Balancing Diets for Amino Acids: Nutritional, Environmental and Financial Implications

Charles G. Schwab[1]
Animal and Nutritional Sciences
University of New Hampshire

Summary

Balancing for amino acids **(AA)** continues to focus on lysine **(Lys)** and methionine **(Met)**, the two AA that are the most limiting for lactating dairy cows fed diets common to North America. Unless a deliberate attempt is made to increase their concentrations in metabolizable protein **(MP)**, their concentrations in MP will always be lower than optimum and efficiency of use of MP for maintenance and milk production will be compromised. Recent efforts have focused on generating new dose-response plots for NRC (2001), as well as initial plots for CPM-Dairy (Cornell University, Ithaca, NY) and AMTS. Cattle (Agricultural Modeling and Training Systems, LLC, Lansing, NY), that relate changes in measured percentages and yields of milk protein to model-predicted concentrations of Lys and Met in MP. The results indicate that the breakpoint estimates for the required concentrations of Lys and Met in MP for maximal content of milk protein for the NRC, CPM, and AMTS models were 6.80 and 2.29%, 7.46 and 2.57%, and 6.68 and 2.40%, respectively. The respective breakpoint estimates for maximal yield of milk protein were 7.10 and 2.52%, 7.51 and 2.30%, and 6.74 and 2.31%. The resulting optimal Lys:Met ratios in MP for the 3 models are considered to be 3.0:1, 2.9:1 and 2.8:1, respectively. Feeding strategies for getting close to achieving these concentrations of Lys and Met in MP include: 1) feeding high quality feeds and well-balanced diets that are focused on maximizing rumen function and synthesis of microbial protein, 2) feeding adequate but not excessive amounts of rumen degradable protein **(RDP)**, 3) preferential use of high Lys protein supplements over low Lys protein supplements whenever possible protein supplementation is needed, 4) feeding a rumen-protected Met supplement in the amounts needed to meet the optimal Lys:Met ratio in MP for the model that is being used, and 5) not overfeeding RUP. For successful AA balancing, it is important to express RDP and rumen undegradable protein **(RUP)** as percentages of dietary dry matter **(DM)** and to monitor and fine-tune their concentrations as needed to avoid over or under-feeding. The benefits of achieving higher concentrations of Lys and Met in MP that lead to increased dairy herd profitability include: 1) increased milk yields, 2) increased concentrations and yields of milk protein and fat, 3) reduced need for supplemental RUP for similar or greater component yields, 4) more predictable changes in milk and milk protein production to changes in RUP supply, 5) reduced N excretion per unit of milk or milk protein produced, and 6) improved health and reproduction. Increases in milk protein and fat concentrations of 0.1 to 0.25 percentage units for protein and 0.1 to 0.15 for fat and returns on investment of 2.0 to 3.5 are typical. Increases in milk yield are more common in early lactation cows than late lactation cows and can be rather significant if balancing for Lys and Met is started before calving. With high feed costs and low milk prices, an important benefit of AA balancing has been the opportunity to increase milk

[1]Contact at: 105 Doc Mac Drive, Boscobel, WI 53805-1763, (603) 767-2938, Email: charles.schwab@unh.edu

and milk component yields with less RUP supplementation and similar or lower feed costs.

Introduction

It is encouraging to see that more and more dairy nutritionists are embracing the practice of balancing for Lys and Met in MP. For those who have embraced the practice and followed recommended feeding strategies for achieving more ideal concentrations of RDP and RUP in the dietary DM and more ideal profiles of Lys and Met in MP, the economic rewards have been excellent. This is particularly true for the producers that are paid by the Class III component formulas where milk protein continues to be the most valued milk component. Return on investment has simply been too high to do otherwise, even when milk prices are low and feed prices are high. The purpose of this paper is: 1) to share the results of a recent re-evaluation of the Lys and Met dose-response plots using the "final version" of the NRC (2001) model, 2) to share the results of a recent effort to develop the same dose-response plots using CPM-Dairy (v.3.0.10) and AMTS.Cattle (v.2.1.), and 3) to review a successful approach for optimizing Lys and Met nutrition for lactating dairy cows.

Re-evaluation of the NRC (2001) Lys and Met Dose-Response Plots

In recognition of the importance of Lys and Met in dairy cow nutrition in North America, NRC (2001) published dose-response plots that related changes in measured percentages and yields of milk protein to model-predicted changes in Lys and Met concentrations in MP. To determine what the "requirements" for Lys and Met in MP are when the NRC (2001) model is used to evaluate diets, the NRC committee used the indirect dose-response approach described by Rulquin and Verite (1993). This approach has the "unique benefit" of allowing requirement values to be estimated using the same model as that used to predict concentrations of AA in MP. By using a rectilinear model to describe the dose-response relationships, breakpoint estimates for the required concentrations of Lys and Met in MP for maximal content of milk protein were determined to be 7.2 and 2.4%, respectively; corresponding values for maximal protein yield were 7.1 and 2.4%. Because they can be rather easily achieved, target levels for Lys and Met in MP have typically been 6.6 and 2.2%, respectively. Both values approximate 96% of the concentrations needed, according to NRC (2001), for maximal content and yield of milk protein. These estimates have served as important targets for routine users of the NRC (2001) model in their quest to increase milk component yields with lower intakes of RUP and lower predicted flows of MP.

