Do You Feed Protein or Amino Acids to Make Milk?

H. Lapierre[1], D.R. Ouellet[1] and L. Doepel[2]

[1]Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, STN Lennoxville, Sherbrooke, QC J1M 1Z3
Email: Helene.Lapierre@agr.gc.ca, Daniel.Ouellet@agr.gc.ca;
[2]Faculty of Veterinary Medicine, University of Calgary, AB T2N 4N1
Email: ldoepel@ucalgary.ca

Take Home Messages

- Amino acids (AA) are the "base-units" used by tissues to synthesize proteins.
- These "base-units" are delivered through digestion of proteins in the intestine: these proteins are a mixture of dietary, microbial and endogenous proteins, and contain a highly variable proportion of AA.
- Utilization of AA varies greatly among themselves and between tissues.
- Therefore, to maximize the match between supply and requirement, dairy rations need to be balanced on an AA basis.
- Two approaches exist to balance rations for AA: proportion (ideal protein) or factorial.
- Estimating and meeting requirements for individual AA is not yet an easy task, but first steps can be taken.

Introduction

Although the term "efficiency" is largely used in the nutrition of non-ruminants and feedlot cattle, historically, dairy cows (or dairy nutritionists) have been evaluated more on their absolute milk production than on their efficiency. There has been, however, over the last decade, a renewed interest into increasing the efficiency of transfer of the crude protein fed to the dairy cow into milk true protein, driven by the need to decrease feeding costs and to limit the impact of livestock production on the environment, an increasing concern amongst consumers. The nitrogen (N) portion of the protein fed and

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not used by the animal is excreted via feces and urine, and contributes to N_2O formation (a greenhouse gas), to ammonia emissions (leading to the formation of fine particulate matters, largely responsible for the deterioration of air quality) and for directly polluting water and soil.

■ Definition of Requirements and Supply

To optimize efficiency, nutritionists have the task to formulate rations that will best match nutrient supply to requirements. This requires the choice of a "unit" that will best define both the supply and the requirements. At the tissue level, it is clear that the raw materials used by the cells to build proteins are free amino acids (AA). Therefore, an estimation of the requirements in terms of AA would theoretically cover exactly what is being used by the animal.

The determination of AA supply to a ruminant is, however, not an easy task. The net supply of AA to the dairy cow is determined by the amount of protein flowing and digested through the small intestine. Obviously, due to the extensive metabolism occurring in the rumen, assessment of the digestive flow of AA cannot be solely based on protein and AA intake, as is the case for monogastrics. Indeed, the net flow of protein at the entrance of the intestine is a combination of dietary protein that has by-passed the rumen and microbial protein synthesized in the rumen.

Major improvements have been achieved over the last decades to refine our assessment of protein supply to dairy cows: we moved from crude protein to degradable and undegradable protein. But none of these is a direct assessment of the real supply to the cow: the former represents the N available to the rumen micro-organisms whereas the latter only represents a fraction of what is available to the animal. Finally, complex rumen sub-models have been developed using rumen degradable protein and energy, rate of passage, etc, to estimate the amount of protein being delivered to the site of digestion and digested, and therefore, available to the animal: the now-called metabolizable protein (MP). These models estimating MP also offer the opportunity to estimate the flow of digestible AA, the basic constituents of proteins. Two questions then arise: 1) Do we really need to consider individual AA to better match supply and requirement? and 2) If so, how do we best estimate the supply and requirements of AA?

In this presentation, we will limit our considerations to essential AA (EAA). They are called "essential" because the dairy cow cannot synthesize them and, therefore, they must be supplied from the combination of dietary rumen undegradable protein (RUP) and microbial protein synthesis. This class includes histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. This does not deny the importance of the non-EAA. The polypeptide chains constituting proteins contain both essential

