How Do the New Protein Rules Affect What We Feed?

Paul T. Chandler, Ph.D.
Chandler & Associates, Inc.
Dresden, TN 38225

Introduction

Dairy producers and their practicing nutritionist always have questions and ideas relating to the protein nutrition of the milking cows. Rations are demanded that produce acceptable amounts of milk and profits must be achieved. Efficiency must be evaluated in terms of nutritional, environmental, and economical aspects. Nutritional response curves from reliable sources suggest that milk yield is optimized at crude protein (**CP**) levels beyond 20% of the dry matter (**DM**). The use of special processed protein products and marine and animal sources seem to be needed at times. But other factors must be considered in that the cost of the final protein unit may not be covered by the marginal amount of production and from an environmental aspect this amount of protein feeding may not be acceptable. It is also critical that protein nutrition be compatible with animal health and within the rules established for the industry.

Within the industry today there are people that have questions with respect to the types of proteins to feed to dairy cattle. On June 5, 1997, FDA published a final rule prohibiting the use of mammalian protein (i.e. animal protein products, such as meat and bone meal) in ruminant feeds. Mammalian protein is defined as protein from mammals, but excludes porcine (pork) and equine (horse) protein from single-species slaughter plants.

There was an interim ruling proposed by the FDA in January, 2004 that prohibits the feeding of bovine (cattle) blood in ruminant feeds. However, to date, there have been no further rules published by FDA prohibiting the use of mammalian proteins in ruminant feeds (AFIA, 2004).

Protein nutrition, as presented in NRC, 2001, is extensive and very much research driven. Protein requirements for milk production are described by two response surface equations, derived from large groups of lactation data representing many published peer reviewed studies. It is appropriate that we study these relationships in detail to gain a better understanding of how to feed our milking cows under these guidelines.

Milk Yield, Dry Matter Intake and Crude Protein

Lactation response to CP is derived from a data set of 393 means from 82 protein studies. The studies were published from 1983 to 2000, with the vast majority appearing in the early to mid 1990's. The derived equation and appropriate statistics from the data set are presented in Table 1. Now these are excellent studies to direct our protein feeding guidelines (Milk Yield = 69 pounds, Dry Matter Intake (**DMI**) = 44.4 pounds, and CP at 17.1% of DM, with rumen degradable protein (**RDP**) and rumen undegradable protein (**RUP**) at 63 and 37 % of CP), but the r^2 was only .29. Even though the relationship is statistically significant and based on a valid data set, it must be recognized that something else is influencing 71% of the variation. This can cause problems at times because we may find situations where we do not expect the performance as observed and we question the validity of our feeding model. It should be noted that the feed efficiency from this data set is 31.4 kg milk to 20.2 kg DM or 1.55 to 1. The protein efficiency is 972/(20.2 x 1000 x 0.171) = 28.1%. This relationship is presented in Figure 1. As noted from the equation and the figure the response to DMI is linear and some declining response is present for CP.

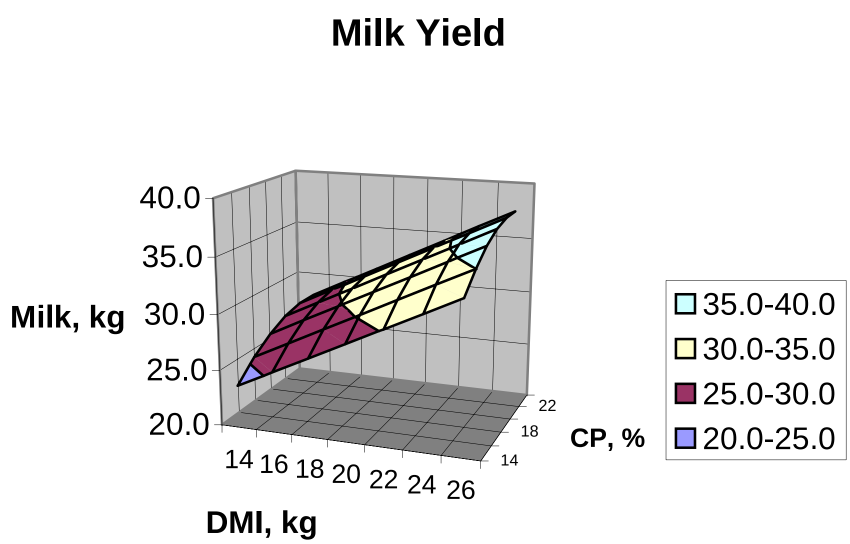

Figure 1. Milk yield in response to dry matter intake (DMI) and crude protein (CP).

