THE ROLE OF BYPASS PROTEIN IN SUPPLYING AMINO ACID NEEDS OF LACTATING COWS

by

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In 1989 the National Research Council (NRC, 1989) revised its crude protein (CP) based feeding standard for dairy cattle to a system based on estimated absorbed protein. This approach permitted some sparing of protein in formulated diets for lactating cows compared to CP standards but it is probable that more protein could be spared if we were able to balance amino acids (AAs) being absorbed from the small intestine with physiological needs. Determining ruminant AA requirements and how to manage the diet to obtain desired absorption of AAs is extremely difficult because most of the dietary protein is degraded in the rumen and production of ruminal microbial protein alters original diet supply of AAs so greatly . . . and these factors vary with different feed ingredients and diet conditions. The following sections describe the variables accounted for NRC (1989) and attempt to apply nutritional logic based on essential AAs to explain why protein supplements which "bypass" degradation in the rumen sometimes show benefit in diets for lactating cows and sometimes do not.

NRC Protein Calculations

The key components of the NRC (1989) protein system are estimation of microbial protein synthesis in the rumen and ruminally undegraded intake protein (UIP), often called bypass protein, which pass to the small intestine. Specifying needed ruminally degradable intake protein (DIP), including NPN, also is necessary to insure optimal BCP synthesis. Thus the NRC requirements are based on UIP and BCP which is dependent on DIP.

In the flow of dietary crude protein through the rumen, it is suggested that NPN, soluble and intermediate degradable protein are a part of DIP while slowly degraded protein goes with the UIP. Many nutritionists recommend feeding half of the DIP in the diet or 30-35% of the total crude protein as soluble protein with the other half of DIP more slowly degraded. The UIP fraction can be divided into two components, that part digested in the small intestine and an unavailable fraction which contains lignified nitrogen and heat damaged protein which is not available to enzymatic digestion and absorption. The unavailable part can be estimated by analyzing for acid detergent insoluble nitrogen (ADIN).

To decide how much UIP and BCP must be absorbed from the small intestine, NRC builds requirements from equations estimating protein needs for maintenance, metabolic (endogenous) fecal N, and protein in milk. Calculated net absorbed protein requirements are the sum of these individual requirements but total absorbed protein needs must be inflated to allow for something less than 100% metabolic efficiency of the use of absorbed protein. NRC assumes 67% metabolic efficiency for maintenance and 70% for lactation. For a 650 kg cow producing 40 kg milk illustrated below, NRC estimated dry matter intake (DMI) at 22.5 kg. Protein equations used by NRC are:

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Urinary CP (g/day) = 2.75 x $BW(kg)^{0.5}$
e.g. for 650 kg cow, CP (g/day) = 2.75 x $650^{0.5}$ = 2.75 x 25.5 = 70.1 g

Scurf CP (g/day) = 0.2 x $BW(kg)^{0.6}$
e.g. for 650 kg cow, CP (g/day) = 0.2 x $650^{0.5}$ = 2. x 48.7 = 9.7 g

Maintenance protein needs in absorbed CP units = (70.1 + 9.7)/.67 = 119 g

Metabolic fecal protein (g/day of absorbed protein) =.09 x indigestible DM
e.g. for 22.5 kg DMI, .33 indigested =.09 x 22.5 x .33 = .668 kg =668 g

Lactation protein = (milk yield x milk protein %)/(metabolic efficiency)
e.g. 40 kg milk = (40 x .033)/.70 = 1.886 kg = 1886 g absorbed protein

NRC also considers growth and conceptus protein requirements, however, these factors are not considered in this discussion.

