The Latest on Amino Acid Feeding

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Abstract

Considerable progress has been made in our understanding of the AA nutrition of dairy cows. Moreover, considerable advances have been made in the development of models to predict adequacy of supply of protein and amino acids for lactating dairy cows. In this paper we have used the NRC (2001) model in conjunction with published experiments to examine the relationship between predicted supplies of metabolizable Lys and Met and milk and milk protein production. These relationships were then used to predict the effects of changing protein supplementation strategies on milk and milk protein production and the resulting effects on income-over-feed-costs. We conclude that even in these tough economic times, replacing high quality protein and protected Met supplements with less expensive poorer quality proteins is not a good decision.

Introduction

Strategies for meeting the protein requirements of dairy cows continue to evolve. The first approach was to feed for CP requirements. In the 1970's, it became evident that intake of rumen-undegraded protein (RUP) was important. For more than 20 years, it was suggested by many field nutritionists that rations fed to high producing cows should contain 36 to 40% (of CP) as bypass protein. This created an excellent market for "high-bypass" protein supplements. With ration CP concentrations of 18 to 19% and alfalfa-based diets, this approach was effective in meeting requirements for RUP. However, this guideline for RUP feeding did work when lower CP diets were fed because intakes of rumen-degradable (RDP) often became too low. The result was decreased feed intake and milk production. In addition, milk protein concentrations were often low, confirming the large contributions of RUP to metabolizable protein (MP) and the effect that that has on creating a more inferior balance of amino acids (AA) in MP. The introduction of the CNCPS model (Fox et al., 1990) and the subsequent CPM models provided the first set of tools to evaluate diets for adequacy of RDP, RUP, and AA. The new Dairy NRC model (NRC, 2001) also predicts requirements for RDP and RUP and predicts AA passage to the small intestine. Although these models are far from perfect, they represent big steps forward in evaluating diets for RDP, RUP, and AA and have been useful for improving the efficiency of conversion of feed CP to milk protein on many dairy farms.

Enter year 2002. Milk prices fell to levels not seen in 20-25 years. Feed prices remained at previous years' levels or increased. The dairy profitability drought continues into 2003. Understandably, dairy producers are looking for ways to decrease costs, including feed costs. Cost per ton of feed seems to again have taken center stage over the cost per ton of digestible nutrients. The use of high quality protein and AA supplements to increase milk protein production and the efficiency of conversion of feed protein to milk protein are now being questioned as to their economic value. Do we forget about the importance of RUP digestibility and AA balance and return to balancing diets only for RDP and RUP, or just CP? Do we keep the high-Lys, high-digestible blood, fish and soybean meals and the protected Met supplements in the diets at our normal inclusion levels, or just feed less? Or, do we scrap these high quality products and feed the less expensive protein supplements? If we reduce feed costs by feeding the less expensive protein supplements, do we forget about Lys/Met ratios in MP? Or, do we accept the fact that AA are indeed the building blocks for protein and that balance affects the efficiency of their use and balance for AA the best we can with the protein supplements we're willing to buy?

The focus of this paper is to use NRC (2001) in conjunction with published experiments to answer some of the questions being asked about AA nutrition in these tough economic times. We use our university dairy herd as the example herd.

The University of New Hampshire Herd (Previous Experience)

For about 11 months ending 2 years ago, 75 of our dairy cows were fed diet containing (DM basis): 29.8% corn silage, 9.6% alfalfa hay, 9.6% grass silage, 15.4% ground corn, 7.4% barley, 4.8% soy hulls, 11.6% soybean meal, 6.4% expeller soybean meal, 1.9% fat, and 3.5% minerals and vitamins. During that 11-month period, milk true protein concentrations ranged between 2.70 and 2.83%. Milk fat concentrations averaged 3.4 to 3.7%.

At the end of the 11-month period, the diet was changed. The new diet contained (DM basis): 30.9% corn silage, 12.3% grass silage, 6.0% alfalfa hay, 19.1% corn, 9.4% barley, 3.7% soy hulls, 7.4% soybean meal, 3.7% canola meal, 0.14% urea, 2.2% of a highly digestible blood/feather meal blend containing 0.075% Smartamine M and 0.10% MHA, 1.9% fat, and 3.1% minerals and vitamins. The animal protein blend replaced the expeller soybean meal to increase Lys in MP. Smartamine M was added to achieve the desired 3.0/1.0 Lys to Met ratio in MP. The canola meal and urea replaced some of the soybean meal to provide a more diverse mix of RDP and to lower the cost of RDP. And finally, RDP and RUP were decreased to eliminate some of what NRC (2001) indicated to be a surplus and to offset the higher cost of the animal protein blend. The new diet contained 17.2% CP as compared to 18.1% for the old diet. According to NRC (2001), the new diet contained 10.6% RDP (instead of 10.8%) and 6.6% RUP (instead of 7.3%). Because of the decrease in RUP, predicted MP flows to the small intestine were decreased from 3071 to 2809 g/d (an 8% reduction). RDP was lowered by 2%. However, predicted concentrations of Lys and Met in MP increased from 6.34% and 1.73% to 6.55% and 2.20%, respectively. Therefore, even though predicted passage of MP was 8% less, the predicted flow of MP-Met (previously the "weakest link") was increased from 53 to 61 g/d, a 16% increase. Predicted MP-Lys flows decreased from 195 to 184 g/d. This was not considered to be a problem because amounts greater than needed to achieve a Lys/Met ratio of 3.0/1.0 using NRC (2001) would be considered to be a surplus.

The cows were switched gradually over a 10-day period to the new diet. For the 2-wk period preceding the transition to the new diet, milk protein concentrations averaged 2.82%. Although considered to be low, this level of milk protein was at the high end of the range (2.70% to 2.83%) for the preceding 11-month period. One week after the change, milk protein concentrations had increased to 3.01%. At the end of wk 2, protein increased to 3.06% and by wk 4 it had increased to 3.13%. Thereafter, and for the next couple of months while it was being monitored, milk protein stabilized between 3.12 and 3.16%. As expected because of the decrease in ration CP, milk urea N decreased from an average of 14.5 to an average of 12.4 mg/dL. Milk fat concentrations also tended to increase. Milk yields probably benefited but it was difficult to determine that as the cows (on average) were advancing in days-in-milk.

