



Strategies to Reduce the Crude Protein (Nitrogen) Intake of Dairy Cows for Economic and Environmental Goals.

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Disclaimer

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Introduction

This fact sheet has been developed to support the implementation of the Natural Resources Conservation Service Feed Management 592 Practice Standard. The Feed Management 592 Practice Standard was adopted by NRCS in 2003 as another tool to assist with addressing resource concerns on livestock and poultry operations. Feed management can assist with reducing the import of nutrients to the farm and reduce the excretion of nutrients in manure.

Of the nitrogen (N) fed to dairy cows, only 21 to 38% actually is exported as milk or meat. That means 62 to 79% of the N fed to cows is for the most part excreted via urine and feces of cows. Most N voided in urine is quickly emitted as ammonia whereas the percent of fecal N converted to ammonia is quite variable depending upon storage management and land application method. Because most N consumed in excess of requirement is excreted in urine, to improve efficiency of N use, urinary N needs to be reduced. Changes in diet formulation can improve efficiency of N use on dairies.

Definitions:

N = nitrogen; CP = crude protein = N X 6.25; NPN = nonprotein N; TDN = total digestible nutrients; RDP = ruminally degraded protein; LYS = lysine; MUN = milk urea N; MCP = microbial crude protein; RUP = ruminally undegraded protein; MET = methionine; FCM = fat-corrected milk; IOFC = income over feed costs

Historical Diet Formulations For Cows

Protein nutrition of dairy cows has evolved over the decades. Initially, the approach was to determine the % or amount of dietary CP that cows needed for milk production. However, any CP consumed in excess of the cows' requirements is excreted via urine. Thus, by feeding the cow to meet, and not exceed, her CP requirement, N excretion is reduced. The major weakness of formulating diets on a CP basis is that it ignores the type of CP consumed. For example, under this system all N in NPN sources (urea for example) is treated the same as the N in soybean meal, and clearly they are much different. The N in NPN does not include long chains of amino acids in the form of "true" protein whereas most of the N in soybean is amino-acid bound. Therefore, soybean meal contributes amino acids to both the ruminal microorganisms and to intestinal amino acid absorption whereas NPN contributes only to the latter (**Figure 1**).

The goal of feeding protein to lactating cows is to support milk protein synthesis while meeting the needs for maintenance, growth and replacement of lost body protein. All proteins synthesized in the body have set amino acid patterns, so if a particular amino acid is lacking during protein synthesis, formation of that protein stops. Thus, we are not really trying to supply dietary protein to cows, we are trying to supply enough of each amino acid such that no single amino acid limits protein synthesis.

Another approach to improve upon balancing diets on a CP basis was the Burrough's metabolizable protein system (Burroughs et al., 1975). This system considered the amount of dietary N that was solubilized in the rumen and

could be used for microbial protein synthesis, a calculation that also involved the amount of TDN available to support microbial growth. To the calculated microbial protein was added the amount of dietary protein that escaped ruminal degradation. Use of ammonia and fermentable carbohydrate for microbial protein synthesis is illustrated in **Figure 1**. Finally, adjustment factors for digestibility and unavoidable fecal losses were applied to yield a Metabolizable Protein value. This system required knowing the amount of protein in feeds that was converted to ammonia in the rumen, the amount of feed protein that escaped ruminal breakdown, and the TDN value for the feeds. The concept was excellent but the system needed refinement.

The amount of dietary protein that is degraded in the rumen is primarily determined by characteristics of the N-containing compound (e.g., solubility and linkages) and how long it resides in the rumen (**Figure 1**). Residence time in the rumen, i.e. ruminal passage rate, is determined by total feed intake (the more the cow eats the faster the feed tends to move through the rumen), particle size and specific gravity (smaller, heavier particles move faster than large, light particles through the rumen), and other factors such as how quickly the microbes ferment the feed. Certain feeds are fermented faster than others (barley is fermented faster than sorghum), and feeds can be treated to reduce their rate of protein breakdown (most treatments involve lowering the protein solubility). Obviously the calculations to determine the amount of dietary protein that is degraded, or conversely undegraded, in the rumen get complicated, hence computer models tremendously speed the calculations.