Because the AA submodel [AA equations (see pages 74-81 in NRC 2001)] had to be developed before the final version of the NRC model was available, a beta version of the model was used to predict the concentrations of Lys and Met in MP in the studies used to develop the dose-response plots. Because of this, and concerned that changes may have been made to the rest of the model as part of model validation that may have changed predicted concentrations of Lys and Met in MP, Schwab et al. (2009) re-evaluated the Lys and Met dose-response plots using the final version of the model.

All steps, as stated in NRC (2001), were repeated. In brief, generating the dose-response plots involves 5 steps: 1) predicting concentrations of Lys and Met in MP for control and treatment groups in experiments in which postruminal supplies of Lys, Met, or both, were increased and production responses measured, 2) identifying "fixed" concentrations of Lys and Met in MP that are intermediate to the lowest and highest values in the greatest number of Lys and Met experiments, 3) calculating, by linear regression, a "reference production value" for each production parameter in each Lys experiment that corresponds to the "fixed" level of Lys in MP and in each Met experiment that corresponds to the "fixed" level of Met in MP, 4) calculating "production responses" (plus and minus values) for control and treatment groups relative to the "reference production values", and 5) regressing the production responses on the predicted concentrations of Lys and Met in MP.

The "revised" dose-response plots that relate changes in milk protein concentrations to changes in predicted concentrations of Lys and Met in MP for the NRC (2001) model are presented in Figure 1. While the plots are strikingly similar to those published in NRC (2001), there are differences between the "published" and "revised" breakpoint estimates for the required concentrations of Lys and Met in MP for maximal content of milk protein. The breakpoint estimates for the required concentrations of Lys and Met in MP for maximal content of milk protein were 6.80 and 2.29%, respectively (see figure legends), slightly lower than the values of 7.24 and 2.38% reported in NRC (2001). The breakpoint estimates for the required concentrations of Lys and Met in MP for maximal yield of milk protein were 7.10 and 2.52%, respectively (plots not shown). These values are also different from the NRC (2001) values of 7.08 and 2.38%. It was concluded by Schwab et al. (2009), from a comparison of the predicted flows of microbial MP and feed MP with the beta and final versions of the 2 models, along with a re-examination of feed inputs, that the primary reason for the differences in breakpoint estimates was differences in feed inputs for some of the studies. It is suggested that the new values be used as the reference values when using the NRC (2001) model to optimize Lys and Met concentrations in MP for lactating cows.

Development of Lys and Met Dose-Response Plots for CPM-Dairy (v.3.0.10) and AMTS.Cattle (v.2.1.1)

Also of concern to us was that other models differ in the approach taken to estimate AA supply and that users of these models did not have analogous dose-response plots for Lys and Met. As a result, Whitehouse et al. (2009) repeated the same steps, using the same studies as used for NRC (2001), to generate Lys and Met dose-response plots for CPM-Dairy and AMTS.Cattle. Because of some of the differences in the biology between the two models, and their differences with NRC (2001), it was expected that the required concentrations of Lys and Met in MP for maximum concentrations and yields of milk protein would differ and be different from NRC (2001).

The resulting dose-response plots that relate changes in milk protein concentrations to changes in predicted concentrations of Lys and Met in MP for CPM-Dairy and AMTS.Cattle are presented in Figures 2 and 3, respectively. As noted in Figures 1 through 3 and Table 1, differences exist among the 3 models in the breakpoint estimates for the required concentrations of Lys and Met in MP for maximal content and yield of milk protein. This was expected, as models differ in the approach for predicting supplies of AA. These differences lead to differences in predicted supplies of RDP, RUP, MP and MP-AA (Whitehouse et al., 2009). The AA prediction model in NRC (2001) is semi-factorial in nature, where some of the parameters are determined by regression. In contrast, CPM-Dairy and AMTS.Cattle use factorial approaches for predicting AA flows to the small intestine (O'Connor et al., 1993). Prediction models based on the factorial method require the assignment of AA values to model-predicted supplies of ruminally synthesized microbial protein, RUP, and if predicted, endogenous protein. The CPM-Dairy (v.3.0.10) uses CNCPSv.5 (Cornell Net Carbohydrate and Protein System, Cornell University, Ithaca, NY), and AMTS.Cattle (v.2.1.1) uses CNCPSv.6. The latest version of CNCPS has expanded carbohydrate **(CHO)** pools, modified CHO A1 through B1 degradation rates, the soluble fractions (e.g., sugar, non-protein nitrogen) flow with the liquid phase instead of the solid phase, and the passage rate equations have been updated. The result of these and other changes have led to reductions in ruminal CHO degradation, higher RUP and lower microbial protein flows, and lower predicted flows of Lys and Met to the small intestine, as compared to CPM-Dairy.

Feeding Strategies for Balancing Diets for Lys and Met

The following feeding strategies have been shown to be effective in balancing diets for Lys and Met and have allowed producers to realize the benefits expected of balancing diets for AA. The obvious goals are to: 1) obtain the herds genetic potential for milk yield and component concentrations, 2) achieve optimum herd health, 3) maximize conversion of feed crude protein **(CP)** and MP to milk protein, 4) minimize wastage of dietary N, and 5) maximize income-over-feed-costs and dairy herd profitability. A brief discussion of each step follows.

Step #1: Feed a blend of high quality forages, processed grains, and byproduct feeds to provide a blend of fermentable carbohydrates and physically effective fiber that maximizes feed intake, milk production, and yield of microbial protein.