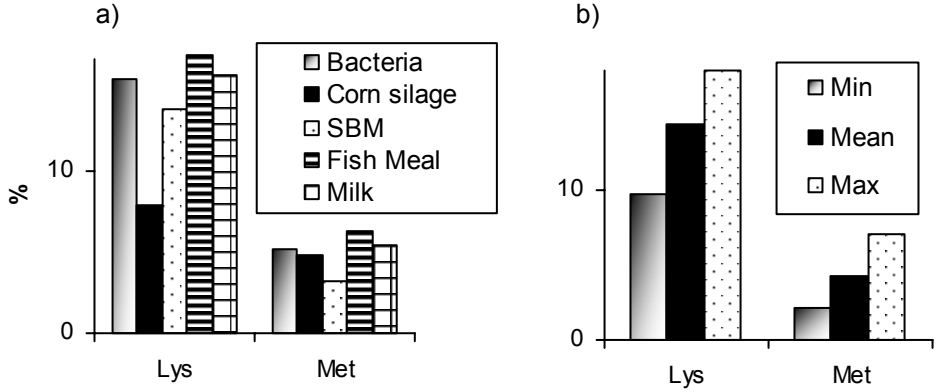
and non-EAA, but the non-EAA can be synthesized by the dairy cow. There is, however, a sub-group within the non-EAA, called semi-essential, for which synthesis is not sufficient to support high levels of production. Arginine is the most typical AA of this group as *de novo* synthesis of arginine could represent up to 40% of total supply to the animal (Doepel et al., 2004). As data are scarce on non-EAA, especially the determination of *de novo* synthesis and therefore an accurate estimation of their real supply to the dairy cow, we will limit our discussion to the fate of the EAA.

■ Why Should We Consider Individual AA?

If AA were always supplied in the same proportions from MP to the dairy cow or if all AA had similar metabolic fates, we would not need to partition total protein supply and requirement into individual AA. Is it the case?

Supply of AA

The comparison of the profiles of individual AA from microbial protein and different feed ingredients quickly indicates the disparity in their AA composition and therefore possible variations in the profile of AA of protein digested by dairy cows (Figure 1a, NRC 2001). Effectively, large variations in the concentration of individual AA in duodenal protein have been reported (Figure 1b, NRC 2001). This clearly indicates that proteins cannot be considered as a homogenous entity and need to be characterized in terms of their single components, the AA, to assess what is really provided to the dairy cow.



Adapted from NRC (2001)

Figure 1a: Composition in lysine and methionine (% of essential AA) of feed ingredients, bacteria and milk.

Figure 1b: Measured concentration of lysine and methionine (% of essential AA) in duodenal protein in studies used by NRC (2001) to develop equations predicting AA duodenal flow.

The first challenge is to adequately predict the supply of AA. A number of rumen sub-models have been developed to predict the fraction of feed ingredients by-passing the rumen, utilisation of degradable nitrogen (N) and energy for microbial growth and subsequent passage into the duodenum in order to estimate the total flow of protein to the duodenum. Models use different approaches to estimate the flow of individual AA available to the dairy cow, either assessing AA composition for each duodenal fraction (RUP, microbial protein: e.g. CNCPS version 4, AminoCow® version 3.5.2.) or using regression equations linking the percentage of an EAA in duodenal protein to the percentage of this AA in RUP and the percentage of RUP in duodenal protein (NRC, 2001). Duodenal flow combined with digestibility factors estimates the amount of AA available to the animal. We have, however, to keep in mind that not all of the duodenal flow represents a net input of AA to the dairy cow. Up to 20% of the duodenal flow may originate from endogenous proteins (Ouellet et al., 2002 & 2007). At the entrance of the duodenum, endogenous proteins comprise mainly mucoproteins, saliva, sloughed epithelial cells and enzyme secretions into the abomasum. This endogenous fraction constitutes a recycling of AA previously absorbed from the small intestine, returned to the gut tissue via arterial circulation and used to build proteins that are returned into the lumen of the gut prior to the duodenum. As such, they do not represent a net input of AA for the animal but are just a form of recycling. Although not perfect, these different predictive schemes offer a realistic estimation of AA supply to the dairy cow (Pacheco et al., 2006).

Utilisation of AA across Tissues

The proportion of each AA relative to total protein supply is clearly not constant, but once the AA are absorbed, are their metabolic fates similar across tissues? In dairy cows, metabolism of AA has been mainly studied across the mammary gland (an obvious target for research) and also across the splanchnic tissues. The splanchnic tissues comprise the portal-drained viscera (gut, spleen, pancreas and associated mesenteric fat) plus the liver. In dairy cows, despite the fact that these tissues contribute less than 10% of body mass (Gibb et al., 1992), they account for close to 50% of whole body oxygen consumption (Huntington, 1990) and contribute also close to 50% to whole body protein synthesis (Lapierre et al., 2002).