It is possible to evaluate this equation with respect to the first derivative to determine the marginal returns to protein feeding (Table 2). At a specific level of DMI the cows responded to increasing dietary CP up to 23% of the DM. Protein content was 63% RDP and 37% RUP. At each percentage increment of protein with a 20 kg DMI we are adding 200 grams of protein and milk response is initially 850 g, but declines to zero by the time the protein level exceeds 23%. Milk response to each percentage unit of protein initially approaches 3%, but then declines in a linear fashion.

Efficiency of protein production is very high, exceeding 30% for protein levels at 16% and below. The protein efficiency declines very consistently and rapidly as ration protein percentage increases, but at 20% dietary CP the efficiency is still above 25%. As protein efficiency declines it must be recognized that greater amounts of nitrogen waste must be released into the environment.

Level of CP selected for feeding will be strongly influenced by the cost of protein sources and the value of milk produced. Table 3 provides a return above CP feed cost for milk at varying market prices. These projections were derived for a DMI of 20 kg and a factorial calculation of the value of RDP and RUP from soybean meal and a commercial protein blend priced at $225 and $525 per ton, respectively.

Table 1. Milk yield response to dry matter intake and crude protein.[a]

	Milk, kg	**=**	**Intercept**	**DMI, kg**	**CP,%**	**CP^2**
Coefficient			-9.8	0.8	2.3	-0.05
Variable				**Mean, kg**	**Mean, lb**	
Milk				31.4	69.1	
Dry matter intake				20.2	44.44	
CP, %				-----------17.1----------------		
RDP, % of DM				-----------10.7(63)-----------		
RUP, % of DM				------------6.2(37)------------		

[a] Taken from Table 5-2, NRC, 2001.

Table 2. Marginal returns and protein efficiency associated with increased protein.[a]

CP, % of DM	Milk, kg	Return, g	Milk Increase, %	Efficiency[b]
14	28.60	----	----	32.7
15	29.45	850	2.97	31.4
16	30.20	750	2.55	30.2
17	30.85	650	2.15	29.0
18	31.40	550	1.78	27.9
19	31.85	450	1.43	26.8
20	32.20	350	1.10	25.8
21	32.45	250	0.78	24.7
22	32.60	150	0.46	23.7
23	32.65	50	0.15	22.7
24	32.60	-50	-0.15	21.7

[a] Derived for 20 kg dry matter intake.
[b] Projected at milk with 3.2% protein.

Feeding economy is achieved at all milk prices for protein inclusions up to 18% of the DM. With very high milk prices there is some tendency for higher profits to be achieved with 19 to 20% CP inclusion.

Most applied dairy nutritionist have accepted a CP requirement of 16 to 17% of the DM with occasional values of 18% for early lactation or for smaller breeds producing aggressive amounts of milk. In fact many practicing nutritionist, because of the negative relationship between reproductive efficiency and dietary CP levels, would not tolerate CP values beyond 18% of the DM. But with optimum balance of RDP and RUP we may be able to feed CP more aggressively and this basic NRC equation supports economical responses beyond 18% of the DM.

Rumen Degradable and Undegradable Protein

Lactation response to RDP and RUP was derived from a data set involving 38 studies and 206 treatment means. The earliest study was published in 1987 and the latest in 2000. The regression involving DMI, RDP and RUP gives a prediction of milk yield with an r^2 of 0.52. This is somewhat better than the first response model, but still we must recognize that 48% of the variation is not accounted. The regression equation as presented on page 50 in NRC, 2001 is:

$$\text{Milk} = -55.61 + 1.15 \times \text{DMI} + 8.79 \times \text{RDP} - 0.36 \times \text{RDP}^2 + 1.85 \times \text{RUP};$$

where milk and DMI are in kg/day and RDP and RUP are as a % of DM.