Microbial protein, based on research to date, has an excellent AA composition for lactating dairy cows. The average reported concentrations of Lys and Met in bacterial true protein approximate 7.9 and 2.6%, respectively; values that exceed the concentrations in nearly all feed proteins (NRC, 2001) as well as the optimal concentrations in MP as estimated by the NRC (2001), CPM-Dairy (v.3.0.10) and AMTS.Cattle (v.2.1.1) models (Table 1). Realizing maximal benefits of feeding a balanced supply of fermentable CHO on feed intake, milk production, and yields of microbial protein requires use of high quality and appropriately processed feeds, adequate intakes of physically effective fiber, well-balanced and consistent diets, unlimited supplies of fresh water, and superior bunk and feed management.

Step #2: Feed adequate but not excessive levels of RDP to meet rumen bacterial requirements for AA and ammonia.

Realizing the benefits of feeding a balanced supply of fermentable CHO on maximizing yields of microbial protein also requires balancing diets for RDP. Rumen degraded feed protein is the second largest requirement for rumen microorganisms. It supplies the microorganisms with peptides, AA, and ammonia that are needed for microbial protein synthesis. The amount of RDP required in the diet is determined by the amount of fermentable CHO in the diet. Diet evaluation models differ in their estimates of RDP in feeds and animal requirements. The NRC (2001) model typically predicts RDP requirements of 10 to 11% of dietary DM. Regardless of the model that you use, use the predicted requirements as a guide and fine tune according to animal responses. Monitor feed intake, fecal consistency, milk/feed ratios, milk fat concentrations, and milk urea nitrogen **(MUN)** to make the final decision. A common target value for MUN is 10 to 12 mg/dl, but values lower than this are not uncommon in high producing cows.

Don’t short-change the cows on RDP - carbohydrate balancing can be negated with an inadequate supply of RDP. Underfeeding RDP decreases microbial digestion of carbohydrates, decreases feed intake, decreases synthesis of microbial protein and production of volatile fatty acids **(VFA)**, and decreases milk yield. A deficiency of RDP can suppress the ability of the microorganisms to reproduce without affecting their ability to ferment CHO. This can result in lower than expected milk/feed ratios because of lower than expected synthesis of microbial protein.

Avoid over-feeding RDP to the point that rumen ammonia concentrations markedly exceed bacterial requirements. Not only does it result in wastage of RDP, but research (e.g., Boucher et al., 2007), as well as a summary of N passage studies where rumen ammonia concentrations were also measured (Peter Robinson, University of California-Davis, personal communication), indicates that rumen ammonia concentrations in excess of bacterial requirements decreases flows of microbial protein to the small intestine.

Step #3: Feed high-Lys protein supplements to achieve a level of Lys in MP that comes as close as possible to meeting the optimal concentration (see Table 1).

If protein supplementation is required, select high quality, high-Lys protein supplements (e.g., soybean meals and roasted soybeans, blood meal, and fishmeal). In this case, "high quality" refers to consistency in distribution of RDP and RUP and highly digestible RUP where one is certain that RUP-Lys digestibility is not compromised. Feeding low-Lys, high-protein feeds, such as corn gluten meal, is not consistent with balancing for Lys and Met. Moreover, feeding larger amounts of distiller's grains compromises balancing for Lys and requires feeding more RUP that would otherwise be needed to realize similar yields of milk protein. It is understood that it is often economical to feed larger amounts of distiller's grains, but it comes at the metabolic expense of having to over-feed RUP and under-feeding fermentable CHO. Selecting high-Lys protein supplements has been the only option, until the recent release of some rumen-protected Lys (RP-Lys) products, to at least partially compensate for the low content of Lys in the RUP fractions from forages, concentrates, and distiller's grains. Achieving target formulation levels for Lys in MP will become easier, and the value of lower Lys protein supplements extended, if the RP-Lys products can be demonstrated to be cost effective sources of MP-Lys.

Step #4: Feed a "rumen-protected" Met supplement in the amounts needed to achieve the optimal ratio of Lys and Met in MP.

Feeding a rumen-protected Met supplement, in conjunction with one or more of the aforementioned high-Lys protein supplements, is almost always necessary to achieve the correct Lys/Met ratio in MP (Table 1). We continue to be surprised with first time evaluation of diets how often we see Lys to Met ratios in MP of 3.3 or higher - values as high as 3.5 and 3.6 are not uncommon. "Out of balance" Lys to Met ratios lower the efficiency of use of MP for protein synthesis, and the more "out of balance" the ratios, the less efficient the use. This has been repeatedly shown in research and with on-farm AA balancing.

To achieve the desired predicted ratio of Lys to Met in MP (Table 1) and to ensure full use of the available MP-Lys for protein synthesis, one MUST use a realistic estimate for the amount of MP-Met provided by the Met product that you are feeding. Over-estimating the amount of the MP-Met that some of the Met supplements provide has been way too common. This is unfortunate because it leads to disappointing production outcomes, and more often than not, leaves the nutritionist and dairy producer believing that balancing for Lys and Met has minimal impacts on animal performance. Relying on the blood and milk protein content response approaches as being the most appropriate techniques for arriving at estimates of 'Met and Lys bioavailability', a summary of the available research indicates that Smartamine M (Adisseo, Alpharetta, GA) clearly has the greatest efficacy as a source of MP-Met. The industry use of a Met bioavailability value of 80% appears reasonable when the manufacture's recommendations for mixing with other supplements and rations are followed. The data are not as consistent for Mepron M85 (RP Nutrients, Inc., Springfield, WI) and MetaSmart (Adisseo, Alpharetta, GA) as for Smartamine M, but it appears from most of the experiments, the