Net Utilisation of Essential AA across the Gut

Measurement of net utilisation of EAA across the gut is not an easy task. Contrary to other tissues where the supply only comes from blood, net supply of AA to the gut combines both arterial supply and AA digested from the lumen of the small intestine. First attempts to determine the net utilisation of AA across the portal-drained viscera were in sheep where small intestinal

disappearance was compared with portal absorption: the recovery in the portal vein relative to the amount that had disappeared from the small intestine ranged from 19% for histidine to 69% for lysine (Lys), suggesting a huge net utilisation of AA by the gut (Tagari and Bergman, 1978). More recent data, including that from dairy cows (Berthiaume et al., 2001), reported higher recoveries than in this initial study, ranging from 43% (threonine) to 95% (histidine). Does this ratio really represent what is being lost through passage across the gut? Based on our previous description of duodenal flow of AA, we have to keep in mind that part of the small intestinal disappearance is not a net supply as the endogenous proteins secreted prior to the duodenum that are digested and reabsorbed do not contribute to the net supply. Therefore, without any net utilisation of AA by the gut tissue, portal absorption will always be less than apparent small intestinal disappearance.

The real losses of AA across the gut are oxidation and endogenous secretions that are not reabsorbed and therefore secreted in the feces. There is very limited data in ruminants on endogenous protein secretions and gut oxidation, both processes being very challenging to measure directly. However, recent studies reported oxidation across the portal-drained viscera of leucine in dairy cows (Lapierre at al., 2002) and of leucine and methionine but not of lysine and phenylalanine in sheep (Lobley et al., 2003). On the other hand, the endogenous secretions that are not reabsorbed and that are secreted in the feces represent a net loss to the animal. Larsen et al. (2001) evaluated an apparent re-absorption of the endogenous N fraction in the small intestine of 62%. The endogenous secretions are influenced by diet composition such as fibre and other factors (e.g. anti-nutritional factors, internal parasites; see review Ouellet et al., 2007). In addition, the proportions of threonine, serine and proline are high in mucins which may emphasize preferential need to fulfill requirements for these AA with increased endogenous losses.

In dairy cows, indirect measurements (comparing estimated flow of digested AA and measured portal absorption) have suggested substantial losses of the branched-chained AA (isoleucine, leucine and valine), probably via oxidation, and of threonine, most likely due to its high concentration in endogenous secretions (Pacheco et al., 2006). The reader can refer to a more complete review on AA utilisation by the portal-drained viscera across farm species in Lobley and Lapierre (2003). Overall, despite the fact that exact amounts and regulatory mechanisms are still unknown, there is enough evidence to suggest significant net utilisation of some EAA by gut tissues, mainly through oxidation and loss of endogenous proteins in the feces, with substantial difference between AA.

Net Utilisation of Essential AA across the Liver

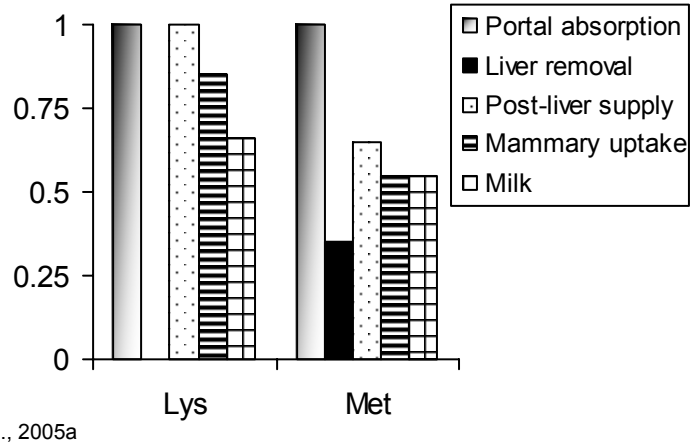
Due to the anatomical location of the liver, there is a little more information on AA metabolism across the liver than across the gut. From a database of studies where N transfers across the splanchnic tissues had been studied (22 treatments), the liver removed 45% of total AA being absorbed (AA being measured individually or as alpha-amino-N; Lapierre et al., 2005a). We have to be very cautious in the interpretation of this number before we apply it to all AA. Does this 45% extraction apply to all AA under all circumstances? This removal encompasses all AA, essential and non-essential. The liver removes AA for different purposes. Among other functions, it has the important role of avoiding hyperaminoacidaemia (overload of AA in the blood) and therefore extracts AA in excess through urea synthesis; it also uses AA for the synthesis of proteins exported to the plasma; and finally it catabolizes some AA, mainly non-essential, for the synthesis of glucose. These different roles of the liver already suggest variable hepatic removal of the different AA.

