

## **Industry Presentation**

### **Feeding Lysine: A Nutritionist and Dairy Producer's Perspective**

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#### **INTRODUCTION**

Protein is a relatively high input cost in dairy rations. In addition, nitrogen excretion into the environment is an area of increasing concern and regulation by state and federal agencies. Managing both the cost of protein in the diet and nitrogen excretion into the environment is dependent on maximizing the efficiency with which protein is used by the cow. Cows actually do not have a requirement for protein per se, but rather require amino acids (**AA**). Proteins are made up of long chains of AA and can be classified as either essential (**EAA**), which cannot be synthesized by animal tissues or cannot be synthesized in sufficient amounts to meet requirements (arginine and histidine), or non-essential, which can be synthesized by the cow (NRC, 2001). Essential AA must be provided in the diet in the form of rumen undegradable protein (**RUP**) or produced by rumen bacteria during microbial protein synthesis in the rumen. Lysine (**Lys**) is one of the 10 EAA and its predominant biological function is almost exclusively for synthesis of protein (milk protein, growth, pregnancy, maintenance).

Efficient utilization of dietary protein depends on the ability to formulate diets that deliver the optimal amount of metabolizable AA (AA actually absorbed from the intestine) in the right proportions to meet the needs of the cow. Once a single EAA becomes limiting, the other absorbed AA

cannot be utilized to produce proteins and protein efficiency begins to decline. Lysine and methionine (**Met**) have been shown to be the 2 EAA most often first limiting for milk protein production (Schwab et al., 1976; Polan et al., 1991; Armentano et al., 1997). Lysine is most likely to be first limiting in diets based on corn, corn silage, and corn byproducts; which are all rich in Met (King et al., 1991). It should not be surprising that Lys and Met are generally considered to be limiting in most U.S. dairy cattle rations; as most commonly used feedstuffs are low in Lys and Met content relative to the Lys and Met content of milk protein, bacterial protein, and lean tissue (NRC, 2001; Table 1).

Increasing metabolizable Lys levels in deficient diets can occur through increasing microbial protein production (microbial protein is high in Lys and has an AA profile very near that of milk protein) or by feeding feeds with high RUP and rich in Lys (blood meal, fish meal, processed soybeans, and soybean meals). A significant potential challenge with Lys is variability in level of intestinal digestibility. Lysine in the presence of heat, moisture, and reducing sugars can undergo Maillard reactions resulting in indigestible end-products. This will reduce the bioavailability of the Lys. This process can occur under controlled conditions designed to increase protein bypass; but can also occur randomly, such as in overheated silages.

**Table 1.** A comparison of the essential amino acid composition of body lean tissue, milk, and ruminal bacteria with that of some common feeds<sup>1</sup>.