Met bioavailability value for the 2 products is somewhere between 35 and 50%. Research indicates no measurable effects of Alimet (Novus International, Inc., St. Charles, MO) or Rhodimet AT88 (Adisseo, Alpharetta, GA) on blood Met concentrations when fed to cows on Met-adequate diets or on content of milk protein when fed to Met-deficient cows. Therefore, it appears that feeding 2-hydroxy-4-methylthiobutyrate (**HMB**; Adisseo, Alpharetta, GA) in either the acid or salt form, has little or no replacement value for RP-Met supplements. It appears quite certain that the Met bioavailability of these 2 products is less than 5%. Pulse-dosing large amounts into the rumen have yielded apparent rumen escape values of 40 to 50%. However, this is not the way the products are fed commercially. Unlike Smartamine M, Mepron M85, and MetaSmart, adding incremental amounts of these products to Met-deficient diets has not increased milk protein or blood Met concentrations.

The RP-Lys products have been introduced only recently and have not had the research scrutiny of the aforementioned RP-Met supplements. However, because they are all lipid encapsulated or protected products, and depend on both the mechanical and enzymatic aspects of digestion throughout the gastrointestinal tract for Lys release, it is unlikely that more than 50% of the protected Lys would be available for absorption in the small intestine.

Step #5: Don't overfeed RUP.

There are several disadvantages to overfeeding RUP. These include: 1) lowered concentrations of Lys and Met in MP [because most sources of supplemental RUP are deficient in Lys, Met, or both (fish meal is the only exception)], 2) lowered milk production (because surplus RUP usually replaces fermentable CHO in the diet, the primary substrates for synthesis of milk components), 3) a more expensive diet [because most sources of supplemental RUP are more expensive than most sources of nonfiber carbohydrates (**NFC**)], and 4) increased urinary and fecal N (because of lowered conversions of feed protein to milk protein).

Identifying the optimum concentration of RUP in dietary DM is challenging. As a first step, it is critically important that one expresses RUP as a percentage of dietary DM (as one does for RDP) and that one change it as dictated by animal performance. There is no logical basis for expressing RUP as a percentage of CP - RDP provides peptides, AA, and ammonia for rumen microorganisms and RUP supplies intestinally digestible AA for the cow. Too often, when RUP is expressed as a percentage of CP, "more RUP" in a diet results in less RDP in the diet because there is a targeted level of ration CP that the nutritionist is trying to maintain. This approach is not consistent with balancing diets for RDP, RUP, and AA.

As a second step for identifying the optimum concentration of RUP in the dietary DM, it is suggested that insofar as feeding management allows, let the cows tell you how much they need. The nutritional model that you use can be used as a guide for determining RUP requirements, but it should not be used to provide the final answer. There are 2 reasons for this recommendation. First, there are too many factors that determine the cows' requirement for RUP to allow the model to be very accurate. Three important factors affecting RUP requirements are: 1) supply of microbial protein, 2) RUP digestibility, and 3) the AA composition of RUP. Each of these factors can have a significant effect on how much RUP is needed. And second, current models do not adjust MP requirements, and thus RUP requirements, for changes in predicted concentrations of AA in MP. This is a serious deficiency, and until models are designed to predict milk and milk protein yields from supplies of MP-Lys and MP-Met, just know that the MP requirement, and therefore the RUP requirement, for a given yield of milk and milk protein decreases with higher concentrations of Lys and Met in MP.

Don't be surprised, as a result of balancing for Lys and Met in MP, how little RUP is actually needed in the diet. Moreover, field experience indicates that cows are more responsive to changes in diet RUP content when RUP has a good AA balance vs. when the balance is not good. This makes sense because the nutritional potency of the RUP is greater when it has a good AA balance vs. a poor AA balance.

Benefits of Balancing for Lys and Met in MP

Balancing for Lys and Met in MP, using the steps as outlined, has led to many important benefits, both in research and on-farm implementation. The benefits include: 1) increased milk yields, 2) increased concentrations and yields of milk protein and fat, 3) reduced need for supplemental RUP for similar or greater component yields, 4) more predictable changes in milk and milk protein production to changes in RUP supply, 5) reduced N excretion per unit of milk or milk protein produced, 6) improved health and reproduction, and 7) increased dairy herd profitability. Given that these benefits to balancing for Lys and Met in MP have been achieved supports the conclusion that while other AA may become limiting, it seldom occurs before the recommended target levels for Lys and Met are achieved.

There are many good reviews in the literature summarizing the benefits of enriching rations in metabolizable Lys and Met that provide more detail about each of the above benefits (e.g., Garthwaite et al., 1998; NRC, 2001; Rulquin and Verite, 1993; Schwab et al., 2007; Sloan, 2005). Two examples of experiments that were designed to demonstrate the value of increasing concentrations of Lys and Met in MP on increasing the efficiency of use of MP for milk and milk protein production were those of Noftsger and St-Pierre (2003) and Chen et al. (2009).