To better acknowledge the fate of individual AA across the liver, another database, where the net splanchnic flux of individual AA had been measured, was used (14 treatments; Lapierre et al., 2005a). Two families of EAA were quite distinctive in their behaviour across the splanchnic tissues and related well with the groups described by Mepham (1982) according to their metabolism across the mammary gland. Amino acids from Group 1, for which mammary uptake is about equal to secretion into milk protein, are substantially removed by the liver and post-liver supply is approximately equal to mammary uptake. Histidine, methionine, phenylalanine plus tyrosine, and tryptophan are included in this group. On average, hepatic removal relative to net portal absorption varied from 36% for methionine to 48% for phenylalanine (Lapierre et al., 2005a). In contrast, AA from Group 2, already identified as those for which mammary uptake exceeds milk output, are, on a net basis, barely removed by the liver with a post-liver supply higher than mammary uptake. Group 2 consists of the branched-chain AA (isoleucine, leucine and valine) and lysine. Therefore, despite the fact that the liver is the major site of ureagenesis, not all of the EAA in excess are, on a net basis, extracted by the liver. They can be deaminated elsewhere in the body and the N returned to the liver through shuttles like alanine or glutamine prior to excretion of excess N as urea. The distribution of enzymes responsible for AA catabolism is directly linked with the two groups described above. For Group 1 AA, degradative enzymes are predominantly restricted to the liver while for Group 2 AA, the enzymes responsible for catabolism are widely distributed across tissues, including liver, muscle, fat, gut and mammary gland (Lobley and Lapierre, 2003).

Net Utilisation of Essential AA across the Mammary Gland

As previously proposed by Mepham (1982) and discussed in the previous section, for AA of Group 1 (histidine, methionine, phenylalanine plus tyrosine, and tryptophan), there is a stoechiometric transfer of their mammary uptake to milk output. This indicates, on a net basis, that the equivalent of all AA taken up as free AA from blood circulation is incorporated into milk protein. However, for AA of Group 2 (isoleucine, leucine, valine and lysine), uptake usually exceeds output. These are roughly the observations made in connection with splanchnic measurements (Lapierre et al., 2005a) and also made in studies on mammary metabolism in dairy cows (see review from Rulquin et al., 2007), except for histidine which showed a small increment of the uptake:output ratio with increased supply. Another question that also arises is: why does the mammary gland extract AA of Group 2 in excess of its needs for milk protein synthesis? It should be stated here that the mammary uptake of non-EAA (except arginine) is usually not sufficient to support the amount of non-EAA used to make milk protein, i.e. there must be synthesis of non-EAA within the mammary gland. This means that some AA need to be taken up in excess to provide the N needed for intra-mammary synthesis of the non-EAA. Indeed, it has been shown that the extra-N from lysine was used for the synthesis of non-EAA within the mammary gland (Lapierre et al., 2005b).

Figure 2 summarizes the fate of two AA representative of Group 1 (methionine) and Group 2 (lysine) across the splanchnic tissues and the mammary gland (Lapierre et al., 2005a). Overall, it is clear that the metabolism of AA varies among them and between tissues.



From Lapierre et al., 2005a

Figure 2. Net flux across tissues of two essential AA representative of Group 1 (methionine) and Group 2 (lysine) in dairy cows, relative to portal absorption.

■ Recommendations for Individual AA

There are two approaches used to estimate AA requirements in dairy cows. The first approach is to define requirements with a dose-response relationship between the proportions of AA in MP supply for maximal use of MP for milk protein synthesis. This is the approach adopted by NRC (2001), with recommendations proposed for lysine and methionine. The other approach, the factorial approach, cumulates the requirements for individual functions (maintenance, growth, pregnancy and lactation) with a definite AA composition and a defined efficiency of transfer of the digested AA for each function. Examples are the Cornell Net Carbohydrate and Protein System (Fox et al., 2004) and AminoCow®.

