Using the 2001 Dairy NRC to Optimize the Use of Dietary Protein for Milk Protein Production

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Introduction

A major goal of the Subcommittee on Dairy Cattle Nutrition responsible for NRC (2001) was to develop energy and protein systems that were more accurate in diet formulation and evaluation than NRC (1989). This required the development of energy and protein systems: (1) that are more accurate in predicting energy and protein requirements, (2) that are more accurate in predicting energy and protein supplies, and (3) that could predict supply of absorbable amino acids **(AA)**. It should go without saying that a goal of dairy cow nutrition is to meet the cow's requirements for the desired level of milk and milk protein production with a minimum amount of dietary crude protein **(CP)**. This requires meeting ruminal requirements for rumen-degradable protein and the cow's requirement for absorbable AA without over-feeding CP. The 2001 NRC appears to be useful in accomplishing this goal.

The intent of this paper is to highlight the major differences between NRC (1989) and NRC (2001) and to review those factors considered important in using NRC (2001) as a tool to optimize use of dietary CP for milk protein production.

Differences Between the 1989 and 2001 NRC Energy and Protein Systems

Terminology

There are no differences in terminology for the expression of energy units. To be consistent with the *Journal of Dairy Science*, rumen-degradable feed protein (**RDP**) replaces the use of degraded intake protein (**DIP**) and rumen-undegradable feed protein (**RUP**) replaces undegraded intake protein (**UIP**). Rumen-degradable feed protein plus RUP equals diet CP. To avoid the implication that proteins are absorbed, and to be consistent with the *Nutrient Requirements of Beef Cattle* (NRC, 1996), the term metabolizable protein (**MP**) replaces absorbed protein (**AP**). Metabolizable protein is defined as total absorbed AA.

Energy and Nutrient Supply

Energy. In NRC (1989), feeds were assigned total digestible nutrient **(TDN)** values that had been determined over a period of decades with sheep and cattle. Most values were determined at maintenance. A simple linear equation was used to convert maintenance TDN values to net energy of lactation **(NE_L)**. The equation included a constant discount of 8% because of an assumed intake of 3X maintenance. The 8% discount was based on a 4% reduction in digestibility per increment of energy intake above maintenance. This approach had several limitations. First, it was assumed that the TDN value of a feed was fixed and independent of its actual nutrient composition. Second, it was assumed that diet composition has no affect on the TDN value of an individual feed. And third, it was assumed that all lactating cows in the United States eat at 3X maintenance. Clearly, none of these assumptions are correct.

To overcome these limitations, the following method is used to estimate **NE_L** values for feeds in NRC (2001). The first step is the calculation of a maintenance TDN value for each feed. The maintenance TDN value is calculated from composition data. The composition data needed for the equations are neutral detergent fiber **(NDF),** acid detergent fiber **(ADF)**, neutral detergent insoluble CP **(NDICP)**, acid detergent insoluble CP **(ADICP)**, ether extract **(EE)** (or total fatty acids), CP, lignin, and ash. Maintenance TDN is calculated as the sum of calculated true digestible non-fiber carbohydrate **(tdNFC)**, true digestible NDF **(tdNDF),** true digestible CP **(tdCP)**, and true digestible fatty acids **(tdFA).** The equations for calculating the quantities of tdNFC, tdNDF, tdCP, and tdFA assume digestibility values of 98% for NFC [unless adjusted by a processing adjustment factor **(PAF)** that is different from 1.0; see below], a variable digestibility value for NDF that depends on its content of NDICP and lignin, a variable digestibility value for CP that depends on its content of ADICP, and a digestibility value of 100% for fatty acids when diets contain 3% or less EE. Regarding the PAF for NFC

(i.e., starch), it is known that physical processing (grinding) and heat and steam treatment of high starch feeds (e.g., bakery byproducts, cereal grains, and corn silage,) can affect NFC digestibility. Therefore, an empirical approach was used to arrive at PAF values for the NFC of high NFC feeds (Table 1). The calculated tdNFC is multiplied by the PAF to get a more accurate tdNFC value. Maintenance TDN values for fat supplements are calculated from the known percentages of fatty acids and glycerol in the supplements, experimentally determined FA digestibility values, and the knowledge that digestible fat has a caloric density that is 2.25 times higher than digestible carbohydrates. To summarize, maintenance TDN (%) = tdNFC + dNDF + tdCP + (tdFA x 2.25). Because the above approach calculates true digestibility and not apparent digestibility, and because it has been determined that metabolic TDN is about 7%, then apparent TDN is calculated by subtracting 7 from the above "true" TDN value.