Figure 2 presents a visual view of the response surface for crude protein level and the amount of that protein which escapes rumen degradation. A very important interaction between CP percentage and the amount of that protein, which escapes from the rumen, is illustrated in this response surface. Under CP feeding situations where the escape value of the feed protein mixture is not too high, lower 30% range, CP feeding is optimized at 16 to 18% of the DM. With high values of escape protein, 38 to 42% of the CP, the response to feed CP percentage is almost linear up to 20% CP of the DM. When adequate amounts of high quality rumen escape proteins are fed it is very likely that cows will respond economically to higher amounts of total CP.

But as with the first model it is important to determine, if these rates of CP feeding will be economical, that is return higher values above feed cost. Using the prices for RDP and RUP as applied in Table 3, maximum returns are noted with 18% or higher CP and rumen escape values of 40 to 42 percent.

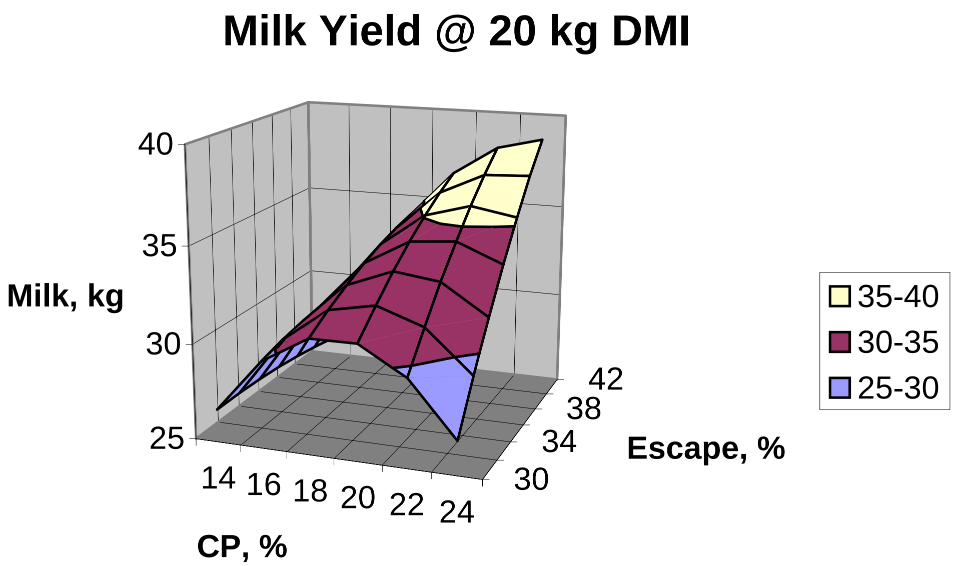

Figure 2. Milk yield as influenced by protein amount and the percentage that escapes.

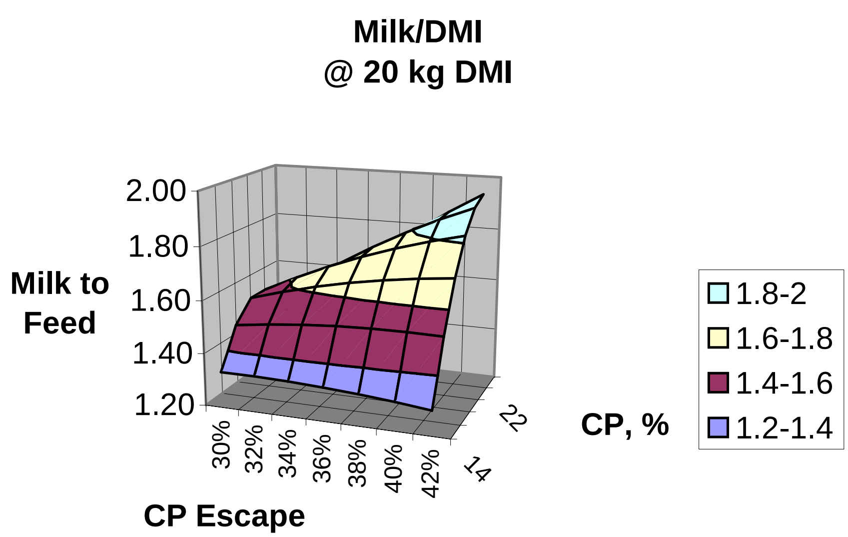

Figure 3. Milk to dry matter intake ratios as influenced by protein escape and level.