Based on the proportion approach (or ideal protein), similar recommendations for lysine and methionine were proposed in the mid-90's from the laboratories of Rulquin et al. (1993) and Schwab (1996). The last NRC (7^{th} edition, 2001), using a similar methodological approach to Rulquin et al. (1993) but with an updated database, determined that lysine and methionine should represent, respectively, 7.2 and 2.4% of MP supply, close to the recommendations of 7.3 and 2.5% of protein digestible in the intestine (PDI) estimated by Rulquin et al. (1993). More recently, histidine was suggested to be the first limiting AA in diets with a high proportion of grass (Korhonen et al., 2000). For this AA, however, recommendations vary widely from 2.4% of MP (Doepel et al., 2004) to 3.2% of PDI (Rulquin et al., 2001), with an intermediate value of 2.7% of MP recommended by CPM-Dairy (Chalupa and Sniffen, 2006).

Although estimation of AA requirement expressed as a proportion of total supply was selected initially as the best way to denote AA recommendations due to limited knowledge on AA nutrition precluding a factorial approach (NRC, 2001), with recent increased knowledge on AA metabolism, is it still the most appropriate expression of requirement? The expression of the requirements as a proportion of MP has the advantage of simplicity and has certainly helped to convey the importance of balancing dairy rations for AA. Some points, however, lead to questioning the relevance of this approach if we want to further refine the estimation of EAA requirements. These issues will be discussed using lysine as an example, but the same conclusions would be drawn for all EAA. First, the proportion of the sum of EAA in MP supply at the duodenum is not constant. For example, from the database used by Doepel et al. (2004), where all the digestive flows of EAA had been estimated with NRC (2001), the proportion of total EAA relative to MP supply in control treatments varied from 42 to 48% (mean 45.4%). Lysine supply averaged 104.9 g/d in these studies. Assuming a fixed supply of EAA, including this constant amount of lysine supply, the proportion of lysine present in the MP would vary between 5.87 and 6.71% with the EAA proportion increasing from 42 to 48% of MP (Table 1).

Table 1: Effect of the proportion of essential amino acids (EAA) relative to metabolizable protein (MP) on the expression of a constant lysine (Lys) supply relative to MP.

Lys supply, g/d	% EAA / MP	Total MP	% Lys / MP
104.9	42.0	1788	5.87
104.9	45.4	1655	6.34
104.9	48.0	1564	6.71

This is an important consideration as a decreased proportion of EAA indicates, obviously, an increment in non-EAA and these do not influence milk protein yield (Whyte et al., 2006). Extreme situations provoking these discrepancies between the ratio of EAA to MP are experiments where AA are infused. One extreme example of the limitation of this concept is demonstrated in a study with abomasal infusion of water, EAA, non-EAA and total AA (EAA + non-EAA): it is clear that the parameter that predicts milk protein yield is the absolute amount rather than the proportion of the EAA relative to MP (Table 2). Addition of 380 g of non-EAA did not improve milk protein yield while maximum milk yield was observed when 360 g of EAA was added; there was no further increase in milk protein when non-EAA were added to EAA (total AA): across treatments, the proportion of lysine relative to MP varied greatly and was not related to milk protein yield.

Table 2: Effect of supply of amino acids on milk protein yield.

	Treatments[1]			
	Water	EAA	non-EAA	TAA
MP supply[2], g/d	1221	1556	1600	1936
EAA supply[2], g/d	559	919	559	919
Lys supply[2], g/d	82	141	82	141
Lys, %MP	6.72	9.06	5.13	7.28
Milk protein yield, g/d	967	1104	966	1150

[1]Abomasal infusion of essential amino acids (EAA), non-EAA or total AA (TAA); from Whyte et al., 2006.
[2]Supply is estimated from digestive flow plus the abomasal infusion to yield the metabolizable protein (MP) supply.