Table 1. Processing Adjustment Factors (PAF) for NFC[1].

Feedstuff	PAF
Bakery waste	1.04
Barley grain, rolled	1.04
Bread	1.04
Cereal meal	1.04
Chocolate meal	1.04
Cookie meal	1.04
Corn grain, cracked dry[2]	0.95
Corn grain, ground[2]	1.00
Corn grain, ground high moisture[2]	1.04
Corn and cob meal, ground high moisture[2]	1.04
Corn grain, steam flaked[3]	1.04
Corn silage, normal	0.94
Corn silage, mature	0.87
Molasses (beet and cane)	1.04
Oats grain	1.04
Sorghum grain, dry rolled	0.92
Sorghum grain, steam-flaked[4]	1.04
Wheat grain, rolled	1.04
All other feeds	1.00

[1] From NRC (2001). For feeds not shown, PAF = 1.0.
[2] Mean of several experiments, actual PAF depends on particle. Finer grinding will increase PAF.
[3] Mean density of 0.36 kg/L; PAF should be negatively correlated with density.
[4] Mean density of 0.36 kg/L; PAF should be negatively correlated with density.

The second step in estimating a NE_L value for a feed is the calculation of a maintenance digestible energy **(DE)** value. These are calculated for most feeds by multiplying the above calculated concentrations of tdNFC, tdNDF, tdCP, and tdFA in the feed by known heat of combustion values (Mcal/kg) for each of the digestible fractions (carbohydrates = 4.2, protein = 5.6, and long chain fatty acids = 9.4). Modified equations are used for calculating the maintenance DE values for animal protein meals, fat supplements with glycerol, and fat supplements without glycerol, but in the same fashion, the values are calculated from composition data and known heat of combustion values. In all cases, a correction for metabolic fecal energy is made which assumes that the heat of combustion of metabolic fecal TDN is 4.4 Mcal/kg.

The third step in calculating the content of NE_L in feeds involves accounting for the effects of increasing feed intake on digestibility and the fact that the rate of decline in digestibility is related to the digestibility of the diet at maintenance. From regression analysis of published TDN values of diets fed at different intakes, a multiple regression equation based on intake and digestibility of the diet (estimated as diet TDN) was developed to estimate a discount factor. As expected, the discount increases as intake and diet TDN at maintenance increase (Figure 1). The maintenance DE is multiplied by (1 – discount factor) to obtain DE at productive levels of intake.

The final step in calculating NE_L in feeds is to calculate, from the discounted DE concentration, the metabolizable energy **(ME)** value, and from the ME concentration, the NE_L concentration. In both cases, NRC (2001) uses improved equations to calculate ME and NE_L.

An overview of the method used to calculate NE_L in diet DM is shown in Figure 2. It is important to note that the TDN value is the TDN at maintenance. The TDN value is only used in the energy system to calculate the discount factor; it is not used directly to calculate NE_L. However, as noted below, *discounted TDN* is used in the protein system to calculate microbial protein passage to the small intestine.

Protein and amino acids. The NRC (2001) subcommittee concluded that the protein model in NRC (1989) had serious limitations. The following discussion is an attempt to highlight the major differences between the two protein systems to show how many of the limitations of NRC (1989) were addressed in NRC (2001).