The economics of the diet changes were most favorable. Because we assumed that milk yield was not increased, we also assumed that DM intake was not affected. A cost analysis of the diet indicated about a 5 cents per cow per day increase in feed costs. However, because of the increases in milk protein and milk fat concentrations, milk income was increased by $0.70 per cow per day. The increased income-over-feed-costs (IOFC) was $0.65.

The University of New Hampshire Herd (Current Situation)

The ingredient composition of the ration we currently feed to our cows that are not on experiment is presented as Diet 1 in Table 1. The chemical composition of the diet and NRC (2001) and CPM Dairy evaluations for RDP, RUP, and MP and predicted flows of Lys, Met, and histidine (His) are presented in Table 2. For purposes of model evaluations, as noted in the first footnote to Table 2, we used production inputs of 99 lb of milk, 3.70% fat, and 2.90% true protein. These are mean values for the cows during the first 20 wk of lactation. Because we do not have precise feed intakes on our non-research cows (feed refusals are not weighed), we allowed NRC (2001) to predict DM intake (58.6 lb). The cost of the feedstuffs (dollars per ton, dollars per lb of DM, and dollars per cow) and the total diet cost are presented in Table 3. The total feed cost is $5.08 per cow per day. The IOFC and associated calculations are presented in Table 4.

As with commercial dairy producers, we find the IOFC of $7.05 (Table 4) to be unacceptable, certainly if it persists for another 6 months. Like the commercial producer, we have curtailed spending on some things but we have not given in to lowering the quality of our diets. We did, however, introduce our cows to citrus pulp (3.4%) and beet pulp (1.7%) within the last 3 months and increased total forage from 49% to 52% of diet DM (all at the expense of corn and barley) (Table 1). Although these changes resulted in a small decrease in feed costs, the changes were made to improve rumen health, not to reduce feed costs. Because of the excellent cow health and milk component production we have realized since optimizing Lys and Met nutrition, we have not changed our protein/AA supplementation strategy. However, as described in the next section, we have explored three alternate options for protein supplementation to reduce feed costs.

The University of New Hampshire Herd (Options Explored for Protein Supplementation)

Before we could realistically evaluate options to changing our protein/AA supplementation strategy, we needed to develop a method for predicting the effect that changes in supplies of metabolizable Lys and Met would have on milk and milk component production. Our approach was as follows. We had previously entered 206 diets from published experiments into the NRC (2001) model. The diets were from experiments published in the Journal of Dairy Science in which the objective was to compare the effects of feeding different protein supplements on milk production and milk composition, and in some cases, passage of N fractions to the small intestine. Because of the lack of experiments in which cows produced in excess of 40 kg (88 lb) of milk, we identified an additional 5 studies consisting of 20 diets and entered the reported diets and animal data into the NRC (2001). The latter studies were selected primarily because of high reported milk yields.

Relevant data from the NRC model generated Summary and Duodenal Amino Acid Supply Reports were recorded. To generate plots of measured yields of milk and milk protein vs. predicted supplies of MP-Lys and MP-Met, data were restricted to diets in which MP balance was within 250 g/d of zero balance (± 250 g/d). For the Lys plots, we wanted to add the restriction that the ratio of Lys to Met in MP had to be less than 3.0/1.0 to ensure that Lys was more limiting in MP than Met. However, only in a few experiments was the ratio of Lys to Met in MP less than 3.0/1.0. Therefore, to give ourselves an adequate number of data points from which to get some idea of the relationship between yields of milk and milk protein vs. predicted supplies of Lys, diets yielding predicted Lys/Met ratios up to 3.5/1.0 were used. For the Met plots, we imposed the restriction that that the Lys/Met ratio in MP had to be greater than 3.0/1.0. The resulting Lys and Met plots are presented as Figures 1 and 2, and 3 and 4, respectively.

In addition, differences between measured (actual) milk and MP allowable milk versus model predicted Lys and Met concentration of MP (for the same diets as used in Figures 1-4) are presented in Figures 5 and 6, respectively. These plots confirm the results of several experiments that increasing amounts of Lys and Met in MP to more desirable concentrations increases milk yield.

Alternate option #1: diet 2. In this option, we chose to feed less RUP while maintaining RDP levels (Tables 1 and 2). This was the most attractive option to us because we could maintain our high levels of Lys and Met in MP (6.6 and 2.1%, respectively) with predicted losses of only 9 grams of MP-Lys (182 vs. 191 g/d) and 3 grams of MP-Met (58 vs. 61 g/d) (Table 2). The question is, will yields of milk and milk protein decrease if we feed this diet?

The first step (for all options) was to calculate “reference yields” of milk and milk true protein from the NRC (2001) predicted supplies of MP-Lys and MP-Met presented in Table 2 for diet 1. To do this, we used the equations given in the legends of Figures 1-4. The predicted milk yields were 95.1 lb using the Lys equation (Figure 1) and 99.0 lb using the Met equation (Figure 3). The predicted yields of milk protein were 1247 g/d (2.75 lb) using the Lys equation (Figure 2) and 1403 g/d (3.09 lb) using the Met equation

(Figure 4). These predicted yields of milk and protein are strikingly similar to the actual milk and protein yields of 99.0 lb and 2.87 lb, respectively (Table 4). As indicated earlier, we have more confidence in the Met equations for predicting milk and milk protein yields than the Lys equations because the Met equations were derived from a data set in which Met was almost always expected to be first limiting. In contrast, the Lys equations were developed from a data set that included many diets in which Lys was not first limiting. Therefore, we have chosen to use the calculated reference yields of milk and milk protein using the Met equations. As a result, the reference yields of milk and milk protein for diet 1 are 99.0 lb and 1403 g/d (3.09 lb), respectively.

The second step then was to calculate the yields of milk and milk protein for diet 2 from the NRC (2001) predicted supplies of MP-Met (58 g/d; Table 2) using the Met equations. Predicted yields were 97.4 lb of milk and 1341 g/d (2.95 lb) of protein. These calculations indicate that switching from diet 1 to diet 2 would result in a loss of 1.6 lb of milk (97.4 vs. 99.0 lb) and 62 g/d (0.14 lb) of protein (1341 vs. 1403 g/d or 2.95 vs. 3.09 lb). Based on the predicted yields of milk and milk protein, the percentage of protein in milk for diet 2 is calculated to be 2.81%. Assuming the same milk/DM intake ratio of 1.69 as observed for diet 1, DM intake would decrease from 58.6 to 57.6 lb.