On the other hand, if we want to use the factorial approach to determine AA requirements, we have to face our limited knowledge on AA utilization. This approach requires, first, a good assessment of AA needs for the individual functions (maintenance, growth, gestation, and lactation). Nonetheless, even models developed on the proportion approach determine the total requirements for MP based on the factorial approach, before the assessment of the AA balance. Therefore, we need to define exactly each of these functions, and thus what their requirements entail. For example, the so-called

"maintenance" requirement should indeed represent the requirement for the maintenance of a high producing animal and not the requirements of an animal at low intake. In practice, the most important contributor to maintenance requirement is metabolic fecal protein (MFP), estimated based on dry matter intake (NRC, 2001). To transform the MP requirement for MFP into AA requirements, the AA composition of MFP is necessary. Currently, most models using the factorial approach use empty body composition but, in reality, these losses are proteins secreted into the gut and then excreted in the feces. This corresponds exactly to the definition of endogenous protein losses and it would be more appropriate to use the AA composition of endogenous protein secretions. This exact composition is not yet well-defined in ruminants but, as a first step, the average of values obtained from the abomasum secretion in ruminants and across the small intestine in pigs has been proposed (Lapierre et al., 2007). On the same theme, it is necessary to also improve the accuracy of MFP estimation. Recent work has determined rates of endogenous protein secretions across the digestive tract, including fecal endogenous losses, in dairy cows offered different types of diets (Ouellet et al., 2007). More work is required to determine those factors affecting endogenous protein losses and to refine the model used but with the results obtained so far, a value of 21.5 g MP/kg DMI has been proposed for lactating cows fed typical dairy rations (Lapierre et al., 2007a). Scurf secretion is a minor contributor (< 1%) to MP requirement and AA composition based on keratin should be an acceptable average (Doepel et al., 2004). Urinary endogenous-N losses represent less than 10% of MP requirement and AA requirements are also estimated from empty whole body AA composition. This may alter based on a deeper analysis of the various urine-N fractions but the overall impact will probably be marginal.

Bearing in mind the various limitations detailed above, we can compare the proportion and factorial approaches for lysine requirements of cows at different production levels. For this exercise, the average of cows on the medium MP supply in Raggio et al. (2004) is used plus two hypothetical cows, one with lower (20 kg) and one with higher (40 kg) milk production. Comparison of the approaches is given in Table 3 and this also includes estimates of MFP based on NRC (2001) or Ouellet et al. (2007). One major conclusion is that as milk production increases the proportion of required lysine in the MP with the factorial approach also increases, reflecting the higher content of this AA in milk compared with the other functions (urinary, scurf, and MFP). The requirement of the intermediate cow determined by the factorial approach yielded a proportion of lysine in MP supply close to the NRC value (7.24 vs. 7.20; Table 3). Nonetheless, the factorial approach and logical consideration of the biology of the lactating animal both indicate that for high producing dairy cows a larger proportion would be necessary and conversely lower producers would require a smaller proportion of lysine in the MP supply.

Table 3. Estimation of lysine requirements in lactating cows using the proportion[1] or the factorial approach[2].

	Level of production				Level of production		
	Low	Med	High		Low	Med	High
DMI, kg/d	22.0	24.2	25.3				
MPY, g/d[3]	600	853	1200				
Requirements	MP, g/d			*% Lys*[4]	Lys, g/d		
Urinary endo.	105	105	105	*7.0*	7.4	7.4	7.4
Scurf	15	15	15	*3.7*	0.5	0.5	0.5
MFP	536	570	591	*6.0*	32.3	34.3	35.6
MFP-Ouellet[5]	*472*	*519*	*546*		*28.4*	*31.2*	*32.7*
Duo endo.[6]	156	172	179				
Milk	896	1273	1791	*8.7*	79.1	112.4	158.1
Total	1707	2134	2681				
Total-Ouellet	*1643*	*2083*	*2633*				

Estimations of Lys requirements[1]

	Proportion			Factorial		
Lys, g/d	123	154	193	119	155	202
Lys, % MP	7.20	7.20	7.20	6.98	7.24	7.52
Using MFP from Ouellet						
Lys, g/d	*119*	*150*	*190*	*115*	*152*	*199*
Lys, % MP	*7.20*	*7.20*	*7.20*	*6.76*	*7.10*	*7.41*

[1]The proportion approach uses MP requirement from NRC (2001) times the recommendations that Lys supply should represent 7.2% of MP supply.
[2]The factorial approach uses the MP estimated from the NRC (2001) times a determined AA composition for each function (see text for definition).
[3]MPY: milk protein yield.
[4]Percentage of Lys in protein used to transform the MP requirement into Lys requirement.
[5]Metabolic fecal protein requirement estimated from the data of Ouellet et al. (2007).
[6]The duodenal endogenous flow is included in the NRC (2001) requirement of MP, but is not included in the factorial approach.