In NRC (1989), RUP values for feeds were presented but they were mean values based on a

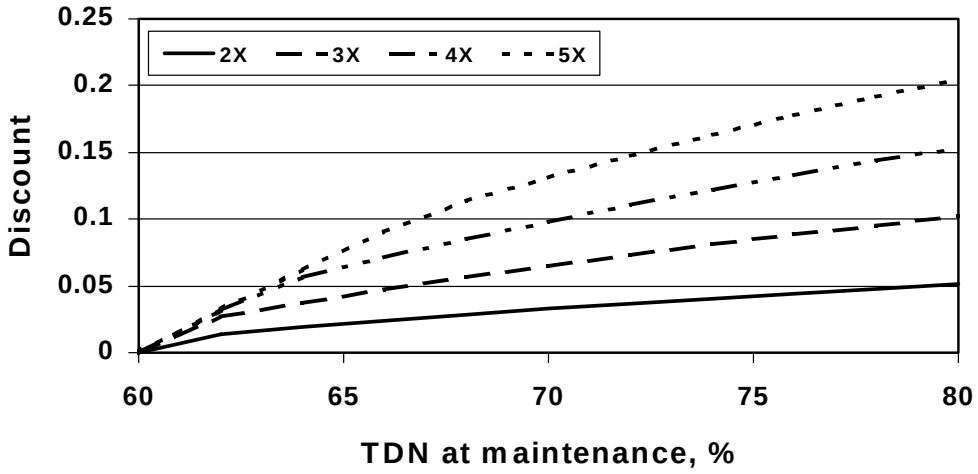

Figure 1. Discount factor calculated using NRC (2001). Feed DE values estimated at maintenance are multiplied by (1 - discount) to estimate DE values at energy intakes of 2, 3, 4, and 5 times maintenance energy intake. From Weiss (2002).

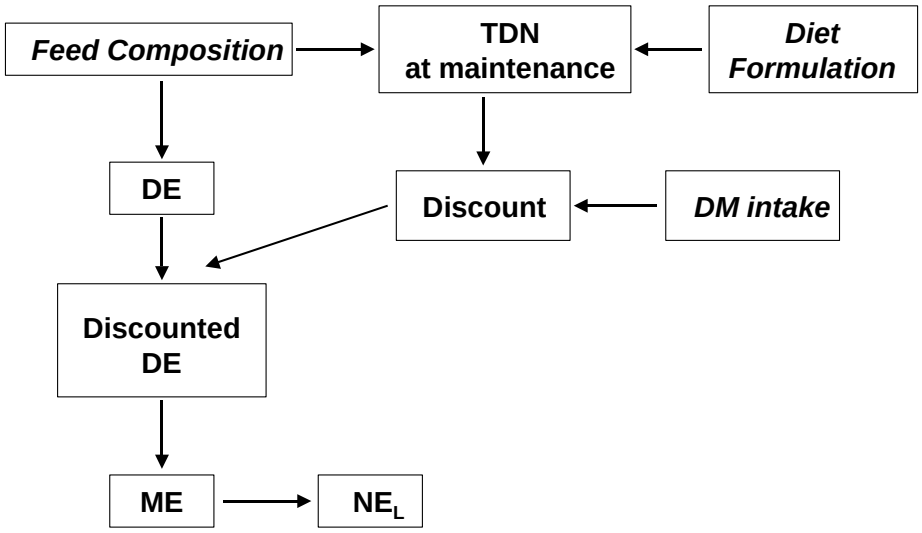

Figure 2. Overview of the method used in NRC (2001) to calculate NE_L in diet DM. Terms in italics are entered by the user, all other values are calculated using NRC software. The TDN value is the TDN of the entire diet. From Weiss (2002).

combination of *in vivo* and *in situ* estimates from cattle and sheep. Since that publication, many experiments, using several different approaches (*in vivo*, *in situ*, and *in vitro*), have been published that provide estimates of the RUP and RDP content of feeds. A review of this work yielded three conclusions: (1) the RUP content of a feed is not constant and is influenced by a variety of diet-related factors, (2) there is no apparent perfect approach for estimating protein degradability in the rumen, and (3) the *in situ* approach had emerged as the most widely used and accepted research approach for estimating protein degradability of feed proteins.