Based on the predicted changes in DM intake and milk and milk protein production, herd profitability would decrease by feeding diet 2. Diet 2 is a less expensive diet ($0.0853 vs $0.0867/lb (Table 3) and the cows are predicted to eat less of it (Table 4). However, the predicted decrease in expected feed cost of $0.17 ($4.91 vs. $5.08) (Table 4) is considerably less than the projected loss in milk income of $0.44 ($11.69 vs. $12.13) (Table 4).

Alternate option #2: diet 3. In diet 3, we chose to remove the blood meal, feather meal, and protected Met product altogether while maintaining the same CP, RDP, RUP, and NDF levels as diet 1. The idea was to remove any animal proteins and protected AA sources in an attempt to lower ration costs by using other protein rich sources such as protected soybean meal, corn distillers grain, and corn gluten meal which are less expensive (Tables 1 and 2). Lys flows decreased from 191 g/d in diet 1 to 181 g/d in diet 2. Met flows decreased from 61 g/d to 54 g/d, which resulted in an increase in the Lys/Met ratio in MP (3.35/1 vs. 3.13/1) (Tables 1 and 2).

Overall, diet 3 was less expensive than either diets 1 or 2 (Table 3). However, this occurred with a loss in quality of MP. From this diet, we would expect a decrease in milk yield and milk protein concentration as well as a decrease in milk fat concentration which we and others (Noftsger and St-Pierre, 2003) have observed when there is a decrease in quality of MP. Using the same procedure previously described (Alternate option #1: diet 2) DM intake (55.7 vs. 58.6 lb), milk yield (94.2.0 vs. 99.0 lb), milk protein concentration (2.70 vs. 2.90%), protein yield (2.54 lb vs. 2.87 lb), fat concentration (3.56 vs. 3.70%), and fat yield (3.35 vs. 3.66 lb) decreased substantially. There was also a decrease in the efficiency of conversion of feed N into milk N which could have an adverse effect on producers with nutrient management constraints. Despite a lower feed cost, feeding diet 3 vs. diet 1 results in a lower IOFC ($6.35 vs. $7.05). This example reinforces our belief that lowering feed costs by sacrificing feed quality ultimately results in less income due to reduced milk production and milk quality.

Alternate option #3: diet 4. The next logical step in our process was to determine if we could use the ingredients from diet #3, but this time attempt to improve the Lys/Met ratio to 3/1 while maintaining the same feed CP, RDP, RUP, and NDF as diet 1 (Tables 1 and 2). In order to obtain a 3/1 ratio without using an animal protein source complemented with a protected Met product, Met could only be increased in MP by decreasing Lys. This was accomplished by removing the protected soy product and increasing the corn distillers grain and corn gluten meal.

Overall, Lys was decreased (170 vs. 181 g/d) while Met was increased (56 vs. 54 g/d). This resulted in an improvement in the Lys/Met ratio from 3.35/1 to 3.04/1 and increased the supply of Met, which was the first limiting AA.

Again, using the procedure outlined above, predicted milk yield (96.0 vs. 94.2 lb), protein concentration (2.75 vs. 2.70%), protein yield (2.64 vs. 2.54 lb), fat concentration (3.60 vs. 3.56%), and fat yield (3.46 vs.

3.35 lb) all increased. Although the cost of diet 4 is greater than the cost of diet 3, the IOFC is $0.29 more per cow per day. However, the IOFC is still $0.14 per cow per day less than diet 2 and $0.41 less per cow per day than diet 1.

Summary. Among the 3 options discussed, we believe that option 2 is the only alternative option to our current diet (diet 1). The reason option 2 may be beneficial over the current diet, is that we may be feeding some surplus of RUP. If this is the case, then diet 2 would not cause any losses of production.

It is clear that feeding animal protein sources complemented with a protected Met source improves not only the quality of MP, but also improves the overall "bottom line" despite higher feed costs. This is an important aspect to take into account because milk protein and milk fat production as well as milk yield are the driving forces behind a dairy producer's milk check.

The Ohio State University Experience

Recently, researchers at Ohio State (Noftsger and St-Pierre, accepted) conducted a research project aimed at manipulating MP and AA supplies in dairy cow rations by feeding two levels of CP and within those two levels, changing the intestinal digestibility of the RUP. The diets and NRC (2001) and CPM Dairy 2.0.23 evaluations are shown in Tables 5 and 6. The diets were similar in content except for the sources of RUP which were varied to obtain a high or low digestibility of RUP. In addition, the low CP-highly digestible RUP containing diet was supplemented with protected Met and MHA. An analysis of feed costs using the same prices as in the University of New Hampshire analysis is presented in Table 7. Effects of dietary treatments on DM intake, milk production, milk composition, milk income, and IOFC are presented in Table 8.

In general, lactational responses were consistent with model predicted flows of Lys and Met (g/d). For example, milk yield was lower for cows fed the LoCP-HiDRUP diet than cows fed the HiCP-HiDRUP diet. A decrease in milk yield was expected because flows of MP Met (the obvious first limiting AA) were lower for the LoCP-HiDRUP diet (48.0 vs. 50.0 g/d). Similarly, when protected Met was added to the LoCP-HiDRUP diet to increase flows of MP Met from 48.0 to 55.0 g/d, milk yield increased. Moreover, as expected from previous research, milk protein concentration was also increased. As a result of this positive effect on milk protein production, the conversion of milk N to feed N was increased from 32.7 to 36.2%. The only observation in this study that cannot be explained on the basis of predicted Lys and Met supplies was the significantly lower levels of milk yield on the HiCP-LoDRUP diet as compared to the HiCP-HiDRUP diet. Inclusion of 8.0% porcine meat meal in the diet may have been the cause of depressed DM intake (Table 8), thereby accounting for decreased milk yield.

As shown in Table 7, overall feed costs were highest for the LoCP-HiDRUP + Met diet. The best ratio of Lys/Met in MP was obtained with this diet by increasing the flow of MP-Met (g/d) to more adequate levels. The Ohio State experiment corroborates our conclusions in the previous section that lowering feed costs by decreasing the quality of MP in the diet will not result in increased IOFC (Table 8).