To meet the 2673 g absorbed protein needs for the above cow (119 + 668 + 1886), NRC recommends feeding 1331 g UIP and 2254 g DIP (3585 g total protein in 22.5 kg DM = 15.9% protein). Since it is well documented that microbial growth in the rumen and, hence, microbial crude protein production (BCP in NRC notation), is directly related to the fermentable energy available, NRC used Mcal of NE_L as their energy measure. With the NRC equation, BCP was estimated to be 2513 g and 80% was estimated to be true protein. NRC assumed 80% of true protein available in the small intestine is absorbed. Thus:

Absorbed protein = (1331 g UIP) x .80 + (2513 BCP x .80) x .80 = 2673 g

The 2673 g was calculated to equal the total absorbed protein needed which was calculated earlier and 3585 g total dietary protein was the estimated requirement to deliver that amount. If a crude protein standard had been used instead of UIP-based requirements, NRC would have recommended 3809 g dietary protein (16.9 % of dietary DM). Thus, 224 g crude protein was spared by designing the diet to supply minimum DIP for optimum rumen function and minimum UIP to meet remaining needs.

Amino Acid Flow to the Small Intestine

In recent years, research with duodenally fistulated lactating cows which measured the flow of amino acids to the small intestine has given us much better information with which to predict AA absorption. For example, Table 1 shows data from three experiments at the University of Illinois from the laboratory of Dr. J. H. Clark that were obtained from high producing cows eating normal levels of DM. The experiments were designed to test hypotheses that addition of a UIP source, fish meal, should result in a greater flow of AAs to the small intestine and that a rumen inert fat, Megalac, should lower BCP because there would be less fermentable energy available in the rumen for BCP production.

Comparing differences in flow of individual AAs between diets within an experiment shows no trend toward increased AA flow with added or increasing fish meal. Neither, was there clearcut lowering of AA flow due to addition of Megalac even though rumen organic matter (OM) digestibility was lowered by addition of Megalac. This was because microbial growth from Megalac-containing diets was more efficient (more grams of microbial N/kg of digested OM).

Dr. Clark summarized these studies along with many others comparing AA flow to the small intestine with diets of variable UIP in a review paper given at the 1991 American Dairy Science Association meetings (to be published later in the Journal of Dairy Science). He concluded there was very little change in total AA flow because the trend was for BCP AAs to decline as UIP AAs increased. Therefore, the nutritional challenge will be to find how to make dietary changes to assure that BCP production is optimized when UIP is added. However, Cameron et al. (1991) found that added starch to increase fermentable carbohydrate did not result in increased BCP because fiber digestion was depressed thus giving no net change in OM digestion of AAs delivered to the small intestine (Table 1).

Table 1. Diets and amino acids flows to the duodenum.

	From Cameron et al. 1991				From Klusmeyer et al. 1991a				From Klusmeyer et al. 1991b			
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Alfalfa, early	35.00	35.00	35.00	35.00	30.00	30.00	30.00	30.00	30.00	30.00	40.20	40.20
Corn Silage	20.00	20.00	7.50	7.50	20.00	20.00	20.00	20.00	20.00	20.00	26.80	26.80
Corn Meal	39.40	38.65	37.05	36.30	37.67	33.87	40.05	36.05	36.85	33.09	21.55	17.48
Megalac						4.00		4.00		4.00		4.00
SBM(49%)					9.32	10.03	3.97	4.30	10.70	11.39	9.42	10.17
Fish meal	3.00	3.00	5.00	5.00			3.98	4.31				
Urea		0.75		0.75								
Starch or glucose			12.50	12.50								
Minerals	2.60	2.60	2.95	2.95	3.01	2.10	2.00	1.34	2.45	1.52	2.03	1.35
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
MEASURED GRAMS AA DELIVERED DAILY TO DUODENUM WITH DIETS DESCRIBED ABOVE												
Arginine	148	150	153	168	164	151	149	156	170	162	164	146
Histidine	71	71	71	77	69	62	61	63	82	79	79	70
Isoleucine	153	152	149	164	181	166	162	168	171	171	169	150
Leucine	313	319	303	331	326	295	294	297	363	339	347	301
Lysine	211	205	212	237	185	164	164	173	235	230	229	214
Methionine	62	66	65	75	58	51	52	56	61	52	59	47
Phenylalanine	155	156	153	167	185	170	163	168	180	173	177	155
Threonine	155	153	151	169	175	163	156	163	185	173	183	162
Valine	179	179	180	198	217	190	194	199	203	199	198	175
Tryptophan	Not measured											