Because of the availability of at least some published *in situ* data for all but a very few of the feedstuffs in the feed library of the NRC (2001) model, and because *in situ* derived data allows for kinetic description of ruminal protein degradation, the subcommittee chose to use *in situ* derived data for computing RDP and RUP values. The *in situ* procedure allows for separating CP into three fractions: (1) fraction A (escapes from the bag during an initial pre-soak period; assumed to be completely degraded in the rumen), (2) fraction B (disappears gradually from the bag during ruminal exposure and will disappear completely with unlimited exposure to fermentation; the amount that is degraded depends on how long the feed is in the rumen), and (3) fraction C (remains in the bag at the end-point of degradation; assumed to be undegradable in the rumen). The equations for computing RDP and RUP values (% of CP) are RDP = $A + B[K_d/(K_d + K_p)]$ and RUP = $B[K_p/(K_d + K_p)] + C$. In addition to the need for the three CP fractions and the digestion rate (K_d) of fraction B (the latter is determined by removing bags after varying times of ruminal exposure), the equations also require an estimate of passage rate (K_p) of undigested feed. Thus, three equations were developed for predicting passage rates of undigested feeds; one for wet forages, one for dry forages, and one for concentrates. The K_p equations consider effects of DM intake, concentrate in diet DM, and content of NDF in forage DM on passage rates. Therefore, these dietary and feed factors are considered in the calculation of RDP and RUP (See Table 15-2a in the NRC publication for estimates of RUP in feeds at two levels of DM intake and two levels of forage in diet DM).

As in NRC (1989), the RUP fraction of CP in NRC (2001) is assumed to be 100% true protein. Unlike NRC (1989), where a constant digestibility of 80% was used for RUP for all feeds, RUP digestibility in NRC (2001) is considered to be dependent on feed type. From a review of published measurements of RUP digestibility using the mobile bag technique and the 3-step in vitro procedure of Calsamiglia and Stern (1995), mean values of RUP digestibility were assigned to each feed. For feeds with limited or no data, the values used in the French Protein System (Jarrige, 1989) were adopted. The assigned values range from a low of 50% for canola seeds and cottonseed hulls to a high of 100% for molasses. In most cases, the mean values assigned to each feed were rounded to the nearest 5 percentage units to emphasize the lack of precision involved at arriving at the mean values. Thus, the supply of MP from RUP for each feed is calculated as RUP flow x RUP digestibility.

In NRC (1989), microbial CP production in lactating cows was calculated from NE_L intake. In growing animals, it was predicted from TDN intake. Since the publication of NRC (1989), many studies have been published in which flows of microbial CP to the small intestine were measured. Of particular benefit to the 2001 subcommittee was the data obtained with lactating cows at levels of feed intake that were higher than previously published. Using this newer data, it was observed that the 1989 NRC equation for predicting microbial CP production for lactating cows performed reasonably well at lower intakes of NE_L but over-predicted microbial protein flows at higher NE_L intakes (primarily because of failure to discount NE_L at higher feed intakes). Thus, it was clear that a new microbial protein equation had to be developed, at least for lactating cows. The equation used in NRC (2001) for predicting grams of microbial CP for both heifers and cows is 130 x kg (discounted) TDN. However, this equation is used only when RDP intake equals or exceeds 1.18 x TDN-predicted microbial CP yield. When RDP intake is less than 1.18 x TDN-predicted microbial CP yield, then microbial CP yield = 1.18 x RDP intake. Like NRC (1989), the supply of MP from microbial CP is calculated as microbial CP flow x 0.64 (80% true protein x 80% digestible).

The 1989 NRC did not recognize a contribution of endogenous CP to MP. In NRC (2001), albeit small, the contribution of endogenous protein is recognized. Sources contributing to endogenous protein passage to the small intestine would include saliva, sloughed cells (from the respiratory tract, mouth, esophagus, rumen, omasum, and abomasum), and enzyme secretions into the abomasum. Endogenous CP is calculated from DM intake. The content of MP in endogenous CP is assumed to be 40%.

It has been known for decades that absorbed AA, and not protein per se, are the required nutrients. Used principally as building blocks for the synthesis of proteins, absorbed AA are vital to the maintenance, growth, reproduction, and lactation of dairy cattle. It is

also understood from poultry (NRC, 1994) and swine (NRC, 1998) research that an ideal profile of absorbed essential AA **(EAA)** exists for maintenance, growth, and lactation. While these ideal EAA profiles remain to be established for dairy cattle, it is known that feeds vary in AA composition and that the ingredient composition of the diet affects the AA composition of duodenal protein.