By increasing Met in MP from 1.73 to 2.09% (a 21% increase) to achieve a more favorable ratio with Lys (6.7 to 6.8% of MP), Noftsger and St-Pierre (2003) was able to reduce ration RUP from 7.6 to 6.4% of ration DM, while achieving higher concentrations of milk protein (3.09 vs. 2.98%), a trend toward higher protein yields (3.17 vs. 3.04 lb/day), a trend toward higher milk fat (3.73 vs. 3.64%), and a trend toward higher fat yields (3.76 vs. 3.67 lb/day). There were no differences in milk production between the unbalanced and balanced diets (101.6 vs. 102.5 lb/day, respectively). The study involved both primiparous and multiparous cows. There were treatment by parity effects for protein production and milk fat percentage for the 2 treatments. Multiparous cows responded to the lower RUP, AA balanced diet with higher protein yields (3.63 vs. 3.32 lb/day), while yields were similar for the primiparous cows (2.73 vs. 2.75 lb/day). The primiparous cows responded to the lower RUP, AA balanced diet with higher milk fat percentage (3.91 vs. 3.66), while percentages were similar for the multiparous cows (3.54 vs. 3.62).

In a recently completed study involving 5 dietary treatments, Chen et al. (2009) fed a positive control diet with 16.9% CP and 6.17% Lys and 1.85% Met in MP (NRC, 2001), a negative control diet with 15.7% CP and 6.60% Lys and 1.84% Met in MP (without Met supplementation), and the negative control diet supplemented with 3 different Met supplements (0.16% MetaSmart, 0.06% Smartamine M, and 0.06% Smartamine M + 0.1% Rhodimet AT 88). The Met supplements were fed in amounts to increase Met in MP such that the predicted Lys to Met ratio in MP was improved from 3.6 to 3.0. The diets were based on alfalfa and corn silages, and all diets contained high moisture corn, solvent extracted soybean meal, and a premix. The high protein diet also contained distillers dried grains and expeller soybean meal. The 70 primiparous and multiparous Holstein cows averaged 147 DIM. Milk yields were similar across treatments (average = 91.7 lb/day), but content of protein was higher (average = 3.17%) for the 3 AA balanced diets than for the negative control (3.03%) and positive control (3.05%) diets. Milk fat percentages and yields were similar across treatments but favored the positive control and Met supplemented diets. Production of energy-corrected milk was significantly higher for the MetaSmart diet as compared to the negative control diet but similar to the other 3 treatments. This study supports numerous field observations indicating production and economic advantages to feeding lower RUP, AA balanced diets. Income-over-feed costs **(IOFC)** were increased by about $0.30/cow/day as compared to feeding the higher protein diet.

As expected, the responses that one achieves in balancing diets for Lys and Met in MP depends on ones “starting point”. It should also be noted that where it is possible, field nutritionists with experience in balancing for Lys and Met will also lower dietary RDP and/or RUP if the previous diets allow. This has the benefit of often reducing the usual added expense of replacing low Lys protein supplements with high Lys protein supplements and the cost of adding one or more rumen protected Met sources to the diet. When employing these feeding strategies, field nutritionists typically report a return on investment **(ROI)** of 2.5 or higher when balancing for Lys and Met in MP. Driver (2007) reported an average ROI of 3.35:1 in a 10-herd study conducted in 2006. The ROI ranged from 1.1 to 5.5 for the 10 individual herds. Increases in milkfat content and milk yields are also common and contribute to the favorable ROI.

Balancing diets for Lys and Met, because of the stated benefits, is an attractive option for increasing dairy herd profitability, even with current low milk prices and high feed costs. It is no longer uncommon to hear reports of increases in milk protein concentrations of 0.15 to 0.25 percentage units, increases in milk fat concentrations of 0.10 to 0.15 percentage units, 2 to 4 lb/day more milk, and increases in IOFC approaching 40 to 50 cents/cow/day as a result of more precise balancing for RDP and RUP and balancing for Lys and Met.

Using the described feeding strategies for optimizing diets for AA, it has been possible to lower dietary CP levels across all production groups, while achieving improvements in percentages and yields of milk protein and fat. Additionally, because of the reduction of dietary RUP achieved by this approach, a frequent result by some nutritionists has been lower total concentrate costs by allowing the inclusion of lower cost feeds that can contribute well to total dietary NFC. This approach has been implemented with herds at all levels of milk production with equal effect.

And finally, it has been gratifying to see the return of high milk component concentrations (3.3 to 3.4% protein and 4.0% fat), along with improved health and breeding, in high producing Holstein herds. In retrospect, such levels of performance should probably be expected when the limiting AA are no longer limiting and cows are finally able to realize their genetic potential. Two conclusions: 1) consider observed increases in milk protein percentages as the most visible of the responses to improved AA nutrition - it is “only the tip of the iceberg” regarding the array of benefits of more adequately meeting the cow’s requirements for the most limiting AA ,and 2) accepting low components because of “high production” is an excuse for poor AA nutrition.

Conclusions

The adoption of the concept of balancing diets for AA continues to increase. Benefits include: 1) increased yield of milk and milk components, 2) reduced N excretion per unit of milk or milk protein produced, 3) more predictable changes in milk and milk protein production to changes in RUP supply, 4) improved herd health and reproduction, and 5) increased herd profitability. Increases in milk protein and fat concentrations of 0.1 to 0.25 percentage units for protein and 0.1 to 0.15 for fat and returns on investment of 2.0 to 3.5 are typical. Increases in milk yield are more common in early lactation cows than late lactation cows and can be rather significant if balancing for Lys and Met is started before calving. With high feed costs and low milk prices, an important benefit of AA balancing has been the opportunity to increase milk and milk component yields with less RUP supplementation and similar or lower feed costs.