One final consideration about the proportion approach is that when attempts were made to determine requirements for all the EAA, results cannot realistically be attained for all the EAA. For example, to attain the recommendations of Doepel et al. (2004; Table 4), we have to supply a diet that contains 50% of MP as EAA. In this study, estimations of

recommendations were first obtained as EAA relative to total EAA, but then transferred to MP using an average proportion of EAA on MP of 48% (excluding tryptophan). With this approach, lysine and methionine requirements were yielding similar recommendations to those of Rulquin et al. (1993) and NRC (2001; Table 4).

However, achieving a supply of MP containing 50% EAA is not realistic with practical diets, as we have seen previously that the proportion of EAA relative to total AA varies from 42 to 48%. In contrast, if the latest estimations of Rulquin et al. (2007) are summed, then the sum of EAA is closer to reality, approximately 45%. In this approach, still, the estimated requirement for certain AA, namely the branched-chain AA and Arg, are lower than what is usually provided by the rations, meaning that such low proportions cannot be obtained 'naturally' for these AA. With more realistic proportions of these AA included in the calculations, then the sum of EAA will also approximate to 50% of MP supply.

Table 4. Comparison of estimation requirement and supply of essential amino acids (EAA) relative to digestible protein

AA	%EAA/MP[1]	%AA/PDI[2]	%AA/MP supply[3]
Arg	4.6	3.1	4.6
His	2.4	3.0	2.1
Ile	5.3	4.6	4.9
Leu	8.9	8.9	8.9
Lys	7.2	7.3	6.3
Met	2.5	2.5	1.9
Phe	5.5	4.6	5.0
Thr	5.0	4.0	4.9
Trp	1.7	1.7	1.2
Val	6.5	5.3	5.6
Total	49.6	44.9	45.4

[1]MP: metabolizable protein, from Doepel et al., 2004.
[2]PDI: protein digested in the intestine, from Rulquin et al., 2007.
[3]AA digestive flow and MP supply estimated with NRC (2001) from all the control treatments used in Doepel et al. (2004).

■ Meeting the Requirements

A first step in reaching the AA recommendations would be a judicious combination of ingredients, as for example, corn products are "classically" low in lysine whereas soybean products contain a higher proportion of lysine. However, using the proportion approach, we can reach the level recommended for certain AA, especially methionine, lysine and histidine only through the use of rumen protected AA. Using the factorial approach,

recommendations of g/d of each AA can be reached by increasing supplementation of rumen undegradable protein, but this will lead to excess supply of other AA. Therefore, even with this approach it is probably more economical, and certainly more environmentally friendly, to use rumen protected AA to increase those that are deficient. In practice, however, only methionine is commercially offered currently in a rumen protected form that has been scientifically tested and reported. Lysine was offered for a short period of time a few years ago but then withdrawn from the market. However, the large demand for supplemental lysine created by the availability of distillers grains from corn residue as a by-product of the ethanol industry stimulates the re-introduction of rumen protected lysine products to the market. In fact, a new rumen protected lysine has just been launched, but no independent scientific reports on its efficiency have been presented yet.

A crucial point that has not been debated in the present document is the utilization of a fixed factor of conversion of absorbed MP or AA towards protein anabolism. An average value of 0.67 has been used in all the comparisons presented here in order to simplify the discussion, but it is clear that supply under requirement is used at a higher efficiency whereas supply over requirement yields a lower efficiency. This has been presented in an earlier presentation of Doepel and Lapierre (2006) at this Seminar.

Summary

In conclusion, the biology beyond the rumen clearly indicates why we need to consider individual AA to feed dairy cows. Their proportion in duodenal flow of protein and their metabolic fate across the gut, the liver and the mammary gland varies greatly. Catabolism and therefore efficiency of each AA across different tissues can be altered for each individual AA depending on its supply. Although the perfect system is not yet available to determine requirements, there is compelling evidence that diets need to be balanced for AA. The proportion approach has the advantage of being simple to use and has certainly initiated implementation of AA balance in diets. Nonetheless, as our basic knowledge on AA utilization by the cow increases, we will be able to update the factorial approach and this will, in the long term, be a more soundly based and accurate scheme to efficiently reduce feed cost and excretion of N into the environment but with no detrimental effect on milk protein yield.

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