To advance research on AA requirements and to allow for implementation of the results, the subcommittee decided to extend the protein model to one that would most accurately predict the profile of EAA in duodenal protein and flows of EAA to the small intestine. Rightly or wrongly, the subcommittee did not include the nonessential AA **(NEAA)** because there was no evidence that NEAA would ever be more limiting in MP than any of the EAA. Both factorial and multivariate regression approaches were considered for predicting EAA passage. The multivariate regression approach was selected. This approach required the development of an equation for each EAA and one for predicting flows of total EAA. However, the multivariate regression approach has the advantage of allowing the equations to *fit* to the NRC model calculated flows of microbial CP, RUP, and endogenous CP and the measured AA flow data that was used in the development of the equations. The multivariate regression approach also had the advantage of needing to assign EAA values only to two of the three contributors of protein to the small intestine. However, because predicted flows of CP from microbial protein and endogenous protein are highly correlated, EAA values only needed to be assigned to feeds.

Knowledge of predicted flows of metabolizable EAA and their content in MP is more important than knowing the predicted total flows of each EAA. Thus, the model was extended to predict flows of metabolizable EAA and their content in MP.

MP requirements

Three primary differences exist between NRC (2001) and NRC (1989) in regard to calculating MP requirements. First, new equations were introduced in the new model for predicting MP requirements for endogenous urinary protein, scurf protein, metabolic fecal protein, growth, and pregnancy. The changes to the respective equations were the subtraction of conceptus weight from BW in predicting endogenous urinary protein and scurf protein, subtraction of that portion of intestinally undigested, *ruminally* synthesized microbial protein believed not to be digested in the hindgut (assumed to be 50%) from predicted metabolic fecal protein, adoption of the 1996 Beef NRC equations for predicting MP requirements for growth, and a modified and improved equation for predicting the MP requirement for pregnancy.

Second, the efficiency of conversion of MP to milk protein was changed from 70% to 67%. A conversion of 67% is more in keeping with the value of 65% used in the French system and the value of 69% obtained by Fraser et al. (1987) with gastric infusion studies.

And third, an MP requirement for endogenous MP was introduced. In view of a lack of published data, the efficiency of use of absorbed MP for endogenous MP was assumed to be 67%.

Dietary RDP and RUP Requirements

In contrast to NRC (1989), dietary requirements are calculated for both RDP and RUP in NRC (2001). This is important as RDP is required for rumen microorganisms and RUP is required for the cow. The requirement for RDP is calculated as 1.18 x TDN-predicted microbial CP. This value assumes a constant, net capture of 85% of RDP in microbial CP (1.00 / 0.85 = 1.18). An evaluation of the protein model indicated a zero bias of prediction when microbial protein production was predicted from RDP at all intakes of RDP less than 1.18 x TDN-predicted microbial CP and from discounted TDN values when intakes of RDP were greater than 1.18 x TDN-predicted microbial CP. The equation for predicting the RUP requirement is [MP required – (supplied microbial MP + supplied endogenous MP)] /diet RUP digestibility. The dietary requirement for total CP is the sum of the requirements for RDP and RUP. Because the dietary need for RUP is independent of the dietary need for RDP, there is no attempt in NRC (2001) to express RUP requirements as a percent of dietary CP.

Amino acid requirements

It was the opinion of the 2001 NRC committee that knowledge was too limited, both for model construction and model evaluation, to put forth a model that *quantifies* AA requirements for dairy cattle. However, an alternate and first step to that approach is to begin to define the ideal content of EAA in MP. This requires establishing dose-response relationships between changes in concentrations of EAA in MP (at least those considered to be the most limiting) and animal responses. As described, the model predicts concentrations of EAA in MP. Moreover, several studies have evaluated milk protein responses to changes in concentrations of lysine **(Lys)** and