References

Boucher, S.E., R.S. Ordway, N.L. Whitehouse, F.P. Lundy, P.J. Kononoff, and C.G. Schwab. 2007. Effect of incremental urea supplementation of a conventional corn silage-based diet on ruminal ammonia concentration and synthesis of microbial protein. J. Dairy Sci. 90:5619-5633.

Chen, J., G. Broderick, D. Luchini, B. Sloan, and E. Devillard. 2009. Effect of metabolizable lysine and methionine concentrations on milk production and N utilization in lactating dairy cows. J. Dairy Sci. 92 (Suppl. 1):151. (Abstr.)

Driver, S. 2007. From concept to practice – experience in the USA. International Amino Acid Seminar – Belgium.

Garthwaite, B.D., C.G. Schwab, and B.K. Sloan. 1998. Amino acid nutrition of the early lactation cow. In: Proc. Cornell Nutrition Conf., Oct. 20-22, Rochester, NY, p. 38-50.

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

Noftsger, S., and N.R. St-Pierre. 2003. Supplementation of methionine and selection of highly digestible rumen undegradable protein to improve nitrogen efficiency for milk production. J. Dairy Sci. 86: 958-969.

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.

Rulquin, H., and R. Verite. 1993. Amino acid nutrition of dairy cows: Productive effects and animal requirements. In Recent Advances in Animal Nutrition pp 55-77. Edited by P.C. Garnsworthy and D.J.A. Cole. Nottingham University Press, Nottingham.

Schwab, C.G., S.E. Boucher, and B.K. Sloan. 2007. Metabolizable protein and amino acid nutrition of the cow: Where are we in 2007? In: Proc. of the 68th Annual Minnesota Nutrition Conference, p. 121-138. University of Minnesota, St. Paul.

Schwab, C., N. Whitehouse, D. Luchini, and B. Sloan. 2009. Reevaluation of the breakpoint estimates for the NRC (2001) required concentrations of lysine and methionine in metabolizable protein for maximal content and yield of milk protein. J. Dairy Sci. 92 (Suppl. 1):103. (Abstr.)

Sloan, B. 2005. Benefits and opportunities to formulating dairy rations for individual amino acids. In: Proc. of the Colorado Dairy Nutrition Conference, Colorado State University, Fort Collins.

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.)

Table 1. Breakpoint estimates for required concentrations of lysine (Lys) and methionine (Met) in metabolizable protein (MP) for maximal content and yield of milk protein for the NRC, CPM, and AMTS models.

Item	Optimal Lys	Optimal Met	Lys r^2	Met r^2	Optimal Lys/Met
			NRC Model		
Content of milk protein	6.80	2.29	0.82	0.75	2.97
Yield of milk protein	7.10	2.52	0.65	0.36	2.82
			CPM Model		
Content of milk protein	7.46	2.57	0.83	0.73	2.90
Yield of milk protein	7.51	2.50	0.53	0.46	3.00
			AMTS Model		
Content of milk protein	6.68	2.40	0.83	0.76	2.78
Yield of milk protein	6.74	2.31	0.65	0.38	2.92

