cow while maintaining or improving performance. Furthermore, opportunities exist for balancing amino acids in diets fed to transition cows. Current systems for balancing amino acids are most effectively utilized during peak and later lactation; further research is required before concrete recommendations for transition cows can be made.

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