Current approaches to meeting the amino acid needs of cows

First, we try to maximize microbial protein synthesis in the rumen. Microbial protein is high in LYS, and LYS is often the most limiting amino acid for milk production in feeding situations commonly found in the confined operations. Maximizing microbial protein synthesis involves supplying fermentable carbohydrates and soluble N sources to enable rapid bacterial growth. We need ammonia and other forms of soluble N to be available to the bacteria simultaneously with the fermentation of the carbohydrates so the bacteria have everything they need for growth, which includes protein synthesis (**Figure 1**). If the N is solubilized and degraded too quickly, much is absorbed as ammonia and subsequently excreted as urea N in urine or MUN. If too little N is solubilized in the rumen, the ammonia concentration in the ruminal fluid is too low to maximize microbial protein synthesis (Stokes et al., 1991; Clark et al., 1992). Generally, the amount of fermentable carbohydrate in the rumen is most limiting to microbial protein synthesis. Hence, the NRC (2001) predicts the yield of MCP as $0.13 \times \text{TDN (discounted)}$, i.e., 130g MCP/kg of TDN (discounted) when RDP exceeds $1.18 \times \text{MCP yield}$. If the RDP intake is $< 1.18 \times \text{TDN predicted MCP}$, then MCP is 0.85 of RDP intake. Thus, if a cow consumes 15 kg of TDN (discounted), MCP flowing to the intestine is estimated as: $15 \times 0.13 = 1.95 \text{ kg}$.

Secondly, diets are formulated to supply amino acids for milk production by including dietary proteins that will not be completely degraded in the rumen and have a high content of the amino acids believed to be most limiting for milk production. Some feed proteins have relatively high LYS concentrations (porcine blood meal), some have relatively high MET concentrations (corn gluten meal), and some have a good balance of LYS and MET (fish meal). Thus, diets contain multiple proteins, all of which degrade at different rates in the rumen. In addition, the ruminal degradation rates for the 20 amino acids found in proteins vary substantially. Fortunately, all these data are contained in software programs so the estimated flow of feed amino acids into the small intestine is quickly calculated. Use of computer models allows us to take advantage of complementary protein and other N sources to achieve lower CP diets to achieve comparable milk yields.

Case I. Using RDP/RUP feed data to achieve diets with a lower % CP.

Reynal and Broderick (2005) fed four diets that varied in RDP. Their diet description and results are given in **Table 1**. Urinary N excretion decreased about 60 g/cow/day as the % CP and % RDP decreased in the diet, however, the % milk protein also decreased. Their data suggest 11.7% RDP in ration DM as the best compromise between profitability and environmental quality.

Table 1. Effect of Percent Ruminal Degradable Protein on Dietary Components and Cow Responses

	Dietary Treatments			
	A	B	C	D
CP, %	18.8	18.3	17.7	17.2
RDP, % DM ¹	13.2	12.3	11.7	10.6
RDP, % of CP	70.2	67.2	66.1	61.6
RDP, % DM ²	12.5	10.9	9.2	7.7
RUP, %DM ¹	5.8	6.2	6.0	6.6
RUP, % of CP	30.8	33.9	33.9	38.4
RUP, %DM ²	6.3	7.4	8.5	9.5
NE _L , ² Mcal/lb DM	0.709	0.704	0.704	0.704
3.5% FCM, lb/d	93.1	94.2	93.3	91.3
Milk true protein, %	3.14 ^a	3.14 ^a	3.07 ^b	3.04 ^b
MUN, mg/dL	15.9 ^a	15.6 ^a	13.6 ^b	12.8 ^b
BUN, mg/dL	13.8 ^a	14.0 ^a	11.8 ^b	12.4 ^b
Ruminal NH ₃ -N, mg/dL	12.33 ^a	11.76 ^a	8.68 ^b	5.71 ^c
Urinary N excretion, g/d	295 ^a	293 ^a	237 ^b	239 ^b
Fecal N excretion, g/d	222	220	219	197
N Efficiency				
Milk N, % of N intake	29.6	29.5	30.4	30.4
lb of milk/lb of N excreted	84.5 ^a	87.2 ^a	94.3 ^b	99.8 ^b

¹ Measured in vivo.

² Predicted by NRC (2001) model.

^{abc} Means within the same row without a common superscript differ P < 0.05.

Case II. Formulations using RUP/RDP and specific amino acids to reduce CP intake. This concept applies RDP/RUP in predicting amino acid flows to the small intestinal tract, then adding specific amino acids to meet the cow's requirements. The advantage is to reduce total N intake and hence, N excretion, while reducing total feed costs. Examples of using amino acid formulation to reduce CP and maintain milk yield are given below.