To achieve rumen escape numbers of this magnitude it is necessary to feed significant amounts of by-pass protein type products. Emphasis must be placed on the amino acid content of these components because the contribution to metabolizable protein is sufficient to create imbalances. Also the amount of escape protein within the products must be defined and supplied in consistent amounts and in a rather concentrated form.

Feed Efficiency

The dairy industry is very much concerned with overall nutrient efficiency and, as noted earlier the conversion of feed to milk protein is in the range of 25 to 30% with higher CP feeding contributing to a lowering of the efficiency factor. Total DM efficiency is very important and that is presented in Figure 3. Typically dairy cows produce around 1.5 units of milk per unit of DM consumed. The data set used to derive the first response surface gave a feed efficiency of 1.55 to 1 (Table 1). The feed efficiency associated with the second response surface is 1.59 to 1 for the 20 kg DMI. At very low dietary CP, maximum efficiency is achieved when 36% of the CP escapes. At a more acceptable protein level for lactating cows (CP = 18%), maximum efficiency is not achieved until the escape value reaches 42%.

Feeding of these very high escape values with high CP diets has not been fully researched, but there are studies published which fully support the concept. Table 4 provides a brief summary of the research results involving the use of a commercial high protein, high escape, marine and animal product that has been researched extensively. In these studies the control diet was basically a vegetable protein diet with escape or by-pass values in the low to mid 30% range. The by-pass protein blend was used to replace some or all the vegetable base proteins and to increase the overall protein escape value to the 40% range. Feed efficiency from these studies, expressed as units of 3.5% fat corrected milk to units of DM, varied from a low value of 1.32 to the highest value of 1.97. This range in feed conversion values is within the limits of those illustrated from the response surface in Figure 3. In all of these studies, the inclusion of the protein blend increased feed conversion into milk. There seems to be good agreement between the efficiency values from response functions of NRC, 2001 and the actual results from controlled experiments. An average of the experiments noted suggest that an 8% improvement in feed efficiency is achieved by increasing the amount of escape protein in milking cow diets.

Table 3. Return above protein cost at varying milk price.[a]

					Price of milk, $/CWT			
CP,%	**CP, g[b]**	**RDP, g**	**RUP,g**	**CP,$[c]**	**$10.00**	**$12.00**	**$14.00**	**$16.00**
14	2800	1764	1036	$1.41	$4.88	$6.14	$7.40	$8.65
15	3000	1890	1110	1.51	4.96	6.26	7.56	8.85
16	3200	2016	1184	1.62	5.03	6.36	7.69	9.01
17	3400	2142	1258	1.72	5.07	6.43	7.79	9.14
18	3600	2268	1332	1.82	5.09	6.47	7.85	9.24
19	3800	2394	1406	1.92	5.09	6.49	7.89	9.29
20	4000	2520	1480	2.02	5.06	6.48	7.90	9.31
21	4200	2646	1554	2.12	5.02	6.45	7.87	9.30
22	4400	2772	1628	2.22	4.95	6.38	7.82	9.25
23	4600	2898	1702	2.32	4.86	6.30	7.73	9.17
24	4800	3024	1776	2.42	4.75	6.18	7.62	9.05

[a] Based on 20 kg dry matter intake.
[b] CP is 63% RDP and 37% RUP.
[c] RDP and RUP valued at $0.1055 and $0.4399 from a factorial analysis of soybean meal and a commercial protein blend priced at $225 and $525 per ton, respectively.

Summary

Milking cows respond with increasing outputs of milk to increases in DM consumption and RUP in basically a linear fashion. Crude protein concentration or % of the DM provides milk responses in a curvilinear fashion. A strong interaction exists between CP concentration and the amount of protein that escapes the rumen and provides a metabolic component post ruminally. It is not practical to define the optimum amount of escape protein necessary until the CP of the ration is defined.