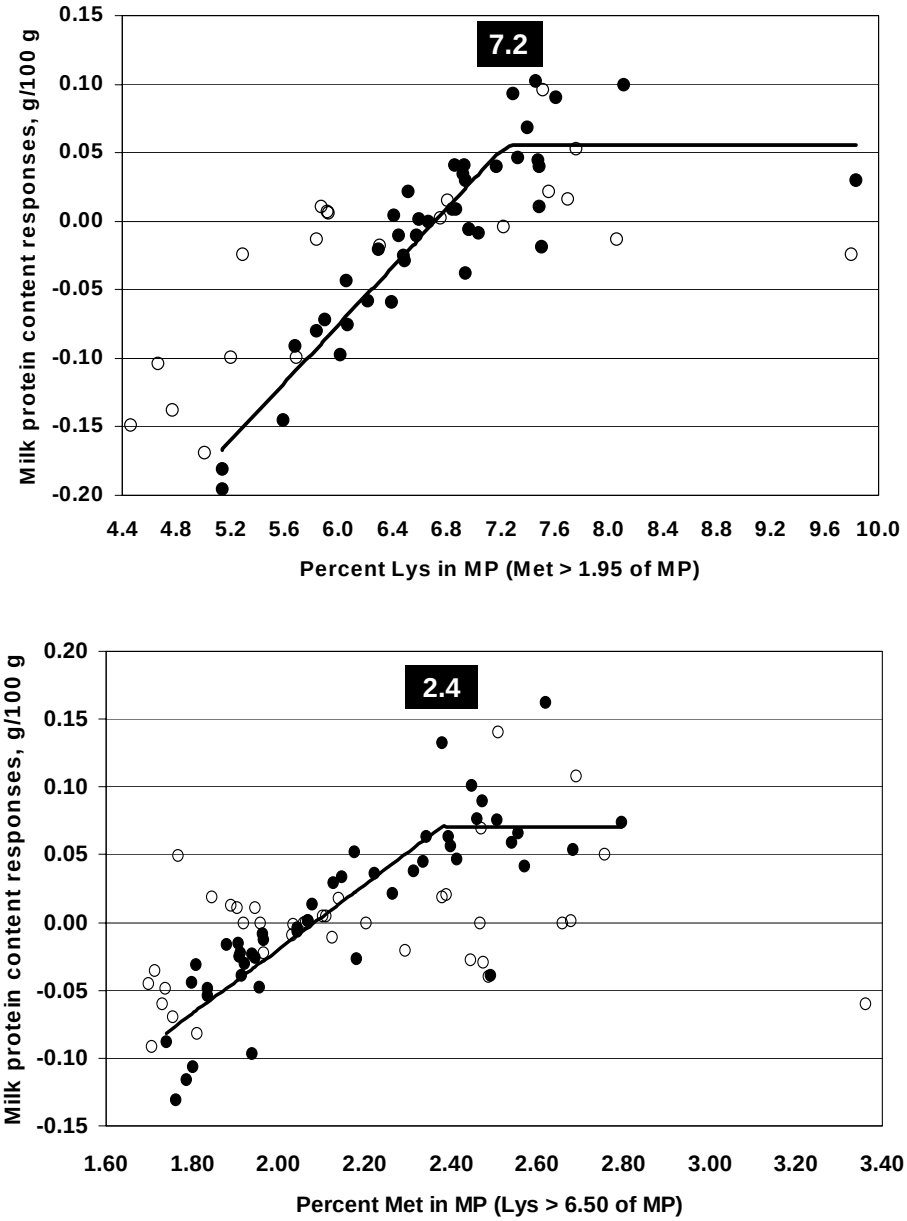

Figure 3. Milk protein content responses as a function of Lys and Met in metabolizable protein (MP). For the Lys plot, regression analysis was limited to those observations where the corresponding Met values were 1.95% or more of MP. For the Met plot, the regression analysis was limited to those observations where the corresponding Lys values were 6.50% or more of MP.

methionine **(Met)** in duodenal protein. Therefore, the prerequisites were in place to use the model to define the requirements for Lys and Met in MP for lactating cows.

The approach was that described by Rulquin et al. (1993). Experiments were identified in which one or more amounts of either Lys or Met were infused continuously into the abomasum or duodenum or fed in ruminally-inert form. To calculate the concentrations of Lys and Met in MP, all cow and diet data were entered into the model. Contributions of supplemental Lys and Met to flows of metabolizable Lys and Met from the basal diet were calculated as described in the

publication. Also described in the publication are the calculations that allowed the pooling of data from different experiments (p. 81-85).