References

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National Research Council. 2001. Nutrient Requirements of Dairy cattle, 7th rev.ed., Washington, D.C.: National Academy Press.

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Table 1. Ingredient composition of diets used in NRC (2001) and CPM Dairy 2.0.23 analyses.

Ingredient, % DM	Diet 1[1]	Diet 2[2]	Diet 3[3]	Diet 4[4]
Corn silage	36.0	36.0	36.0	36.0
Grass/legume silage	9.9	9.9	9.9	9.9
Alfalfa hay	6.2	6.2	6.2	6.2
Ground corn	15.9	16.3	14.0	14.9
Barley meal	6.3	6.4	6.3	6.5
Soyhulls	3.4	3.5	3.0	3.2
Citrus pulp	3.4	3.5	3.0	3.2
Beet pulp	1.7	1.8	1.5	1.6
Soybean meal	9.1	9.5	8.8	6.4
Blood meal	1.74	0.96	-	-
Urea	0.43	0.44	0.41	0.61
Feather meal	0.32	0.17	-	-
Smartamine M	0.068	0.051	-	-
Soyplus	-	-	2.4	-
Corn distillers grain, dried	-	-	1.7	2.7
Corn gluten meal	-	-	1.3	3.4
Megalac	2.0	2.0	2.0	2.0
Vit/min	3.4	3.4	3.4	3.4

[1] Current UNH lactating diet.
[2] Modified UNH lactating diet with less RUP (i.e., lower blood/feather/Smartamine M).
[3] No blood/feather/Smartamine M but with same RUP as diet 1.
[4] No blood/feather/Smartamine M but with a 3:1 Lys:Met in MP (NRC, 2001) and the same RUP as diets 1 and 3.

Table 2. Comparison of NRC (2001) and CPM Dairy 2.0.23 evaluations of the diets.[1]

	Diet 1[2]		Diet 2[3]		Diet 3[4]		Diet 4[5]	
Item	NRC	CPM	NRC	CPM	NRC	CPM	NRC	CPM
CP, % DM	17.2	17.2	16.6	16.6	17.2	17.2	17.2	17.2
RDP, % DM	10.7	10.6	10.7	10.7	10.7	10.8	10.7	10.7
RUP, % DM	6.5	6.6	5.9	5.9	6.5	6.4	6.5	6.5
NDF, % DM	29.3	30.0	29.5	29.8	29.9	29.9	30.1	30.2
MP balance, g/d	42	201	-81	57	85	97	69	86
RDP balance, %	110	-	110	-	110	-	110	-
NH$_3$ balance, %	-	144	-	146	-	150	-	154
Peptide balance, %	-	99	-	98	-	104	-	94
Lys, g/d	191	210	182	197	181	187	170	175
Met, g/d	61	68	58	65	54	58	56	60
His, g/d	72	91	66	82	64	75	62	74
Lys, % of MP	6.6	6.9	6.6	6.8	6.1	6.3	5.8	5.9
Met, % of MP	2.1	2.2	2.1	2.2	1.8	1.9	1.9	2.0
His, % of MP	2.5	3.0	2.4	2.8	2.2	2.5	2.1	2.5
Lys/Met in MP	3.13/1	3.11/1	3.14/1	3.03/1	3.35/1	3.25/1	3.04/1	2.91/1

[1] Diet evaluations were conducted with the following parameters: 1320 lb cow, 3.00 BCS, 100 DIM, 25 days pregnant, 99 lb milk yield, 3.70% fat, 2.90% true protein, and NRC predicted DMI of 58.6 lb/d.
[2] Current UNH lactating diet.
[3] Modified UNH lactating diet with less RUP (i.e., lower blood/feather/Smartamine M).
[4] No blood/feather/Smartamine M but with same RUP as diet 1.
[5] No blood/feather/Smartamine M but with a 3:1 Lys:Met in MP (NRC, 2001) and the same RUP as diets 1 and 3.

Table 3. Costs of feedstuffs and diets presented in Table 1.[1]

				Cost ($)/58.6 lb DM intake			
Ingredient	DM, %	$/ton[2]	$/lb DM	Diet 1[3]	Diet 2[4]	Diet 3[5]	Diet 4[6]
Alfalfa hay	90.8	215	0.118	0.43	0.43	0.43	0.43
Corn silage	30.0	27	0.045	0.95	0.95	0.95	0.95
Grass/legume silage	24.4	34	0.070	0.40	0.40	0.40	0.40
Barley meal	88.3	124	0.070	0.26	0.26	0.26	0.27
Ground corn	89.2	126	0.071	0.66	0.67	0.58	0.62
Soyhulls	89.3	113	0.063	0.13	0.13	0.11	0.12
Citrus pulp	85.8	108	0.063	0.13	0.13	0.11	0.12
Beet pulp	88.3	141	0.080	0.08	0.08	0.07	0.08
Soybean meal	89.9	196	0.109	0.58	0.61	0.56	0.41
Urea	100	300	0.150	0.04	0.04	0.04	0.05
Soyplus	89.6	214	0.119	-	-	0.17	-
Corn distillers grain, dried	90.2	129	0.072	-	-	0.07	0.12
Corn gluten meal	86.4	280	0.162	-	-	0.13	0.32
Blood meal	91.9	380	0.207	0.21	0.12	-	-
Feather meal	89.6	265	0.148	0.03	0.02	-	-
Megalac	95.3	805	0.422	0.49	0.49	0.49	0.49
Vit/min	97.6	527	0.270	0.53	0.53	0.53	0.53
Smartamine M	100	9080	4.540	0.17	0.14	-	-
Total forage				1.79	1.79	1.79	1.79
Total concentrate[7]				3.30	3.21	3.12	3.12
Total				5.08	5.00	4.91	4.90
Protein supplements[8]				1.02	0.91	0.97	0.90
				Cost ($)/ton DM			
Concentrate[7]				235.37	228.80	222.54	222.19
Protein supplements[8]				299.89	280.11	225.05	233.48
				Cost ($)/lb of DM			
Diet				0.0867	0.0853	0.0838	0.0836

[1] Diet evaluations were conducted with the following model inputss: 1320 lb cow, 3.00 BCS, 100 DIM, 25 days pregnant, 99 lb milk yield, 3.70% fat, 2.90% true protein, and NRC predicted DMI of 58.6 lb/d.