Example 1. VonKeyserlingk et al. (1999) formulated two diets for cows that were primarily in early lactation. The control diet was formulated according to the 1989 NRC recommendations. A second diet was formulated with the CNCPS system and included a commercial protein source and intestinally available MET source. Using a commercial protein source and "rumen by-pass" MET allowed the CP level in the grain mix to be reduced by 2.9% units and total TMR by 1% unit (Table 2).

Table 2. Diets formulated using NRC (1989) guidelines or CNCPS program.

Item	NRC (1989)	CNCPS
CP, % DM	18.7	17.7
ADF ¹ , % DM	21.1	21.8
NE _L , Mcal/lb	0.82	0.86

¹Acid detergent fiber

No difference was observed in DM intake or milk production between cows fed the diets formulated by the two methods (**Table 3**). The authors concluded that the CNCPS afforded the

opportunity balance rations for reduced CP level without loss in milk production.

Table 3. Performance of dairy cows fed rations formulated by NRC (1989) guidelines or CNCPS formulation program.

Item	NRC (1989)	CNCPS
All cows		
DMI, lb	47.4	46.6
Milk, lb	82.8	81.5
Multiparous Cows		
Milk, lb	96.5	94.3
Milk fat, %	2.88	3.12
Milk protein, %	3.12	3.11
Primiparous Cows		
Milk, lb	69.0	68.8
Milk fat, %	3.17	3.31
Milk protein, %	3.22	3.20

Example 2. Harrison et al. (2000) used the CPM (Cornell, Penn State, and Miner Institute) model to formulate two diets containing undegraded protein sources in the form of canola derivative or animal-marine blend. Each of these diets was estimated to be slightly deficient in LYS and MET. Two additional diets were formulated that were supplemented with a MET source and free LYS-HCl to improve the dietary supply of MET and LYS. The postpartum levels of MET and LYS in the non-supplemented diets were targeted to be at ~ 100% of the requirements (1.9% MET/MP and 6.4% LYS/MP) and 116% of MET (2.2% MET/MP) and 106% of LYS (6.6%

LYS/MP) for supplemented diets. When formulating the diets, it was considered that 20 g of the commercial MET source provided 7 g of ruminal escape MET (Koenig et al.,1998) and 40 g of free LYS-HCl provided 8 g of ruminal escape LYS (Velle et al., 1998). Cows were fed the experimental diets from ~28 days before calving through week 17 postpartum. At 9 weeks post-partum, cows received rBST per label.

There tended to be increased yield of 3.5 FCM for cows fed the diet containing animal-marine bypass protein (**Table 4**). In early lactation, and at 14 to 17 weeks of lactation, there was an improvement in milk that appeared to be related to

supplemental MET and LYS-HCl. In the early weeks of lactation (weeks 1 to 4) the MET supplemented cows fed the animal-marine blend protein source diet produced the most milk. After the beginning of rBST use (week 5), cows fed both un-supplemented diets (canola derivative and the animal-marine blend) produced more milk when supplemented

with MET and LYS-HCl. A trend ($P < 0.14$) was observed for increased milk fat percentage when the diets were supplemented with MET and LYS-HCl. These observations support the use of supplemental MET and LYS particularly during the critical need periods of early lactation and post rBST administration.

Table 4. Performance of cows fed diets containing supplemental sources of rumen undegraded amino acids.

Item	Treated canola protein	Treated canola protein + Lys & Met	Animal-marine blend protein	Animal-marine blend protein + Lys & Met	<i>P</i> <		
					Protein	Supplement	Protein x Suppl
DMI, lb	48.2	48.0	48.8	47.7	NS	NS	NS
Milk, lb	85.4	85.6	87.1	87.3	NS	NS	NS
3.5FCM, lb	86.9	87.6	89.3	91.1	0.08	NS	NS
Milk fat, lb	3.08	3.12	3.19	3.28	0.03	NS	NS
Milk fat, %	3.65	3.71	3.68	3.80	NS	0.14	NS
Milk protein, %	3.09	3.13	3.12	3.36	NS	NS	NS
Milk protein, lb	2.62	2.62	2.68	2.86	0.22	NS	NS

Case III. The importance of formulating for desired ratios of MET to LYS.

In another study (Harrison et al., 2003), researchers employed the CPM formulation model to reduce dietary CP from 18% to 16% by replacing alfalfa silage with corn silage and undegraded protein sources (Tables 5 & 6). Diet #3 was predicted to have the best ratio and

supply of MET and LYS, and resulted in the highest milk yield, and ratio of milk true protein to diet protein (Table 7). The reduced milk yield of cows fed diet #2 emphasizes the need to ensure the ratio of LYS to MET is ~ 3.2 to 1. Total N import (as feed N) onto the dairy was reduced by nearly 9% and IOFC was increased 6.5% by diet #3.