These actually measured amino acid flows to the small intestine give a basis to which we can compare predicted flows derived using factors from NRC (1989) discussed earlier and estimated AA compositions of UDIP and BCP. AA compositions of feedstuffs were obtained from United States-Canadian Tables of Feed Composition (NRC, 1982). Table 2 shows AA composition for several feedstuffs and the fraction of protein expected to go to UDIP. In order to predict the amino acid flow from UIP to the small intestine, we must decide if we can assume the AA composition of the UIP is the same as the original feedstuff. A study by MacGregor et al. (1978) showed that in some feedstuffs there is a great difference between the amino acid profiles of feed and residues of dacron bags after rumen incubation suggesting difference in AA composition of UIP. Owens (1986) contradicts this by suggesting that the amount of protein escaping degradation contributes more to a variation in flow of amino acids to the small intestine than to true differences in the amino acid composition of the UIP and DIP fractions. Therefore, for our calculations, <u>we have assumed the AA composition of the UIP to be the same as in the feedstuff</u>. However, let us hasten to point out that a great deal of data is being collected by Fox, Sniffen, Chase and others collaborating in contninued development of the Cornell Net Protein System (e.g., Chase, 1991) that will perhaps improve their model through utilization of analyses of UIP.

Table 2. Amino acid composition and estimated UIP of several feedstuffs.[1]

Amino acid	Soybean meal 55.1 CP .30 UIP	Blood meal 87.2 CP .82 UIP	Fish meal 66.7 CP .60 UIP	Whole cotton seed 23.0 CP .35 UIP	Corn meal 10.0 CP .52 UIP	DDGS 25.0 CP .47 UIP	Corn silage 8.6 CP .31 UIP	Alfalfa 20.0 CP .25 UIP
Arginine	7.39	4.07	6.13	11.81	5.40	3.54	11.69	4.50
Histidine	2.45	4.98	2.37	2.39	2.50	2.45	2.53	2.11
Isoleucine	4.95	1.09	4.72	4.35	3.90	4.81	3.01	3.72
Leucine	7.35	12.45	7.33	6.66	11.20	8.55	11.21	6.61
Lysine	6.39	7.94	7.72	5.04	2.40	3.33	5.18	5.00
Methionine	1.43	1.11	2.86	1.91	2.10	2.02	5.30	1.17
Phenylalanine	4.92	6.88	4.03	6.61	4.90	5.39	4.34	4.33
Threonine	3.90	4.46	4.09	4.14	3.90	3.70	4.34	3.67
Tryptophan	1.40	1.22	1.06	1.74	.90	.88	.72	1.33
Valine	5.11	8.16	5.28	5.48	5.10	5.62	5.42	4.89

[1]AA composition is reported as % of CP, adapted from NRC (1982).

Estimation of BCP amount and its amino acid composition are the major variables in estimating AA flow to the small intestine. NRC (1989) predicted BCP based on net energy for lactation (NE_L) which was convenient in their context since NE_L was the basis for their calculation of dietary energy requirements. Conceptually, ruminally fermentable organic matter (OM) is a better predictor of energy available for BCP production. An OM-based equation has the advantage of discounting NE_L in diets that is not available in the rumen, e.g. energy from fat and UIP. Clark et al. (1987) used the following equation allowing for change in 35% digestibility of OM if better information is available for a given ration:

BCP nitrogen = .35 x kg OM x 35 g microbial N/kg OM digested
e.g. with 22.5 kg DMI which is 90% OM
BCP N = .35 x (22.5 x .9) x 35 = 248 g N
= 248 x 6.25 = 1550 g microbial crude protein (BCP)