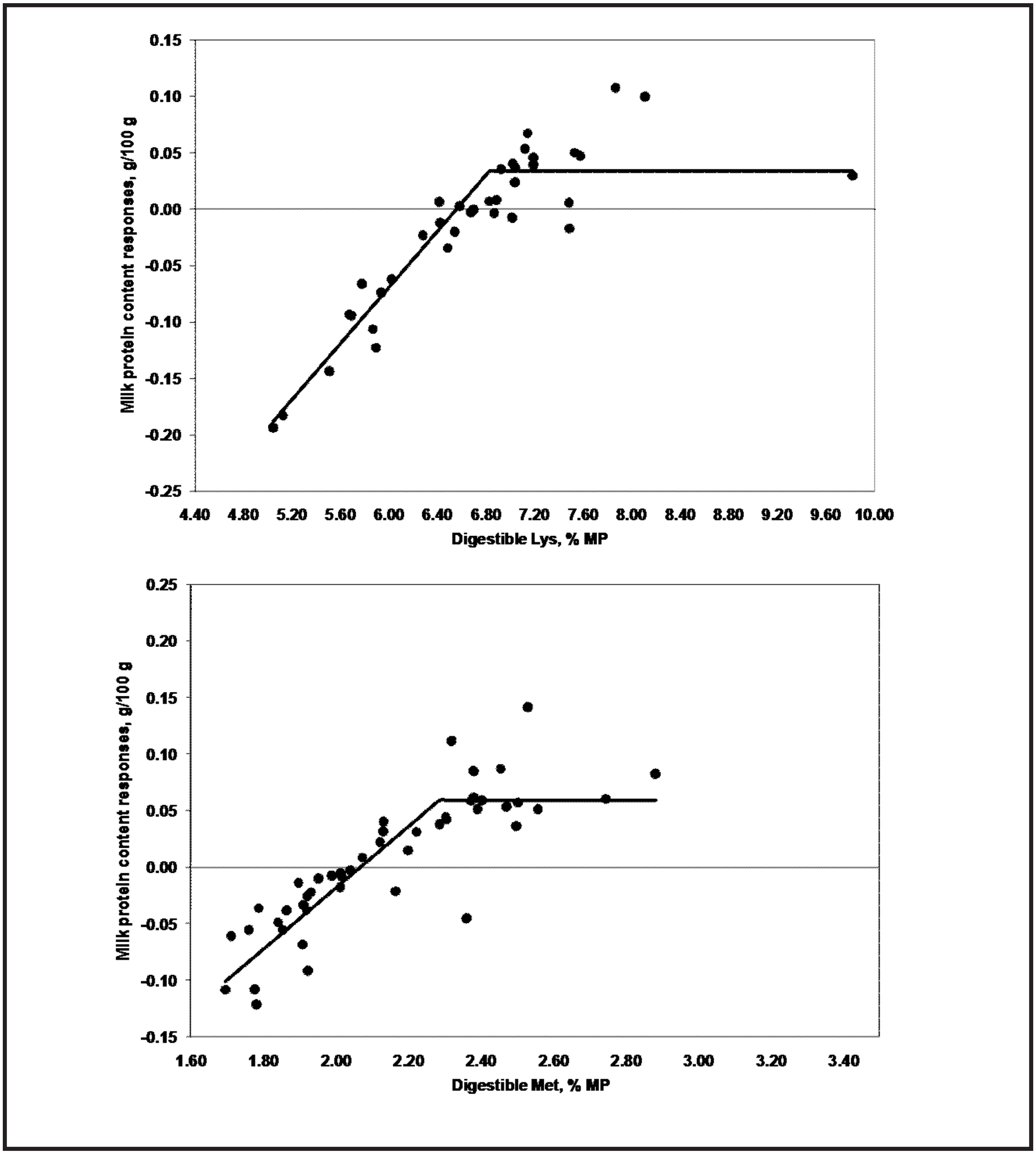

Figure 1. Revised NRC (2001) lysine (Lys) and methionine (Met) plots for milk protein concentrations. Regression analysis for Lys was limited to data where Met was 2.07 % or greater of metabolizable protein (MP). For the linear part of the model, y = -0.818 + 0.125x and for the plateau, y = -0.818 + 0.125 x **6.80**. Regression analysis for Met was limited to data where Lys was 6.16 % or greater of MP. For the linear part of the model, y = -0.560 + 0.271x and for the plateau, y = -0.560 + 0.271 x **2.29**.