Item	Arg <sup>2</sup>	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
	-----% of CP-----									
Lean tissue	6.6	2.5	2.8	6.7	<b>6.4</b>	<b>2.0</b>	3.5	3.9	0.6	4.0
Milk	3.4	2.7	5.8	9.2	<b>7.6</b>	<b>2.7</b>	4.8	3.7	1.5	5.9
Bacteria	5.1	2.0	5.7	8.1	<b>7.9</b>	<b>2.6</b>	5.1	5.8	-	6.2
Alfalfa silage	3.9	1.7	3.9	6.4	<b>4.4</b>	<b>1.4</b>	4.2	3.8	0.9	5.0
Corn silage	2.0	1.8	3.3	8.6	<b>2.5</b>	<b>1.5</b>	3.8	3.2	0.4	4.5
Grass silage	3.1	1.7	3.6	6.1	<b>3.3</b>	<b>1.2</b>	4.4	3.3	1.1	4.9
Barley	5.1	2.3	3.5	7.0	<b>3.6</b>	<b>1.7</b>	5.1	3.4	1.2	4.9
Corn	4.6	3.1	3.3	11.2	<b>2.8</b>	<b>2.1</b>	4.6	3.6	0.7	4.0
Oats	6.8	2.4	3.8	7.3	<b>4.2</b>	<b>2.9</b>	5.2	3.5	1.2	5.2
Wheat	4.7	2.4	3.3	6.6	<b>2.8</b>	<b>1.6</b>	4.6	2.9	1.2	4.2
Brewers grains	5.8	2.0	3.9	7.9	<b>4.1</b>	<b>1.7</b>	4.6	3.6	1.0	4.8
Canola meal	7.0	2.8	3.8	6.8	<b>5.6</b>	<b>1.9</b>	4.1	4.4	1.5	4.7
Corn DDG w/sol	4.1	2.5	3.7	9.6	<b>2.2</b>	<b>1.8</b>	4.9	3.4	0.9	4.7
Corn gluten meal	3.2	2.1	4.1	16.8	<b>1.7</b>	<b>2.4</b>	6.4	3.4	0.5	4.6
Cottonseed meal	11.1	2.8	3.1	5.9	<b>4.1</b>	<b>1.6</b>	5.3	3.2	1.2	4.2
Soybean meal	7.3	2.8	4.6	7.8	<b>6.3</b>	<b>1.4</b>	5.3	4.0	1.3	4.6
Sunflower meal	8.2	2.6	4.1	6.4	<b>3.6</b>	<b>2.3</b>	4.6	3.7	1.2	5.0
Blood meal	4.4	6.4	1.3	12.8	<b>9.0</b>	<b>1.2</b>	6.9	4.3	1.6	8.7
Feather meal	6.9	1.2	4.9	8.5	<b>2.6</b>	<b>0.8</b>	4.9	4.7	0.7	7.5
Fish meal	5.8	2.8	4.1	7.2	<b>7.7</b>	<b>2.8</b>	4.0	4.2	1.1	4.8
Meat meal	7.1	2.1	3.0	6.3	<b>5.4</b>	<b>1.4</b>	3.6	3.4	0.7	4.4

<sup>1</sup> Amino acid values for lean tissue, milk, and ruminal bacteria are from O'Connor et al. (1993) and amino acid values for feeds are from NRC (2001).

<sup>2</sup> Arg = Arginine; His = Histadine; Ile = Isoleucine; Leu = Leucine; Lys = Lysine; Met – Methionine; Phe = Phenylalanine; Thr = Threonine; Trp = Tryptophan; Val = Valine

With the advent of modeling programs that more accurately predict the delivery of metabolizable protein (**MP**) and AA to the cow, there has been significant interest in formulating specifically for AA. In addition sources of concentrated rumen protected Lys and Met now provide nutritionists with tools to more accurately formulate diets for AA by providing the specific AA without feeding excessive levels of MP to achieve

those levels. This has the benefits of increasing the efficiency of protein utilization, while increasing milk and milk component production. This will lead to increased profitability for dairies and reduced excretion of nitrogen into the environment, helping producers meet more stringent environmental restrictions in the future.

## **FEEDING LYSINE**

### **Physical Characteristics and Variability**

Lysine is a basic AA, which means it bears a positive charge at physiological pH. As a result, its  $\epsilon$ -amino group side chain easily forms covalent bonds with other AA and reducing sugars known as the Maillard reaction. Lysine's basic side chain is so reactive that even when it is part of a peptide or protein, its  $\epsilon$ -amino group remains reactive and can still form covalent bonds (Nursten, 2005). Although all AA, peptides, and proteins can participate in the Maillard reaction; Lys is the most common and prevalent AA that participates. This ability has both good and bad attributes when it comes to feeding dairy cows. In ruminant nutrition, heating of feedstuffs allows nutritionists to increase the rumen bypass characteristics of high protein feedstuffs such as blood meal, fish meal, soybean meal, gluten meal, etc. Unfortunately, this reaction tends to not be controlled very well and can result in under- or over-heating of the feedstuff, which greatly increases the variability and inconsistency.

Forages can vary greatly in quality from one year to the next and from one cutting to the next; which can greatly affect not only the AA content of the forage, but also the AA digestibility of the forage. Because of the expense and time required to evaluate the AA content of forages for individual farms, nutritionists must often rely on book values for the AA content of forages and grains. This can lead to inaccurate predictions by ration balancing software of the amount of digestible AA available.