Note that BCP estimated with this equation was 1550 g while NRC estimated 2513 g. With any of these equations, it is assumed that adequate DIP is present so that energy is the limiting factor for BCP production. In the diets in Table 1, OM digestibility was measured at nearly 40%. Using OM digestibility of 40% in the above equation results in a BCP estimate of 1772 g. It is also possible to adjust the equation above for change in efficiency of BCP production (change in grams microbial N/kg OM digested). However, we have used only 35 g N/kg OM digested in subsequent calculations.

An estimate of AA composition of BCP is now needed. Both bacterial and protozoal fractions of microbial protein have been shown to be fairly consistent in their amino acid profiles. Table 3 shows measured amino acids in both ruminal bacterial and protozoal determined by Meyer et al. (1967), two additional references cited by her, and Poley (1965).

Table 3. Amino acid composition of rumen bacteria and protozoa from four laboratories. (AAs as gravimetric percent of true protein)

Amino acid	Rumen bacterial AA compositions[1]				Rumen protozoal AA compositions[1]			
	A	B	C	Poley	A	B	C	Poley
Arginine	5.93	8.06	7.34	3.76	6.52	7.07	6.81	3.39
Histidine	1.45	2.34	1.97	1.60	1.57	2.07	1.80	1.65
Isoleucine	5.65	3.49	6.11	6.36	6.76	6.86	7.02	7.13
Leucine	7.38	7.49	7.48	7.78	7.73	8.11	8.38	8.77
Lysine	7.95	9.64	7.71	7.32	10.63	10.01	9.81	7.95
Methionine	1.96	2.06	2.84	2.33	1.37	2.27	2.10	1.69
Phenylalanine	4.95	5.20	4.87	5.06	5.62	6.12	6.20	5.86
Threonine	5.69	5.74	5.44	5.88	4.82	5.09	4.70	4.94
Tryptophan				1.34				1.31
Valine	6.58	6.80	6.57	7.07	5.39	5.12	5.06	5.71
Alanine	7.76	6.66	6.27	8.48	4.84	5.17	3.85	5.48
Aspartic acid	12.35	11.53	11.64	12.51	12.74	12.27	12.25	13.24
Glutamic acid	13.51	12.31	13.99	12.46	14.48	12.31	16.02	15.79
Glycine	5.91	6.28	5.71	6.45	4.91	5.00	4.58	4.79
Proline	3.67	4.19	3.61	3.66	3.81	3.61	3.35	4.10
Serine	4.33	3.93	3.80	4.45	4.16	3.60	3.65	4.38
Tyrosine	4.92	4.28	4.65	4.84	4.67	5.34	4.42	5.14
Diaminopimelic				0.75				

[1]Laboratories A, B, and C adapted from Meyer et al. (1967); labs B and C were cited data from Purser and Buechler, J. Dairy Sci. 1966 and Weller, J. Biol. Sci. 10:384. Poley = Poley (1965).

When one considers the differences in experiments reported in Table 3 are not only environment and rations but also differences in species, the similarity in results is remarkable. Laboratory A represent determinations of Meyer et al. using cattle, laboratory B used sheep, C used cattle, and Poley used sheep. There are observable differences, however, between bacterial and protozoal compositions. Within the experiments reported in Table 3, AA compositions from differing diets were also compared and were found to be quite similar. However, the <u>amount</u> of microbial cells produced varied tremendously with diet.

Clark's laboratory (Clark et al., 1987) also reported essential AA composition of microbial cells. Composition is presumed to represent an appropriate mixture of bacterial and protozoal cells and is based on AA's as a percent of microbial crude protein (as opposed to % of true protein in Table 3). Weighted averages of the four laboratories for each AA in Table 4 adjusted to expect 80% of the crude protein to be true protein and weighted to expect that 70% of the microbial protein flowing to the small intestine is of bacterial and 30% of protozoal origin are compared with Clark et al. data below. Also listed is the value we chose for use in estimating AA flow to the small intestine. We made the choice on the basis of which value resulted in predicted AA flows to the small intestine being closer to actual values for the experiments reported in Table 1.