Figure 3 shows the plot of predicted concentrations of Lys in MP and the corresponding responses for milk protein content. The final regression analysis was limited to data where Met was adequate or near adequacy (1.95% or more of MP). Using this restricted data, a rectilinear model was slightly superior to quadratic models for describing protein content responses to increasing amounts of Lys in MP. The breakpoint estimate for the required concentration of Lys in MP for maximal content of milk protein is 7.2%. The corresponding plot for milk protein yield (not shown) indicated the breakpoint at 7.1% Lys in MP. Examination of the dose-plots indicates little or no expected loss in content or yield of protein when Lys in MP is 6.9%. Therefore, it is concluded that 6.9% be considered as the requirement for Lys in MP.

Figure 3 also shows the corresponding plot for Met. In this case, the final regression analysis was limited to data where Lys was adequate or near adequacy (6.50% or more of MP). Again, the rectilinear model was superior to the other models for describing the milk protein responses. The breakpoint estimate for the required concentration of Met in MP for maximal content of milk protein is 2.4%. The corresponding plot for milk protein yield (not shown) also indicated the breakpoint at 2.4% Met in MP. As with Lys, examination of the Met dose-plots indicates little or no loss of milk protein when Met is somewhat lower in MP than the requirement value that is determined by breakpoint analysis. Therefore it is concluded that 2.3% be considered as the requirement for Met in MP.

In summary, the model indicates optimal use of MP for maintenance plus milk protein production when Lys and Met approximate 6.9% and 2.3% of MP, respectively. Therefore, the optimum ratio of Lys to Met in MP (using this model) is 3.0/1.0 A unique and practical feature of this approach for determining the required concentrations of EAA in MP is that the *requirements* are estimated using the same model as that used to predict concentrations of EAA in MP.

Using the 2001 Dairy NRC to Optimize Milk Protein Production

Many improvements were made to the energy and protein systems in NRC (2001). Ultimately, all of these improvements contribute to the usefulness of the model for formulating and evaluating diets. This is particularly true for optimizing the conversion of diet CP to milk protein. Following are some important factors to keep in mind when using NRC (2001) for this purpose.

Point #1. Ensure that animal, production, and environmental inputs are correct. This increases model accuracy.

Point #2. Ensure that feed inputs for chemical composition are accurate. Again, this increases model accuracy. Use actual feed analysis as much as possible. This is particularly true for forages. Minimally, actual values should be used for DM, NDF, CP, ash, and lignin. If a feed has an appreciable concentration of fat, a fat analysis is recommended. For byproduct feeds that have high concentrations of NDF and CP (e.g., brewers and distillers grains) and heat-damaged forages, it is also important that measured concentrations of NDICP and ADICP be used. Remember, model default values are means and they may be considerably different from your feeds.

Point #3. In like fashion, the model default PAF values are means and in certain situations are not correct. Some examples would be processed corn silage, high moisture corn, and steam-flaked corn. For example, normal corn silage has a PAF of 0.94 but research shows that processing usually increases starch digestibility by about 5%. Therefore, a more appropriate PAF for processed corn silage would be 0.98 or 0.99 (Weiss, 2002). Moisture content of high grains also affects starch digestibility. High moisture ground corn in the model has an assumed DM content of 75% and was assigned a PAF of 1.04. If high moisture corn is 70% DM than a PAF of 1.05 or 1.06 should probably be used (Weiss, 2002). And finally, density of steam-flaked corn probably affects starch digestion. Steam-flaked corn in the model (mean density of 33 lb/bu) has a PAF of 1.04. If the steam-flaked corn has a higher density, a lower PAF should probably be used.

Point #4. Use more reliable N fraction and K_d data for feeds when it becomes available. Model default values for N fractions and K_d for most feeds are based on limited data (less than 5 observations). For some feeds (e.g., almond hulls, all bakery products, wet brewers grains, high moisture ground corn ear corn, and rye and sorghum silages) n = 0. In those cases, N fractions and K_d values were taken from comparable feeds (see Table 15.2a in the publication). Also, please note Table 15.2b in the publication. This table contains the N fractions, K_d, RUP digestibility, and AA data for less commonly

used feeds and therefore, are not in the computer model. However, you can enter them as new feeds if you are using them. Unfortunately, the N fraction and K_d data are even more limited for these feeds.