[2] University of New Hampshire costs (January 2003).

[3] Current UNH lactating diet.

[4] Modified UNH lactating diet with less RUP (i.e., lower blood/feather/Smartamine M).

[5] No blood/feather/Smartamine M but with same RUP as diet 1.

[6] No blood/feather/Smartamine M but with a 3:1 Lys:Met in MP (NRC, 2001) and the same RUP as diets 1 and 3.

[7] Concentrate includes all feeds except forages.

[8] Includes soybean meal, urea, Soy Plus, corn distillers grain, corn gluten meal, blood meal, feather meal, and Smartamine M.

Table 4. Dry matter intake, milk production, composition and economic analyses for diets 1-4.

Item	Diet 1[1]	Diet 2[2]	Diet 3[3]	Diet 4[4]
DMI, lb/d	58.6	57.6	55.7	56.8
Milk yield, lb/d	99.0	97.4	94.2	96.0
Milk/DMI	1.69	1.69	1.69	1.69
Protein yield, lb/d	2.87	2.73	2.54	2.64
Fat yield, lb/d	3.66	3.55	3.35	3.46
Protein, %	2.90	2.81	2.70	2.75
Fat, %	3.70	3.64	3.56	3.60
Milk N/fed N, %	28.53	28.56	26.56	27.08
Milk income ($/cow/d)				
Protein[5]	5.91	5.62	5.23	5.44
Fat[6]	3.70	3.59	3.38	3.49
Other solids[7,8]	0.21	0.21	0.22	0.22
Quality premium[9]	0.30	0.29	0.28	0.29
Volume[10]	2.01	1.98	1.91	1.95
Total	12.13	11.69	11.02	11.39
Feed cost, $/cow[11]	5.08	4.91	4.67	4.75
IOFC, $/cow	7.05	6.78	6.35	6.64

[1] Current UNH lactating diet.

[2] Modified UNH lactating diet with less RUP (i.e., lower blood/feather/Smartamine M).

[3] No blood/feather/Smartamine M but with same RUP as diet 1.

[4] No blood/feather/Smartamine M but with a 3:1 Lys:Met in MP (NRC, 2001) and the same RUP as diets 1 and 3.

[5] Valued at $2.06/lb

[6] Valued at $1.01/lb

[7] Valued at $0.0367/lb

[8] Based on a total solids content of 12.28%

[9] Valued at $0.003/lb

[10] Valued at $0.0203/lb

[11] Calculated from Table 3 using calculated DM intakes for diets 2-4.

Table 5. Ingredient and nutrient composition of diets from Noftsger and St-Pierre (accepted).[1]

	HiCP		LoCP	
Ingredients	LoDRUP	HiDRUP	HiDRUP	HiDRUP+Met
Corn silage	37.5	37.5	37.5	37.5
Alfalfa silage	12.5	12.5	12.5	12.5
Ground shelled corn	20.0	19.8	22.4	22.3
Soyhulls	3.4	3.4	3.4	3.4
Whole cottonseed	8.4	8.4	8.4	8.4
Soybean meal	6.8	9.4	7.7	7.7
Porcine meat meal	8.00	-	-	-
Blood meal	-	2.00	1.80	1.80
Feather meal	-	1.00	0.44	0.44
Poultry meal	-	1.00	-	-
Urea	-	-	0.19	0.19
Megalac	0.5	0.5	0.5	0.5
Tallow	-	0.32	0.57	0.57
Smartamine M	-	-	-	0.042
Rhodimet AT-88	-	-	-	0.084
Vit/min	2.9	4.4	4.8	4.8

[1] HiCP-LoDRUP is the control diet with porcine meat meal as the source of supplemental RUP; HiCP-HiDRUP has same level of RUP as control but with highly digestible supplemental RUP source; Lo-CP-HiDRUP has highly digestible supplemental RUP source, with overall RUP decreased; LoCP-HiDRUP+Met is the same as the LoCP-HiDRUP but with Met adjusted to obtain a 3.3:1 Lys:Met.

Table 6. Comparison of NRC (2001) versus CPM Dairy 2.0.23 predictions of diet composition and metabolizable AA from Noftsger and St-Pierre (accepted) (DM basis).[1]

	HiCP				LoCP			
	LoDRUP		HiDRUP		HiDRUP		HiDRUP + Met	
Item	NRC	CPM	NRC	CPM	NRC	CPM	NRC	CPM
CP, % DM	18.6	18.3	18.5	18.3	16.9	16.9	16.9	17.0
RDP, % DM	11.4	10.6	10.7	10.7	10.2	10.5	10.2	10.6
RUP, % DM	7.2	7.7	7.8	7.6	6.7	6.4	6.7	6.4
NDF, % DM	29.7	32.8	29.9	32.4	30.0	32.3	30.0	32.3
MP balance, g/d	-183	-300	43	-64	-168	-267	-168	-265
RDP balance, %								
NH$_3$ balance, %								
Peptide balance, %								
Lys, g/d	171		190		181		181	
Met, g/d	49		50		48		55	
His, g/d								
Lys, % of MP	6.3	6.5	6.4	6.7	6.6	6.8	6.6	6.8
Met, % of MP	1.8	1.9	1.7	1.7	1.7	1.8	2.0	2.1
His, % of MP								
Lys/Met in MP	3.49/1	3.42/1	3.81/1	3.94/1	3.77/1	3.78/1	3.29/1	3.24/1

[1] HiCP-LoDRUP is the control diet with porcine meat meal as the source of supplemental RUP; HiCP-HiDRUP has same level of RUP as control but with highly digestible supplemental RUP source; Lo-CP-HiDRUP has highly digestible supplemental RUP source, with overall RUP decreased; LoCP-HiDRUP+Met is the same as the LoCP-HiDRUP but with Met adjusted to obtain a 3.3:1 Lys:Met.