There are many different factors that can contribute to this variation, but one of the

factors that can greatly reduce the digestibility of Lys in forages is poor fermentation that results in *burnt* or *caramelized* forage. If forages are not ensiled properly due to improper moisture content, insufficient packing, etc.; a Maillard reaction can occur, which binds the Lys in the forage and decreases the availability to the cow. In properly fermented forages, the rapid decline in pH greatly decreases the likelihood of Maillard reactions occurring because the reactivity of the Lys side chain that participates in Maillard reactions declines as pH decreases. However, in improperly fermented forages where the pH does not decline rapidly, Lys reactivity remains high and the forage tends to caramelize.

Unfortunately, it is difficult to determine through standard chemical analyses the extent to which Lys has been rendered unavailable. As a result, nutritionists often do not account for the reduced Lys digestibility when formulating rations, which can lead to an over-prediction of digestible Lys. Couple this with the normal year-to-year variation that occurs across all forages and grains and our ability to accurately predict the amount of digestible Lys in our rations can become a problem. While this problem will never be fully eliminated, it is imperative that nutritionists and dairy producers make every attempt to harvest and store as high a quality of forages as possible to reduce this variability. Additionally, we can reduce overall ration protein and AA variation by feeding high quality, consistent sources of RUP. While we do not have control over the weather when harvesting forages, we do have control over how they are stored and over which high RUP feedstuffs we choose to include in our rations.

## **Why Encapsulate Lysine?**

The feedstuffs with the highest concentrations of Lys are blood meal, fish meal, and meat and bone meal; however, these feedstuffs are subject to palatability issues, quality inconsistencies, product availability, and large price variations over time and across different regions of the country. Additionally, as the public becomes more concerned and involved with the management and feeding practices of the U.S. dairy industry; the use of animal derived proteins in dairy cow rations, particularly blood and meat and bone meal, are coming under increased scrutiny. In addition, as is demonstrated in Table 1, it is difficult to meet the Lys requirements of high producing dairy cows using only plant derived protein sources, such as soybean and canola meal. Consequently, there has been a renewed interest in developing a rumen protected Lys product that would provide nutritionists with a concentrated source of Lys to meet the requirements of high producing dairy cows without feeding animal proteins.

Encapsulating Lys is not an easy task as it has an irregular shape which makes it difficult to apply a coating around and it is very hygroscopic (i.e., it readily attracts water) which makes it difficult to handle. These challenges make it difficult to develop an efficacious product that can maintain the balance between having high rumen bypass and high intestinal digestibility while being able to withstand everyday stresses such as mixing, handling, and feeding that an encapsulated product must go through before it even reaches the cow.

Over the years there have been several attempts to encapsulate Lys; however, most attempts have been unsuccessful. Where companies have developed an effective

product, the product was economically uncompetitive with animal protein sources and thus was not marketed very long. In the fall of 2008, Balchem Corporation introduced an encapsulated Lys product to the marketplace called AminoShure-L. Since then there have been several other companies who have also introduced products. A common question that has been asked recently is why the sudden flood of protected Lys products in the dairy industry? One possible explanation for this recent flurry of activity can be derived from a combination of the following factors:

- Animal protein prices and product quality have been extremely variable and inconsistent over the past several years,
- The value of milk protein has remained relatively strong,
- Increased backlash by the popular press and the general public regarding the feeding of animal proteins to dairy cows, and
- Increased pressure on the dairy industry to reduce excretion of nitrogen as a means to reduce our impact on the environment.