Table 5. Chemical Analysis of Total Mixed Rations (% DM)

Item	Diet 1	Diet 2	Diet 3	SE
CP	18.6	16.0	16.0	0.35
NDF ²	38.9	41.2	44.7	1.88
Soluble CP	7.53	5.1	5.4	0.38
Soluble CP, % of CP	40.5	31.9	33.8	
NFC ³	31.9	34.4	30.7	2.16

²Neutral detergent fiber

³Nonfiber carbohydrate

Table 6. Diet Formulation Results from CPM

Item	Diet 1	Diet 2	Diet 3
Lysine, % required	89	99	116
Methionine, % required	91	116	109
Ratio of Lys/Met	3.32	2.89	3.16
MP ¹ balance, g	-477	-104	-117

¹Metabolizable protein

Table 7. Response of cows to diets that differ in crude protein and ratio of lysine to methionine

Item	Diet 1	Diet 2	Diet 3	SE	P <
DMI, lb	44.9	45.1	45.1	2.97	NS
Milk, lb	78.8	77.9	82.5	5.10	NS
Milk Fat, %	3.80 ^a	3.24 ^b	3.79 ^a	0.151	0.01
Milk Protein, %	3.08	3.08	3.07	0.071	NS
MUN, mg/dL	18.8 ^a	13.0 ^b	14.4 ^b	0.92	0.01
CP Intake, lb/d	8.34	7.22	7.22		
Milk True Protein/Feed CP	0.29	0.33	0.34		
Reduction in CP imports, %	----	8.6	8.6		
IOFC ¹ , \$/d/cow	5.49	4.64	5.85		

¹Income over feed costs

Case IV. Impact of reduced dietary % CP on N excretion on a commercial dairy. A field study (Harrison et al., 2002) was conducted with a high producing herd to compare the general herd diet formulated at ~18% CP to a diet that was reformulated at ~17% (Table 8). Milk production was

maintained while N imports to the farm (Tables 9 & 10) were decreased. In addition, the reformulated diet increased IOFC (Table 11). These results agree with those of Wattiaux and Karg (2004) who reported a 16% drop in urinary N when a diet with 18% CP was reformulated to 16.5% CP.

Table 8. Chemical compositions of a control diet and a reformulated diet containing supplemental amino acids

Item	Control	Reformulated
CP, % DM	17.8	17.0
Soluble Protein, % DM	6.4	6.0
Soluble Protein, % CP	35.7	37.0
NDF ¹ , % DM	32.4	32.7
NFC ² , % DM	39.0	39.8

¹Neutral detergent fiber

²Nonfiber carbohydrate

Table 9. Treatment response to a diet reformulated on the basis of metabolizable methionine and lysine

Item	Control	Reformulated	SE	P <
DMI, lb	56.7	55.2		
CP Intake, lb	10.1	9.4		
Milk, lb	99.9	101.9	0.53	0.007
3.5FCM, lb	96.0	96.6	0.46	0.32
Milk fat, %	3.28	3.21	0.014	0.001
Milk protein, %	2.90	2.93	0.006	0.0009
MUN, mg/dL	17.5	14.5		
Milk True Protein: Intake Protein Ratio	0.285	0.316		

Table 10. Effect on nitrogen excretion when a diet was reformulated on the basis of metabolizable lysine and methionine

Item	Control	Reformulated	% Change
N intake, g/d	734	680	-7.4
Milk total N, g/d ¹	240	246	+2.5
Predicted Urinary N, g/d ²	289	239	-17.3
Calculated Fecal N, g/d ³	205	195	-5.0

¹(Milk True Protein/6.38) X 1.17

³Fecal N = Intake N – Milk N – Urine N

²Urinary N (g/d) = 0.026 x BW(kg) X
MUN(mg/dL); J Dairy Sci. 85:227-233.