Table 7. Costs of feedstuffs and diets presented in Table 5.[1]

		Cost ($)/cow per day			
		HiCP		LoCP	
Ingredients	$/ton[2]	LoDRUP[3]	HiDRUP[4]	HiDRUP[5]	HiDRUP+Met[6]
Corn silage	27	0.78	0.84	0.83	0.85
Alfalfa silage	34	0.25	0.27	0.27	0.28
Ground shelled corn	126	0.68	0.73	0.82	0.83
Soyhulls	113	0.10	0.11	0.11	0.11
Whole cottonseed	157	0.35	0.38	0.37	0.38
Soybean meal	196	0.36	0.53	0.43	0.44
Porcine meat meal	195	0.41	-	-	-
Blood meal	380	-	0.22	0.19	0.20
Feather meal	265	-	0.07	0.03	0.03
Poultry meal	260	-	0.07	-	-
Urea	300	-	-	0.02	0.02
Megalac	805	0.10	0.11	0.11	0.11
Tallow	320	-	0.03	0.05	0.05
Smartamine M	9080	-	-	-	0.10
Rhodimet AT-88	3087	-	-	-	0.08
Vit/min	527	0.37	0.59	0.65	0.66
Total forage		1.03	1.11	1.10	1.12
Total concentrate[7]		2.36	2.82	2.77	2.99
Total		3.39	3.93	3.87	4.11
Protein supplements[8]		0.76	0.89	0.67	0.86
		Cost ($)/ton DM			
Concentrate[7]		$197.66	$219.45	$216.16	$229.23
Protein supplements[8]		$215.20	$258.15	$259.36	$322.22
		Cost ($)/lb of DM			
Diet		$0.0711	$0.0767	$0.0759	$0.0762

[1] HiCP-LoDRUP is the control diet with porcine meat meal as the source of supplemental RUP; HiCP-HiDRUP has same level of RUP as control but with highly digestible supplemental RUP source; Lo-CP-HiDRUP has highly digestible supplemental RUP source, with overall RUP decreased; LoCP-HiDRUP+Met is the same as the LoCP-HiDRUP but with Met adjusted to obtain a 3.3:1 Lys:Met.

[2] University of New Hampshire costs (January 2003).

[3] Based on 47.7 lb DMI

[4] Based on 51.3 lb DMI

[5] Based on 51.0 lb DMI

[6] Based on 51.9 lb DMI

[7] Concentrate includes all feeds except forages.

[8] Includes soybean meal, porcine meat meal, blood meal, feather meal, poultry meal, urea, Smartamine M, and Rhodimet AT-88.

Table 8. Dry matter intake, milk production, milk composition and economic analyses of data from Noftsger and St-Pierre (accepted).[1]

	HiCP		LoCP	
	LoDRUP	HiDRUP	HiDRUP	HiDRUP + Met
DMI, lb/d	47.7	51.3	51.0	51.9
Milk yield, lb/d	89.8	101.6	94.4	102.5
Milk/DMI	1.89	1.99	1.86	1.98
Protein yield, lb/d	2.64	3.04	2.82	3.17
Fat yield, lb/d	3.04	3.67	3.45	3.76
Protein, %	2.95	2.98	2.99	3.09
Fat, %	3.42	3.64	3.66	3.73
Milk N/fed N, %	29.7	32.0	32.7	36.2
Milk income ($/cow/d)				
Protein[2]	5.44	6.26	5.81	6.53
Fat[3]	3.07	3.71	3.48	3.80
Other solids[4,5]	0.22	0.21	0.21	0.20
Quality premium[6]	0.27	0.31	0.28	0.31
Volume[7]	1.82	2.06	1.92	2.08
Total	10.82	12.55	11.70	12.92
Feed cost, $/cow	3.39	3.93	3.87	4.11
IOFC, $/cow	7.43	8.62	7.83	8.81

[1] HiCP-LoDRUP is the control diet with porcine meat meal as the source of supplemental RUP; HiCP-HiDRUP has same level of RUP as control but with highly digestible supplemental RUP source; Lo-CP-HiDRUP has highly digestible supplemental RUP source, with overall RUP decreased; LoCP-HiDRUP+Met is the same as the LoCP-HiDRUP but with Met adjusted to obtain a 3.3:1 Lys:Met.

[2] Valued at $2.06/lb

[3] Valued at $1.01/lb

[4] Valued at $0.0367/lb

[5] Based on a total solids content of 12.28%

[5] Valued at $0.003/lb

[6] Valued at $0.0203/lb

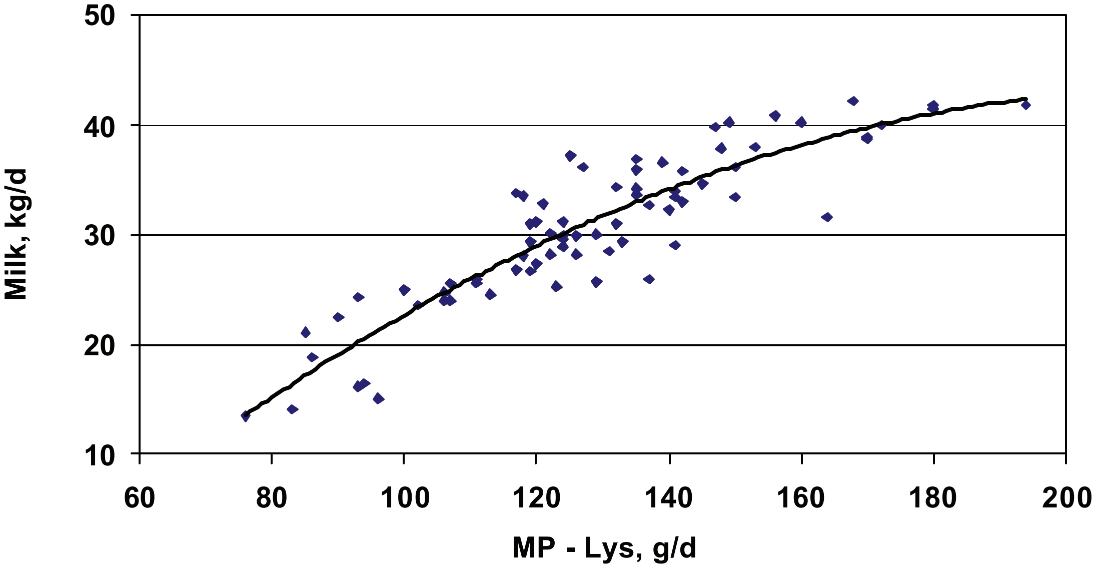

Figure 1. Plot of measured milk yields as measured in 33 published experiments vs. NRC (2001) predicted flows of metabolizable lysine (MP-Lys) ($y = -0.0014x^2 + 0.6301x - 26.056$; $r^2 = 0.82$). The database involved 77 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was < 3.5/1.0.