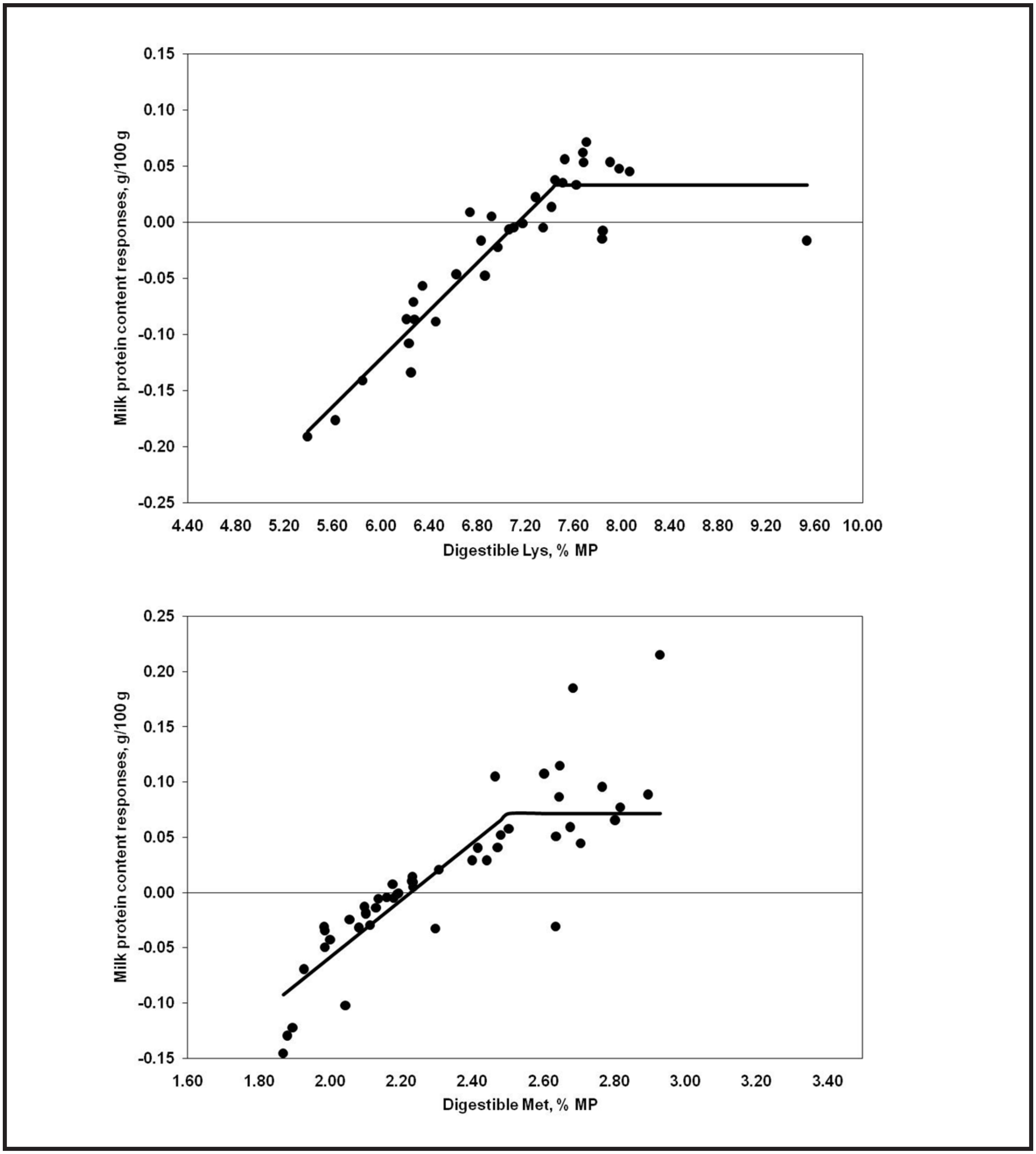

Figure 2. Lysine (Lys) and methionine (Met) plots for milk protein concentrations for CPM-Dairy. Regression analysis for Lys was limited to data where Met was 2.17 % or greater of metabolizable protein (MP). For the linear part of the model, $y = -0.763 + 0.107x$ and for the plateau, $y = -0.763 + 0.107 \times$ **7.46**. Regression analysis for Met was limited to data where Lys was 6.65 % or greater of MP. For the linear part of the model, $y = -0.576 + 0.259x$ and for the plateau, $y = -0.576 + 0.259 \times$ **2.57**.

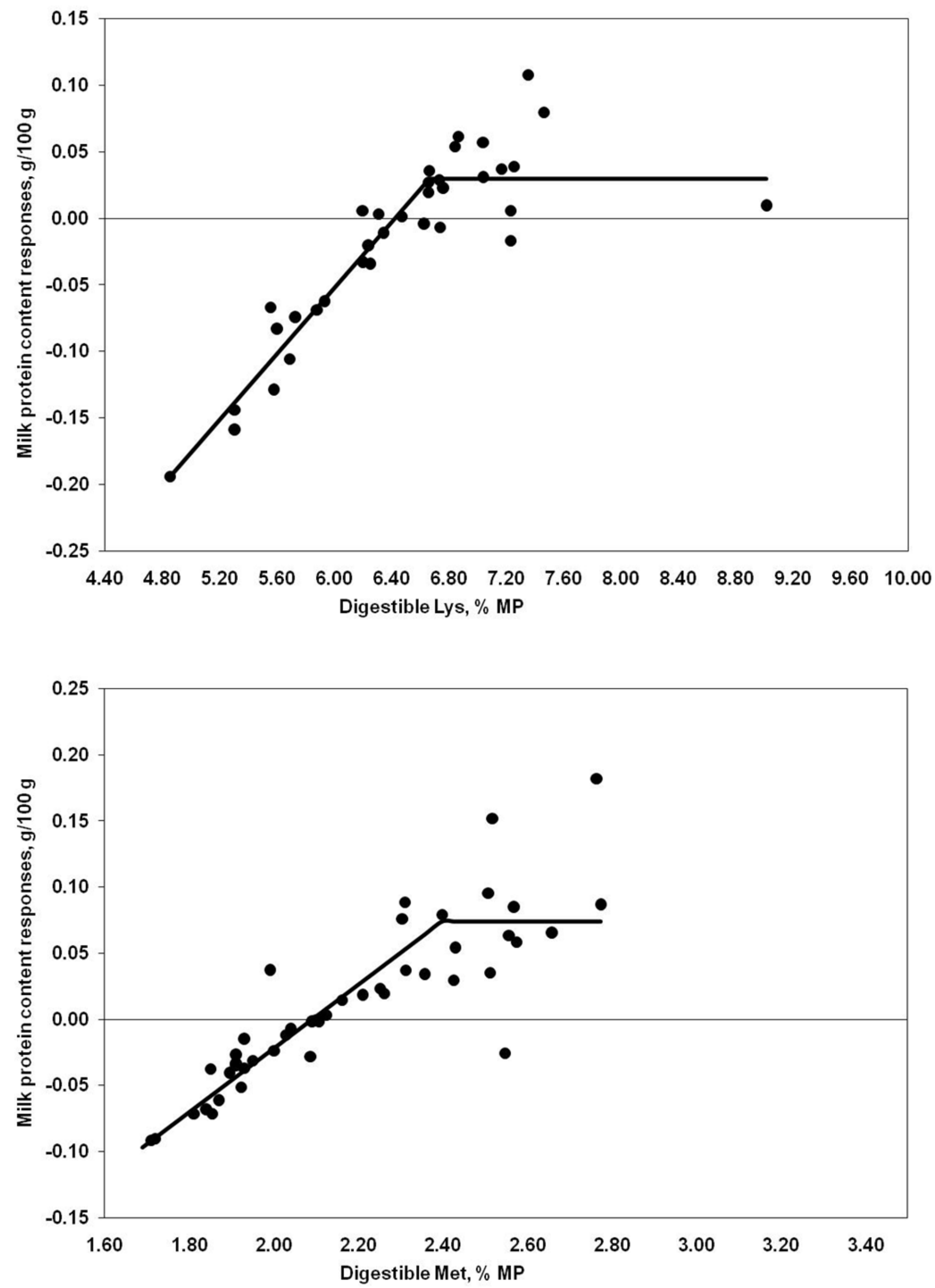

Figure 3. Lysine (Lys) and methionine (Met) plots for milk protein concentrations for AMTS.Cattle. Regression analysis for Lys was limited to data where Met was 1.94 % or greater of metabolizable protein (MP). For the linear part of the model, y = -0.795 + 0.124x and for the plateau, y = -0.795 + 0.124 x **6.68**. Regression analysis for Met was limited to data where Lys was 6.09 % or greater of MP. For the linear part of the model, y = -0.506 + 0.242x and for the plateau, y = -0.506 + 0.242 x **2.40**.