Table 4. Amino acid values chosen for AA model. (AAs as gravimetric percent of crude protein)

Essential AA	From Clark et al. (1987)	Weighted ave. from Table 2	Value chosen for AA model
Arginine	3.84	4.94	3.84
Histidine	1.65	1.46	1.65
Isoleucine	5.22	4.69	5.22
Leucine	7.04	6.19	7.04
Lysine	8.42	6.87	6.87
Methionine	1.67	1.73	1.73
Phenylalanine	4.56	4.23	4.56
Threonine	4.85	4.35	4.85
Tryptophan	-	1.06	1.06
Valine	3.84	5.06	5.06

Applying this information to the diets in Table 1 permits prediction of AA flow to the small intestine. A computer spreadsheet program was developed to do the calculations for the model. AAs from UDIP were estimated with composition data from Table 2 and AAs from BCP predicted using the OM equation with OM digestibility as reported for the actual experiments. AA composition of BCP was from Table 4. Predicted AA flows to the small intestine are in Table 5.

In general, AA flow estimates are relatively close to measured values in Table 1 giving some credence to our ability to predict flows based on predictive equations and estimated compositions. For example, methionine and arginine estimates were quite close to actual flows. Lysine was fairly close on the average but with considerable variation on some diets. However, there is a tendency for the computer model to underestimate more than overestimate as evident from the comparison of the means of predicted values to the means for actually measured values shown in Table 6. Underestimating was greatest for leucine (-21% of actual flows).

Table 5. Predicted AA flows to the duodenum for experimental diets in Table 1. Dry matter intakes, crude protein compositions, and OM digestibilities used in calculations were those reported.

Item	Cameron et al. 1991				Klusmeyer et al. 1991a				Klusmeyer et al. 1991b			
	1	2	3	4	5	6	7	8	9	10	11	12
% CP	15.14	17.17	15.30	17.33	18.00	18.01	18.23	18.26	18.68	18.68	19.54	19.55
% CP as UIP	37.84	33.13	40.25	35.30	32.73	32.26	37.82	37.73	32.53	32.09	30.11	29.65
DMI (lbs)	50.9	50.7	47.6	46.3	55.2	52.4	51.5	49.1	56.1	52.8	54.3	51.3
Rumen OM Dig %	0.47	0.44	0.45	0.47	0.44	0.39	0.44	0.39	0.47	0.39	0.48	0.46
Kg BCP	1.97	1.83	1.75	1.77	1.98	1.62	1.83	1.48	2.17	1.65	2.15	1.87
Kg UIP	1.33	1.31	1.33	1.28	1.48	1.38	1.61	1.53	1.55	1.44	1.45	1.35
G EFP[1]	686	683	642	624	744	706	694	661	756	711	732	691
AP FOR MILK	0.65	0.64	0.65	0.66	0.65	0.61	0.67	0.64	0.67	0.62	0.66	0.64
GRAMS AA DELIVERED TO DUODENUM												
Arginine	154	147	142	140	169	150	169	151	182	155	176	159
Histidine	64	61	60	59	68	59	68	61	73	61	69	62
Isoleucine	155	147	146	145	163	140	161	140	176	145	170	151
Leucine	256	245	236	233	270	235	269	236	289	241	273	242
Lysine	198	188	189	188	203	175	207	182	220	181	219	196
Methionine	63	61	59	58	62	54	67	60	66	55	65	58
Phenylalanine	149	142	138	137	159	138	156	136	172	143	165	147
Threonine	147	140	137	136	153	132	152	132	165	136	160	143
Tryptophan	35	33	33	33	38	33	37	32	41	34	40	36
Valine	167	160	157	155	175	152	175	154	188	157	182	163

[1]EFP = endogenous (metabolic) fecal protein

Table 6. Comparison of predicted AA flows in Table 5 with actual AA flows from Table 1.