Table 11. Economic impact of reformulating a diet on the basis of metabolizable lysine and methionine

Item	Control	Reformulated
Feed Costs, \$/d/cow	4.82	4.88
Milk Income, \$/d/cow	11.92	12.10
IOFC ¹ , \$/d/cow	7.10	7.22

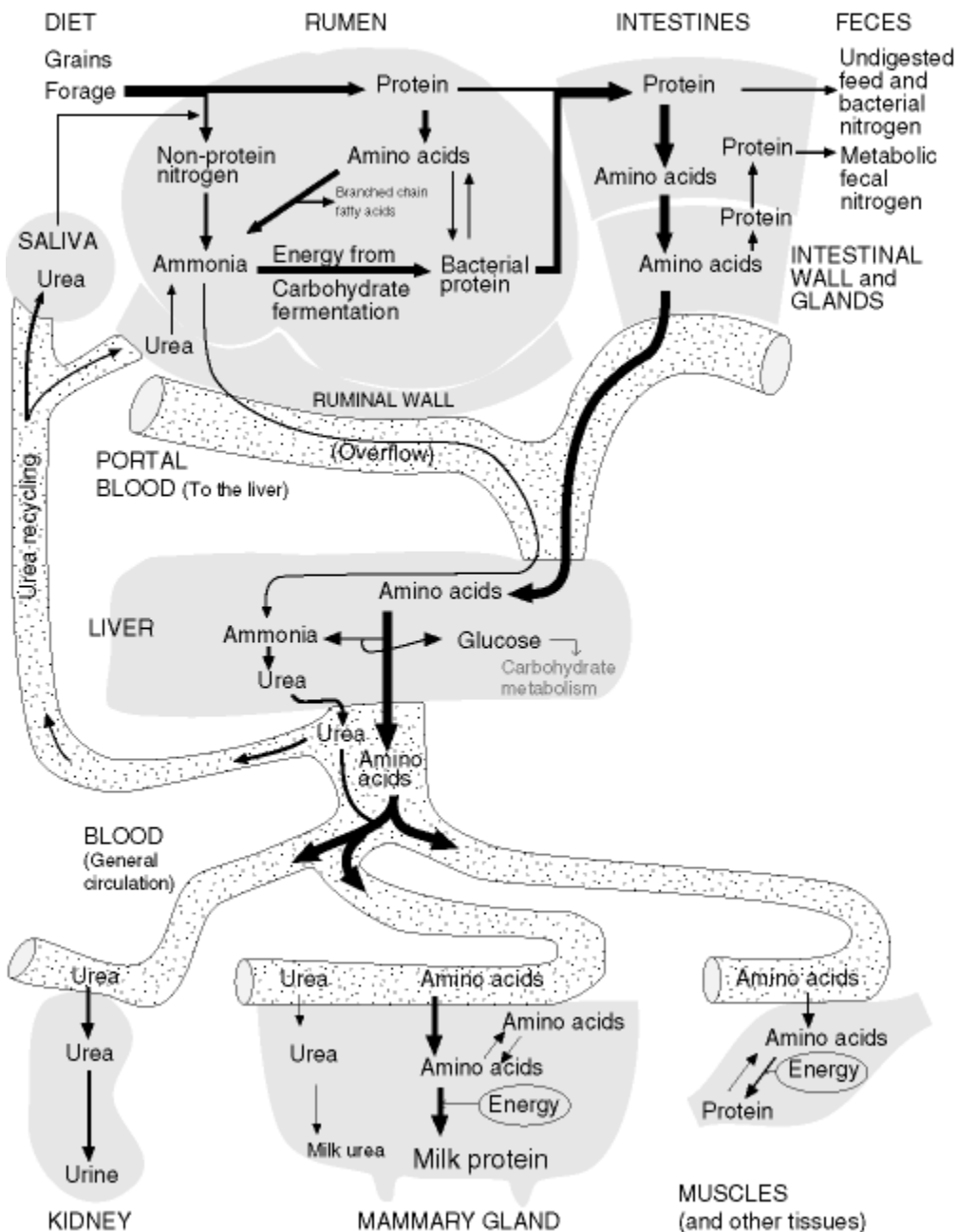
¹IOFC = Income over feed costs

Summary

Reducing CP intake of high-producing cows can be achieved by strategic use of undegraded protein sources and amino acids (LYS and MET) under a variety of diet conditions. Diet reformulations can reduce N excretions by ~10% without negatively affecting milk yield or IOFC.

These successes require the use of ration balancing software that estimate the amino acid (MET and LYS especially) needs of the lactating cow. Use of undegraded protein sources that have dependable concentrations of amino acids is critical to achieve consistent production responses.

Figure 1. Protein metabolism in dairy cows. Microbial protein synthesis requires dietary energy and ammonia. The diet supplies both true protein and nonprotein nitrogen (NPN) to the ruminal ammonia pool. Ammonia not used for microbial protein is excreted as urea in the urine (Wattiaux, 1998).



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