Point #5. Adjust RUP digestibility values if you have reason to do so. This is particularly true for heat-processed, high RUP protein supplements. Again, the model default values are means and in some cases will not be correct.

Point #6. Make sure that you meet the cow's RDP requirement. Don't short-change cows on RDP. A deficiency will suppress the growth and activity of the microorganisms, decrease feed intake, and decrease the efficiency of microbial protein synthesis. Decreased microbial protein production almost always has the net effect of decreasing Lys in MP. This occurs because of the resulting decreased contribution of microbial protein and thus, increased contribution of RUP to MP. Using feeds common to us in the Northeast, I like to see RDP levels in diet DM that are about 0.5 percentage units higher than what the model recommends. I have no concrete evidence at this time that feeding this additional RDP is always necessary. However, I see little reason to take the chance of depriving ruminal microorganisms of the nitrogenous compounds that they need for maximum function. Moreover, NRC (2001) does not attempt to recognize differences in *quality* of RDP as obtained from different feeds (e.g., from urea vs. soybean meal or from silage vs. hay) and the effect that this may have on *microbial capture* and the efficiency of use of RDP for microbial protein production.

Point #7. Do not feed excessive amounts of RDP. Clearly, there is no benefit to this and at the very least, it decreases the efficiency of use of dietary protein for milk protein production.

Point #8. Mix and match protein and rumen-protected Met supplements, and avoid over-feeding of RUP, in an attempt to get predicted concentrations of Lys and Met in MP as close to 6.9 and 2.3 % as you can. Doing so improves the profile of EAA in MP. Enhancing the profile of AA in MP increases the efficiency of use of MP (total absorbed AA) for protein synthesis. At this point, we don't know what the ideal profile of EAA in MP is for the combined functions of maintenance and milk protein production in dairy cows. However, what we do know is that increasing concentrations of Lys and Met from lower levels to higher levels that approach 6.9% and 2.3% in MP, respectively, increases milk protein production and apparent efficiency of use of MP for milk protein production. Increasing concentrations of Lys and Met in MP while maintaining a 3.0/1.0 ratio of Lys to Met is the first step in balancing diets of lactating cows for AA. Because it is only the RUP fraction of diet CP that provides a direct source of AA to MP, increasing the efficiency of use of MP has the benefit of reducing the need for dietary RUP.

Point #9. Do not overfeed RUP. It lowers the efficiency of use of MP for milk protein production. Over-feeding RUP decreases efficiency of use of MP for two reasons: (1) supply of MP exceeds MP requirements, and (2) because on average, RUP has lower concentrations of Lys and Met than microbial protein (Table 2).

Point #10. My experience indicates that it may not be necessary to meet NRC (2001) model-predicted requirements for MP, and thus model-predicted requirements for RUP. This makes sense because the protein model was built and validated using published data generated without regard to diet composition or profiles of AA in duodenal protein. Therefore, it can be expected that cows may need less RUP than what the model predicts if the profile of EAA in MP is *better than average*. In contrast, cows may respond to more RUP than what the model predicts if model-predicted profiles of EAA in MP are *worse than average*.

Conclusions

Many improvements were made to the energy and protein systems in NRC (2001). Improvements in how the new model arrives at TDN intake improves prediction of microbial protein supplies. The adoption of a kinetic approach for describing ruminal degradation of feed protein recognizes that the RUP content of a feed is not constant and is affected by feed and diet composition. Digestibility coefficients are assigned to RUP. Endogenous contributions to MP supply are considered. Flows of metabolizable EAA and their content in MP are predicted. Improvements were made in all equations for calculating MP requirements. Requirements for RDP and RUP in diet DM are calculated. Dose-response plots were developed using the model that relates concentrations of Lys and Met in MP and content and yield of milk protein. Research and field experience (to be shared in the oral presentation) indicates that these improvements have improved the usefulness of the model for improved fine-tuning of diets for milk protein production.

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