Amino acid	Actual flows avg. g/day	Predicted flows avg g/day	Predicted % change from actual
Arginine	156.8	157.8	+.6
Histidine	71.2	63.8	-10.7
Isoleucine	163.6	153.5	-5.8
Leucine	319.0	252.0	-21.0
Lysine	204.9	195.5	-4.6
Methionine	58.7	60.6	+3.4
Phenylalanine	166.8	148.5	-11.0
Threonine	165.7	144.5	-12.8
Tryptophan	-	35.4	
Valine	192.6	165.4	-14.1

Abomasal Infusion or Feeding of Rumen Protected AAs

Before expanding the computer model a step further to predict AA deficiencies, it is important to review data which directly attempted to measure which AAs are most limiting for milk production. Schwab et al. (1976) concluded from research infusing amino acids into the abomasum of lactating dairy cows receiving low-protein diets based primarily on corn that lysine and methionine were the first and second limiting amino acids, respectively. Total grams of milk protein secreted was the most sensitive measure of response because it combines the responses in milk protein percent and milk yield. Lysine and methionine accounted for 43% of the response obtained from infusing all 10 essential AAs or sodium caseinate. Of the remaining amino acids, either threonine or isoleucine emerged as possible third limiting.

King et al. (1991) infused lysine abomasally up to 180 g/day and concluded using break-point analysis of plasma free lysine that 64 g/day of abomasal lysine was needed to satisfy the requirements of cows producing about 30 kg milk/ day. They comment that:

> "the most sobering aspect of this research is the observation of a low incremental production response (low efficiency) to limiting AA supplementation in lactating cows. This observation is in stark contrast to the immediate, sizeable growth response noted in AA supplementation studies with rapidly growing laboratory rodents, suggesting either the classical explanation that there may be other essential AAs either colimiting or first limiting or that the net efficiency of absorbed AA use for productive purposes in animals fed high protein diets is lower."

Their estimated efficiency of conversion of apparently absorbed lysine to milk lysine was about 40% at the 64 gram break-point while the assumed efficiency used by NRC and used in our predictions for all AAs is 70%.

Testing the hypothesis that lysine and methionine are limiting AAs in cows receiving high-corn diets was done in an extensive study combining results from a common experimental design used by six universities (Polan et al., 1991). Ruminally protected lysine and methionine were fed in diets where 50% of total DM was from corn silage, plus ground corn and either soybean meal or corn gluten meal. The soybean meal supplemented diet was the positive control. Corn gluten meal (CGM) diets were either control, CGM + methionine (15 g/day in early lactation), CGM + methionine + lysine (20 g/day in early lactation), or CGM + methionine + double lysine. Levels in mid-lactation and late-lactation were 80% and 60% of early lactation. There was a response to lysine in milk yield, milk protein percent, and milk protein yield within the CGM diets with the effect mostly occurring with the first level of lysine (20 g/day). There was no apparent effect due to added methionine. Production obtained from the soybean meal diet exceeded CGM diets regardless of AA supplementation.

We can conclude that lysine and perhaps methionine may limit milk production in high-corn diets. Beyond that it is difficult to determine any specific AA that may be limiting. It is more probable that response comes to improved availability to all essential AAs rather to a single AA.

Predicting AA Availability for Milk Production

In search of a method to compare AA adequacy of different diets, it is of interest to extend the computer model used earlier to predict AA flow to the small intestine to consider AA absorption and amount available for milk production.