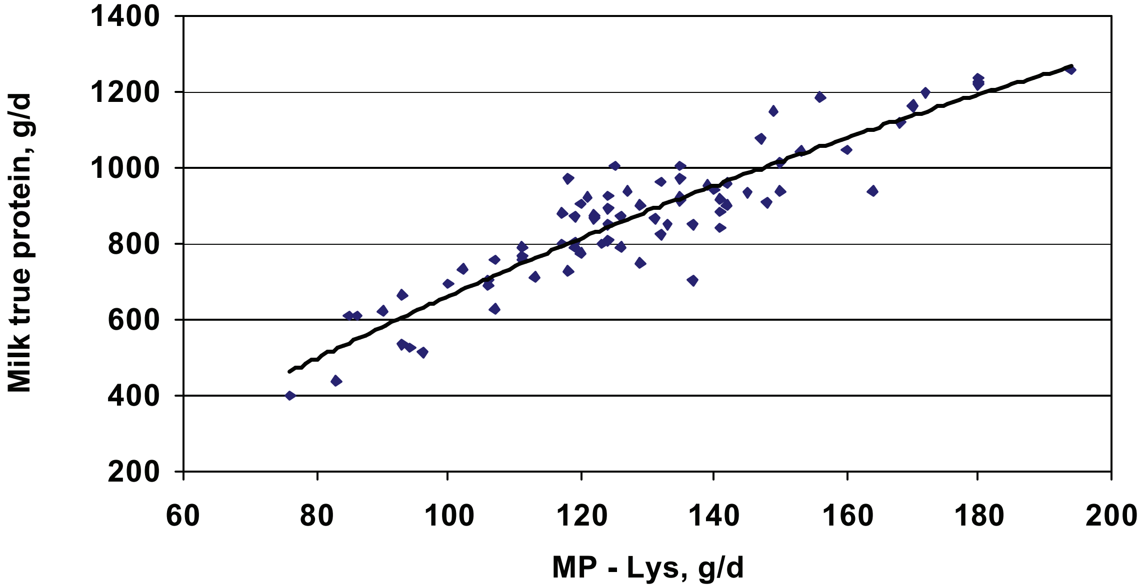

Figure 2. Plot of measured milk true protein yields as measured in 33 published experiments vs. NRC (2001) predicted flows of metabolizable lysine (MP-Lys) ($y = -0.0158x^2 + 11.059x - 288.11$; $r^2 = 0.85$). The database involved 77 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was < 3.5/1.0.

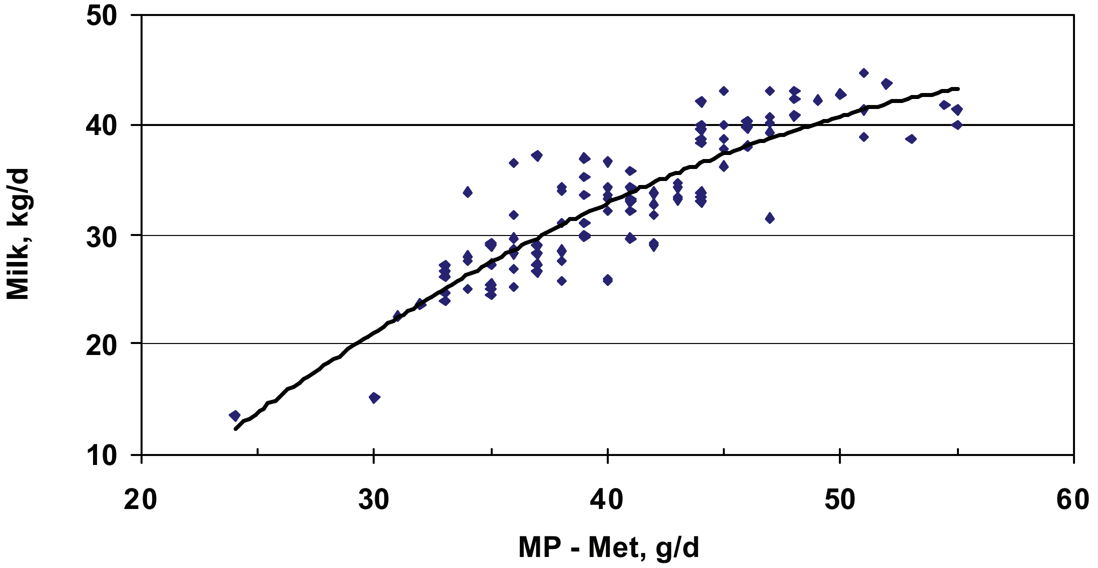

Figure 3. Plot of measured milk yields as measured in 39 published experiments vs. NRC (2001) predicted flows of metabolizable methionine (MP-Met) ($y = -0.0191x^2 + 2.5092x - 36.981$; $r^2 = 0.78$). The database involved 110 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was > 3.0/1.0.