## **BALANCING RATIONS FOR LYSINE**

The question often asked is whether or not it is more important to focus on the amount of Lys and Met being supplied to the cow or the ratio in which they are supplied. The simple answer is that both are important! Ultimately, cows require amounts of nutrients, not percentages and ratios; however, the ratio is important for ensuring that the animal is utilizing the AA as efficiently as possible. As demonstrated by Schwab et al. (2004; Table 2), maximizing the amount of Lys and Met in

**Table 2.** Effect of NRC (2001) predicted percentages of Lys and Met in metabolizable proteins (MP) on calculated flows of MP-Lys and MP-Met and the amounts of MP-Lys and Met that can be used for protein synthesis.<sup>1</sup>

Predicted Lys/Met <sup>4</sup> in MP (%)	Lys/Met ratio	Flows <sup>2</sup>		Used for protein synthesis <sup>3</sup>	
		MP-Lys	MP-Met	MP-Lys	MP-Met
		----- (g/d) -----			
6.4/1.7	3.8/1	179	48	144	48
5.8/1.7	3.4/1	162	48	144	48
5.7/1.9	3.0/1	160	53	159	53
5.8/2.1	2.8/1	162	59	162	54
6.3/2.0	3.2/1	176	56	168	56
6.6/2.2	3.0/1	185	62	186	62

<sup>1</sup> Adapted from Schwab et al. (2004).

<sup>2</sup> Calculations are based on a predicted MP supply of 2,800 g/d.

<sup>3</sup> Based on the assumption that the optimum Lys/Met ratio in MP is 3:1 and the understanding that any AA supplied in excess of need for protein synthesis is not used for protein synthesis and therefore, is catabolized and used for energy.

<sup>4</sup>Lys = Lysine; Met = Methionine

the ration, while maintaining an approximate 3:1 ratio of Lys to Met, will provide the cow with the maximum availability of digestible AA to help meet her productive requirements.

When balancing diets for Lys and Met, it is analogous to taking 3 legs to make a solid stool. In this case the efficient use of protein, assuming Lys and Met are first limiting, requires the optimal ratio of Lys to Met; the optimal levels of Lys and Met expressed as a percentage of MP; and the optimal amounts, in grams, to meet the requirement of the cow. Most nutritionists recognize the need to provide Lys and Met in the proper ratio, although there is some debate as to what the *correct* ratio should be. A realistic target is between 2.9:1 and 3.0:1. This alone is not enough as you could have 3 molecules of Lys and 1 of Met, and thus the correct ratio but the cow would not be able to produce 100 pounds of milk with it.

The second leg of the stool is Lys and Met expressed as a percentage of MP. This is particularly important in terms of achieving efficiency. If Lys and Met percentages are too high (not generally a problem) these expensive nutrients are wasted since other limiting AA will limit performance. If the percentages are too low, then all of the other AA are utilized inefficiently and protein efficiency suffers.

Whitehouse et al. (2009) used 3 different commonly used programs for balancing amino acids to estimate the requirement values of Lys and Met as percentages of MP to maximize milk protein content and milk protein yield and; subsequently, determined the optimal ratios of Lys and Met generated from these results. Schwab and Foster (2009) utilized the data from Whitehouse et al. (2009) and included r<sup>2</sup>-values which are presented in Table 3. There are several interesting points to glean from this table.

- First, while the recommended optimal Lys to Met ratios have been adjusted downward when maximizing both milk protein content and yield, the ratios are still relatively close to the 3:1 ratio that has been previously recommended. Additionally, these recommendations are still relatively new and have not been universally tested in the field to determine whether it is economically worthwhile adjusting rations to achieve the new ratios.
- Second, economics will ultimately dictate the maximum amount of grams of metabolizable Lys and Met that will be fed to maximize milk yield and milk protein yield. However, if nutritionists do choose to adjust their rations to reflect the new recommended Lys to Met ratios, they should achieve these ratios not by reducing the amount of metabolizable Lys in their rations, but rather by increasing the current level of metabolizable Met in their rations to obtain the new recommended ratio of Lys to Met.

As was previously stated, cows ultimately require amounts of nutrients, not percentages and it has been the experience of the authors that most commercial dairy rations currently are not meeting the grams of metabolizable Lys and Met required to maximize milk yield and milk protein synthesis as a result of economics. Hence, reducing the grams of metabolizable Lys to meet a lower ratio of Lys to Met rather than increasing the level of metabolizable Met to meet this ratio may result in lost milk yield and milk protein yield.