We estimated absorbed AA's by assuming 80% absorption of AAs delivered to duodenum. A fraction of absorbed AAs presumed available for milk production was calculated: component requirements of absorbed protein for maintenance (urinary plus scurf protein) and endogenous fecal protein were subtracted from the total absorbed and this amount divided by the total absorbed. For example, suppose we are feeding 22.5 kg of diet DM to the 650 kg cow used in earlier equations to illustrate NRC calculations which is 16% CP of which 35% is UIP. Thus, UIP g = 25 x .16 x .35 x 1000 g/kg = 1400 g. If 80% is digested, absorbed UIP = 1400 x .80 = 1120 g. For BCP = 1550 g (from OM based example earlier), NRC estimates that 80% is true protein and 80% is digested so absorbed protein from BCP = 1550 x .80 x .80 = 992 g. The total absorbed protein is 1120 + 992 = 2112 g. Maintenance protein was 119 g and endogenous fecal protein was 668 g leaving 1325 g available for milk or 1325/2112 = .63, or 63%.

Calculated quantities of absorbed AAs available for milk production were divided by the amount of absorbed AA necessary for each lb of milk giving an estimate of the pounds of milk which could be supported by a particular AA. NRC (1982) tables were referenced for AA composition of nonfat, dried skim milk, and these values applied to an assumed 8.5% solids-not-fat content of Holstein milk with 3.3% protein. AA content of one pound of milk was divided by .70 (assumed metabolic efficiency of absorbed AA's) to estimate absorbed AA necessary per lb of milk. Table 7 shows predicted milk supportable by predicted AA flows.

Table 7. Estimated pounds of milk which could be supported by each AA after maintenance and endogenous fecal protein needs were subtracted. Predictions related back to diets shown in Table 1 and were derived from predicted AA flows shown in Table 5.

	Cameron et al. 1991				Klusmeyer et al. 1991a				Klusmeyer et al. 1991b			
Item	1	2	3	4	5	6	7	8	9	10	11	12
Arginine	118	111	109	108	129	109	133	114	143	114	138	121
Histidine	66	61	62	61	69	58	72	61	76	60	73	63
Isoleucine	63	59	60	60	66	54	68	56	74	57	71	61
Leucine	69	64	63	63	72	59	74	62	79	62	74	64
Lysine	69	64	66	66	71	58	75	63	79	61	78	68
Methionine	62	58	58	57	61	50	68	58	67	52	65	56
Phenylalanine	85	79	79	79	90	74	91	76	100	78	96	83
Threonine	84	78	78	78	86	70	88	74	96	74	92	80
Tryptophan	72	67	68	67	77	64	78	66	86	67	84	73
Valine	65	61	61	61	68	56	70	59	75	58	72	62

The purpose of these calculations was to make relative comparisons regarding the effect of UIP supplements on AA's available for milk production. For example, in the diets above, less milk production was predicted to be supported by available methionine than any other AA but several other AAs were not very different. Even though isoleucine, leucine, and valine appeared marginal based on AA availability for milk production, the model previously underestimated actual flows of these AAs to the small intestine (Table 6). The addition of fish meal had a small positive effect on the estimated milk production possible from available methionine (7-8 lbs., diets 7 and 8 versus 5 and 6). There was no difference in experimentally measured flows to the small intestine (Table 1).

Absolute numbers probably are less meaningful since supportable production levels suggested for several of the AAs are much less than the 79 lb/day average production achieved across the three experiments reported in Table 1.

Responses to UIP Supplementation Compared to Predicted AAs

Although we are not including a review of research publications that have tested UIP supplementation, suffice it to say results are variable. It appears that UIP supplementation with supplements like fish meal or blood meal tend to be more likely to give a response with alfalfa-based diets than with corn silage-based diets. An example from a recently completed experiment at the University of Florida with corn silage-based diets is shown in Table 8 (Tomlinson, 1992, diets 1 to 4). In these four diets, blood meal supplementation was compared with soybean meal at two levels of dietary protein. Slightly more milk yield was obtained with 18% crude protein diets than 14.7% but there was no difference between blood meal and soybean meal diets. Estimated lysine flow to the duodenum was higher with blood meal, particularly at high protein, as reflected in the somewhat higher predicted supportable milk yield (71 lbs/day) but there was no difference in measured milk yields.