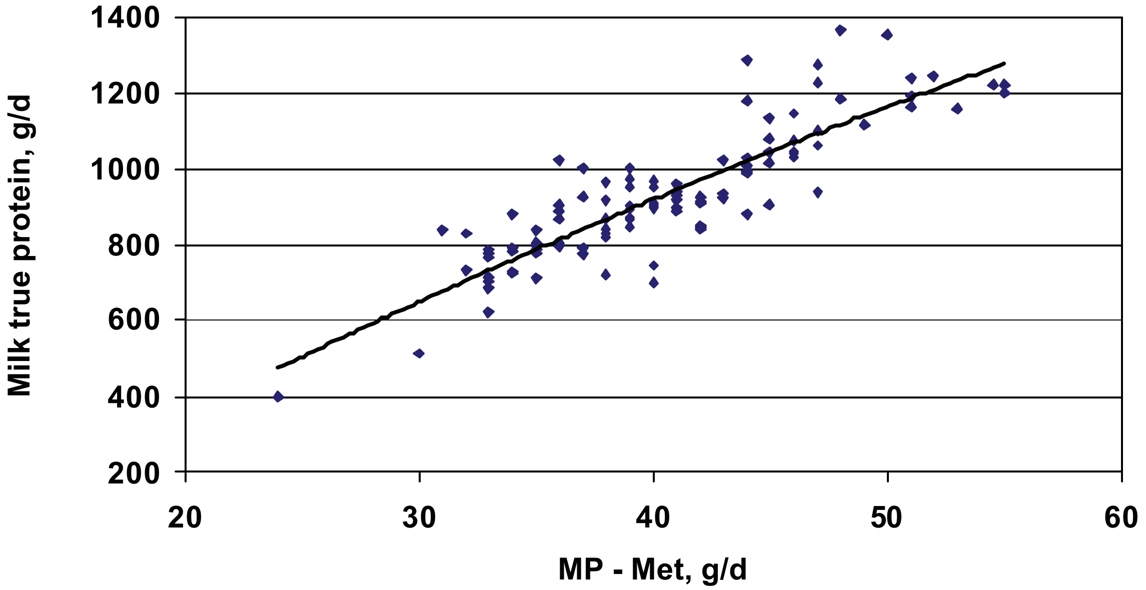

Figure 4. Plot of measured milk true protein yields as measured in 39 published experiments vs. NRC (2001) predicted flows of metabolizable methionine (MP-Met) ($y = -0.1311x^2 + 36.246x - 320.43$; $r^2 = 0.76$). The database involved 110 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was > 3.0/1.0.

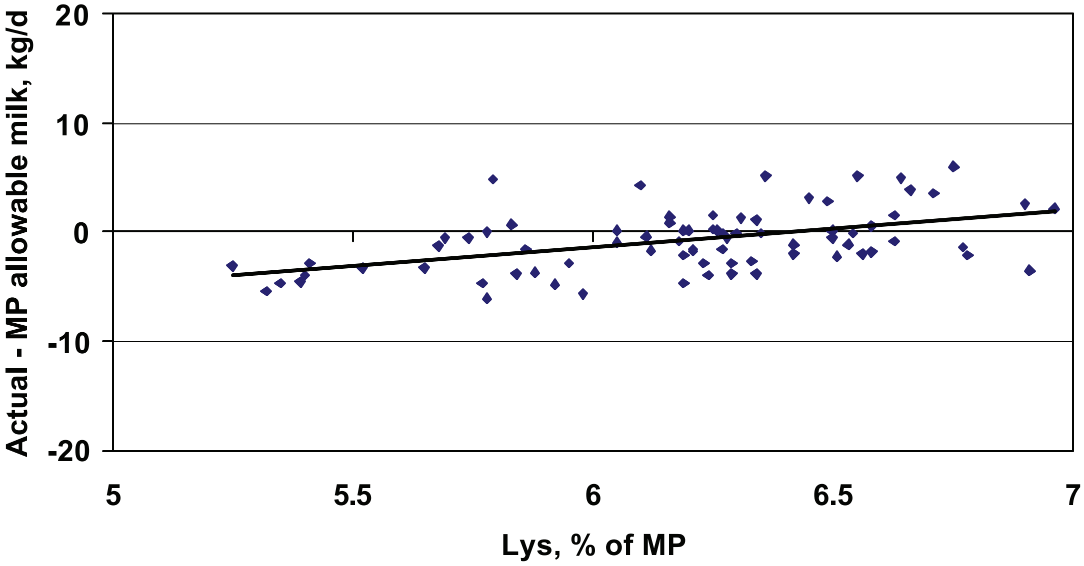

Figure 5. Difference between actual milk and MP allowable milk vs. model predicted Lys concentration of MP ($y = 3.4105x - 21.946$; $r^2 = 0.24$). The data was from 33 experiments involving 77 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was < 3.5/1.0.

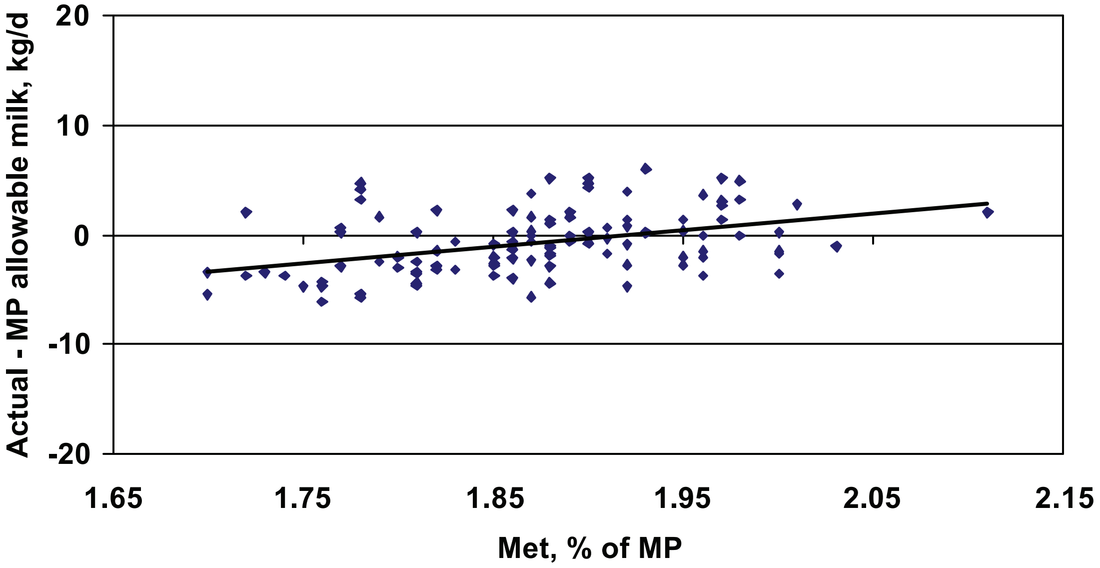

Figure 6. Difference between actual milk and MP allowable milk vs. model predicted Met concentration of MP ($y = 14.835x - 28.534$; $r^2 = 0.16$). The data was from 39 experiments involving 110 diets fed to early and mid lactation Holstein cows. Balance of MP was ± 250 g/d and Lys/Met in MP was > 3.0/1.0.