The third leg of the stool is the total grams of metabolizable AA fed. Cows have a requirement for grams not percentages. As production increases the cow needs more grams to meet her increased production. Consequently placing any artificial cap on the number of grams required can result in reduced performance and efficiency of protein use. Schwab et al. (2004) evaluated the *before* and *after* rations and milk

**Table 3.** Breakpoint estimates for required concentrations of lysine and methionine in MP for maximal content and yield of milk protein for the NRC, CPM, and AMTS models.<sup>1</sup>

	Optimal Lys <sup>2</sup>	Optimal Met <sup>2</sup>	Lys r <sup>2</sup>	Met r <sup>2</sup>	Optimal Lys/Met
<u>NRC Model</u>					
Content of milk protein	6.80	2.29	.82	.75	2.97
Yield of milk protein	7.10	2.52	.65	.36	2.82
<u>CPM Model</u>					
Content of milk protein	7.46	2.57	.83	.73	2.90
Yield of milk protein	7.51	2.50	.53	.46	3.00
<u>AMTS Model</u>					
Content of milk protein	6.68	2.40	.83	.76	2.78
Yield of milk protein	6.74	2.31	.65	.38	2.92

<sup>1</sup> Adapted from Schwab and Foster (2009) and Whitehouse et al. (2009).

<sup>2</sup>Lys = Lysine; Met = Methionine

**Table 4.** NRC (2001) evaluations of *before* and *after* diets for 6 commercial farms in which concentrations of Met and Lys in metabolizable protein (**MP**) were increased.<sup>1</sup>

Item	Herd 1		Herd 2		Herd 3	
	Before	After	Before	After	Before	After
CP, %	17.7	17.8	18.3	18.6	18.3	18.1
RDP, %	10.9	11.2	11.0	11.2	11.4	11.3
RUP, %	6.8	6.6	7.3	7.4	6.9	6.8
MP, g/d	3054	2984	3159	3131	3062	3040
Lys, % MP	5.78	6.53	5.74	6.20	5.84	6.18
Met, % MP	1.65	2.17	1.68	2.08	1.68	2.01
MP-Lys, g/d	177	195	181	194	179	188
MP-Met, g/d	50	65	53	65	51	61
Lys/Met	3.5/1	3.0/1	3.4/1	3.0/1	3.5/1	3.1/1
Milk protein, %	3.06	3.33	2.99	3.12	3.02	3.22
Milk fat, %	3.81	3.92	3.56	3.66	3.61	3.72

  

Item	Herd 4		Herd 5		Herd 6	
	Before	After	Before	After	Before	After
CP, %	19.1	18.2	17.6	17.0	18.1	17.2
RDP, %	12.0	11.2	10.4	10.3	10.8	10.6
RUP, %	7.1	6.9	7.2	6.7	7.3	6.6
MP, g/d	3107	3030	3073	3035	3071	2809
Lys, % MP	5.84	6.25	6.34	6.76	6.37	6.55
Met, % MP	1.67	2.04	1.73	2.35	1.73	2.20
MP-Lys, g/d	182	189	195	193	184	174
MP-Met, g/d	52	62	53	61	50	58
Lys/Met	3.5/1	3.0/1	3.7/1	3.2/1	3.7/1	3.0/1
Milk protein, %	3.00	3.20	3.20	3.50	2.82	3.16
Milk fat, %	3.49	3.64	3.90	4.30	3.32	3.78

<sup>1</sup> Adapted from Schwab et al. (2004).

<sup>2</sup> CP = crude protein; RDP = rumen degradable protein; RUP – reumen undegradable protein; MP = metabolizable protein; LYS = Lysine; and MET = Methionine

production results on 6 commercial dairies in the NRC (2001) model when the concentration of Lys and Met in MP were increased and the ratio of Lys to Met was adjusted to obtain as close to a 3:1 ratio as possible (Table 4). The results indicate that both milk protein and milk fat concentrations increased when these changes were made. The grams of metabolizable Lys and Met were also

increased in all but one of the herds. Interestingly, the grams of metabolizable Lys and Met that were being fed in the *before* rations would not be considered low levels for most commercial dairy rations that are balanced for Lys and Met.