In alfalfa diets formulated as closely possible from information in the abstract (Berzaghi and Polan, 1991), the milk yield response to UIP from fish meal was particularly evident (63.3 lbs/day versus 58.4 for the soybean meal supplemented control). Corn gluten meal also tended to give a response but not as great as fish meal. Broderick (1991) also reported significant increases in milk yield with fish meal supplementation of similar, alfalfa-based diets. Looking at "Predicted Lbs Milk Supported" shows more of all AAs were estimated to be available for milk with diets supplemented with corn gluten meal and fish meal. However, this was also true with blood meal-supplemented corn silage diets, particularly at high protein (diets 2 versus 4, Table 1) where no milk yield response was found.

Conclusions

1. NRC's shift to calculating protein requirements based on absorbed protein which includes UIP and BCP was conceptually well founded and permits some sparing of dietary protein compared with a crude protein standard.

2. Much good data is accumulating on measured AA flows to the duodenum of high producing dairy cows with various types of diets.

3. AA flow to the duodenum seems to be predictable. The simple model utilized in this paper demonstrates that but it needs further development.

4. Lysine has been identified and the most limiting AA in high corn diets.

5. Response to methionine, perhaps second limiting, is difficult to demonstrate.

6. Response to protein or AAs by lactating cows is often subtle, not as dramatic as supplementation of limiting AAs to growing poultry or laboratory rodents.

7. Milk yield response to feeding UIP often is small or none in corn silage based diets supplemented. UIP response is more easily demonstrated in high alfalfa diets where smaller amounts of supplemental protein are added.

8. A preliminary conclusion regarding the AA model developed in this paper is that it was not helpful in predicting actual performance. More questions were raised than answered. For example, if AA flows to the duodenum are similar, how can production differ due to protein nutrition? Would it be because absorption percents differ? Was the assumption that maintenance and endogenous fecal protein needs must be met first incorrect? Was assumed metabolic efficiency of 70% too low? Why did the model underpredict duodenal flows of leucine so greatly (-21%)? etc., etc.

Table 8. Comparison of milk yields obtained in experiments testing UIP supplementation with Predicted Lbs Milk Supported by individual AAs.

	From Tomlinson, 1992				Adapted from: Berzaghi and Polan (1991)		
Ingredients	1	2	3	4	5	6	7
Corn silage	50.00	50.00	50.00	50.00			
Corn meal	27.98	20.77	32.05	26.27	39.15	40.85	40.95
Whole cottonseed	8.00	8.00	8.00	8.00			
Blood meal			2.39	4.63			
SBM(49%)	10.86	18.22	3.84	8.20	6.40		
Corn gluten meal						4.10	
Fish meal							4.00
Alfalfa, early					52.60	52.60	52.60
Urea			0.50	0.36			
Minerals	3.16	3.01	3.22	2.54	2.45	2.45	2.45
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00
% CP	14.67	18.01	14.70	18.08	17.42	17.36	17.57
Milk yield (lbs/day)	59.8	60.5	59.1	61.2	58.4	60.4	63.3
PREDICTED LBS MILK SUPPORTED BY:							
Arginine	106	122	110	135	92	96	106
Histidine	49	56	64	89	53	60	61
Isoleucine	47	52	46	53	51	56	58
Leucine	52	56	62	79	55	70	62
Lysine	51	58	57	74	54	54	63
Methionine	49	53	52	61	42	52	54
Phenylalanine	65	72	76	98	70	82	78
Threonine	62	68	68	84	66	73	75
Tryptophan	54	62	59	75	61	63	68
Valine	48	53	57	74	52	58	60

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