Feed efficiency for milk, defined as units of milk produced per unit of DM consumed is normally in the 1.25 to 1 to the 1.5 to 1 range. With proper introduction of the correct type and amount of escape protein it is possible to improve this efficiency by 8%. Efficiency of feed CP conversion into milk protein is in the range of 25 to 30%. Increasing the CP content of the CP drives this efficiency lower.

When large amounts of escape or by-pass proteins are fed in order to achieve these higher escape values, emphasis must be placed on the CP quality as defined by amounts and ratios of amino acids. If the supplemental protein alters the metabolic balance and/or ratio of amino acids, then production responses will likely not occur.

Table 4. Feed efficiency[a] as influenced by a by-pass blend product[b].

Study[d]	Milk, kg	Fat, kg	FCM[c]	DMI	Feed Efficiency	% Increase
[d]Arizona-SFC-Control	36.30	1.180	34.83	26.30	1.32	----
[d]Arizona-SFC-Blend	39.90	1.220	37.04	26.08	1.38	4.35
[e]Canada-2 Meals-Cont.	26.77	0.981	27.48	19.58	1.40	----
[e]Canada-2 Meals-Blend	30.06	1.113	31.04	19.38	1.60	14.11
[e]Canada-7 Meals-Cont.	27.67	1.001	28.20	19.48	1.45	----
[e]Canada-7 Meals-Blend	30.86	1.108	31.30	19.18	1.63	12.74
[f]Illinois-Control	34.36	1.200	34.32	19.88	1.73	----
[f]Illinois -Blend	36.88	1.310	37.19	18.88	1.97	14.13
[g]Illinois-Low Control	36.30	1.250	35.97	24.50	1.47	----
[g]Illinois-Low Blend	37.30	1.200	35.59	23.90	1.49	1.43
[g]Illinois-Med. Control	37.30	1.180	35.26	24.70	1.43	----
[g]Illinois-Med. Blend	38.70	1.310	37.98	25.10	1.51	5.98
[g]Illinois-High Control	39.40	1.360	39.09	26.00	1.50	----
[g]Illinois-High Blend	37.80	1.250	36.61	23.50	1.56	3.63
					Average =	**8.05**

[a]Defined as units of milk to units of feed dry matter.
[b]By-pass blend product is Pro-Lak, produced by H. J. Baker & Bro., Inc., Stamford, Connecticut U.S.A.
[c]3.50% FCM calculated as (16.216 x kg fat) + (0.4324 x kg milk)
[d]Santos et al., 1999.
[e]Thivierge et al., 2000.
[f] Underwood et al., 2001.
[g]Ipharraguerre and Clark, 2004.

References

AFIA. 2004. BSE Compliance Guide 6-2. http://www.afia.org/BSE_Compliance_Guide.html. Accessed Apr. 7, 2005.

Ipharraguerre, I.R., and J.H. Clark. 2004. Performance of lactating dairy cows fed different sources and amounts of crude protein. J. Dairy Sci. 87(Suppl. 1):161. (Abstr.)

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. Natl. Acad. Press, Washington, D.C.

Santos, J.E.P., J.T. Huber, C.B. Theurer, L.G. Nussio, M. Tarazon, and F.A.P. Santos. 1999. Response of lactating dairy cows to steam-flaked sorghum, steam-flaked corn, or steam-rolled corn and protein sources of differing degradability. J. Dairy Sci. 82:728-737.

Thivierge, M.C., J.F. Bernier, and H. Lapierre. 2000. The effect of protein and energy supplement added to a basal diet fed in 2 or 7 meals daily on milk yield and urinary excretion of purine derivatives. J. Dairy Sci. 83(Suppl. 1):289. (Abstr.)

Underwood, J.P., J.K. Drackley, and J.H. Clark. 2001. Intake and production by Holstein cows fed different amounts and sources of supplemental protein prepartum and postpartum. J. Dairy Sci. 84(Suppl. 1):364. (Abstr.)