It is important for nutritionists to remember that although the Lys to Met ratio is important, it is only one leg of the AA

balancing stool and that it is also important to maximize the total grams of Lys and Met in an economically feasible manner to truly maximize milk yield and milk component production. In many areas of the U.S. where the value of milk fat and, particularly, milk protein make up a large portion of dairy producer's milk checks; striving to maximize the grams of metabolizable Lys and Met, maximizing the concentrations of Lys and Met in MP, and maintaining a ratio of Lys to Met of approximately 3:1 will result in a positive return on investment and maximize profitability.

### CONCLUSIONS

Until recently, feeding additional metabolizable Lys was not an easy task; as there were no synthetic sources of rumen protected Lys available in the marketplace. However, there are several options available today that will allow nutritionists to meet the metabolizable Lys requirements of today's high producing dairy cows, while reducing overall ration CP; which is not only environmentally more favorable, but also creates space in the ration that will allow for more flexibility when balancing dairy cow rations.

It is important for nutritionists to remember that the AA nutrition stool contains 3 legs. To maximize profitability for the dairy producer, not only does the ratio of Lys to Met and the concentrations of Lys and Met in MP need to be met, but also the overall grams of metabolizable Lys and Met must be maximized. Without all 3 legs of the stool, milk yield and milk component production will not be maximized and profitability will be reduced.

### LITERATURE CITED

Armentano, L. E., S. J. Bertics, and G. A. Ducharme. 1997. Response of lactating cows to methionine or methionine plus lysine added to high protein diets

based on alfalfa and heated soybeans. *J. Dairy Sci.* 80:1194-1199.

King, K. J., W. G. Bergen, C. J. Sniffen, A. L. Grant, D. B. Grieve, V. L. King, and N. K. Ames. 1991. An assessment of absorbable lysine requirements in lactating cows. *J. Dairy Sci.* 74:2530-2539.

National Research Council. 2001. *Nutrient Requirements of Dairy Cattle*. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Nursten, H. E. 2005. Nutritional Aspects. Pages 101-108 *In: The Maillard Reaction: Chemistry, Biochemistry, and Implications*. <http://www.rsc.org/publishing/ebooks/2005/9780854049646.asp>. Accessed Jan. 8, 2010.

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.

Polan, C. E., K. A. Cummins, C. J. Sniffen, T. V. Muscato, J. L. Vicini, B. A. Crooker, J. H. Clark, D. G. Johnson, D. E. Otterby, B. Guillaume, L. D. Muller, G. A. Varga, R. A. Murray, and S. B. Peirce-Sandner. 1991. Responses of dairy cows to supplemental rumen-protected forms of methionine and lysine. *J. Dairy Sci.* 74:2997-3013.

Schwab, C. G., L. D. Satter, and A. B. Clay. 1976. Response of lactating dairy cows to abomasal infusion of amino acids. *J. Dairy Sci.* 59:1254-1270.

Schwab, C. G., R. S. Ordway, and N. L. Whitehouse. 2004. Amino acid balancing in the context of MP and RUP requirements. *In: Proc. 15<sup>th</sup> Annual Florida Ruminant Nutrition Symposium*, Gainesville, FL. Pages 10-25.

Schwab, C. G., and G. N. Foster. 2009. Maximizing milk components and metabolizable protein utilization through amino acid formulation. *In: Proc. of the Cornell Nutr. Conf. Feed Manuf.*, Ithaca, NY. Pages 1-15.

Whitehouse, N., C. Schwab, D. Luchini, T. Tylutki, and B. Sloan. 2009. Comparison of optimal lysine and methionine concentrations in metabolizable protein estimated by the NRC (2001), CPM-Dairy (v.3.0.10) and AMTS.Cattle (v.2.1.1) models. *J. Dairy Sci.* 92 (Suppl. 1):103. (Abstr.).