DIETARY MANIPULATION TO REDUCE NITROGEN EXCRETION BY LACTATING DAIRY COWS

Z. Wu, P. R. Tozer, and E. B. Groff
Department of Dairy and Animal Science
Pennsylvania State University

REDUCING NITROGEN EXCRETION

Dairy cows, on average, secrete 25-30% N in milk of the total N they consume, and almost all the remaining N is excreted in feces and urine. Strategies to reduce N excretion include eliminating dietary protein in excess of the requirement, maximizing microbial protein production, and using protected limiting amino acids for reductions in total protein that needs to be fed.

Reducing dietary protein. Typically, research on the protein requirement of lactating dairy cows has been directed toward maximizing milk production with little concern on N efficiency. The NRC (2001) Nutrient Requirements of Dairy Cattle presented a dataset from 82 experiments with 393 treatment means, showing a curvilinear relationship of milk yield and dietary crude protein (CP) content (Figure 1). Milk yield plateaus with 72 lb/d at 23% dietary CP. Few studies included in the dataset were recently conducted using high producing cows. It is likely that milk yield would plateau with a higher production level with modern cows. Despite this, the relationship between milk production and the incremental raising of dietary protein is still a diminished response. The optimal dietary protein level determined from net returns of feeds would be lower than the one that can result in the maximal milk production. Consideration of environmental consequences could also reduce the optimal level.

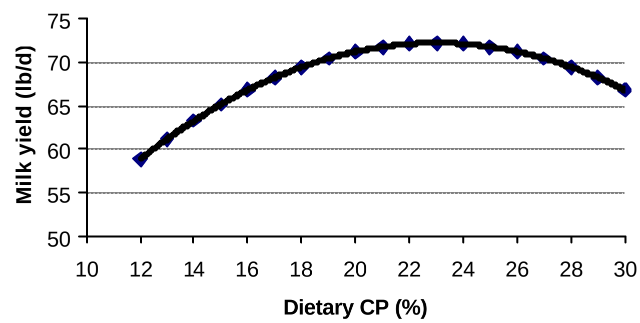

Figure 1. Milk production response to dietary protein (developed from NRC, 2001).

Table 1 lists the protein requirements of lactating dairy cows using some example diets in the NRC (2001). The cow in the example milks 77 lb on d 11 and 99 lb on d 90 of the lactation. Her milk contains 3% true protein for both stages. For d 11 and d 90, she needs 6.7 and 9.5 lb/d of CP, respectively. To provide these amounts of protein, the diet needs to contain 19.5 and 16% CP, with 10.5 and 9.8% from rumen degradable protein (RDP), and 9.0 and 6.2% from rumen undegradable protein (RUP). The higher protein level for d 11 than for d 90 reflects the view that diets for the first weeks of lactation need to be especially condensed in nutrients to compensate for low feed intake.

Table 1. Protein requirements using example diets in NRC (2001).

	Days in milk	
Item	11	90
Milk, lb/d	77.0	99.0
DMI, lb/d	34.3	59.2
Dietary CP		
lb/d	6.7	9.5
%	19.5	16.0
Dietary RDP		
lb/d	3.6	5.8
%	10.5	9.8
Dietary RUP		
lb/d	3.1	3.7
%	9.0	6.2

As mentioned above, few studies have been conducted to determine the lactational response of modern cows to dietary protein level. Three studies (Christensen et al., 1993; Cunningham et al., 1996; Komaragiri and Erdman, 1997) included in the database for Figure 1 utilized cows producing relatively high levels of milk. Diets used RUP supplements to raise the protein content from 16.7 to 19.6% CP on average. Two (Cunningham et al., 1996; Komaragiri and Erdman, 1997) of the studies reported increased milk production, while the third study noted a slight decline in milk production as dietary protein was increased. These studies covered only the first part of lactation, with days in milk averaging 130 at the end of the trials.

Wu and Satter (2000a) reported a study that was conducted for a complete lactation using 58 cows. Treatments were designed to identify the minimum amount of protein needed for the entire lactation. The diets contained 33% alfalfa silage, 22% corn silage, 22-32% finely ground high moisture ear corn, and 10% roasted soybeans.
Expeller soybean meal was used at up to 10% as a replacement of high moisture ear corn to increase the dietary protein level.
This substitution increased about the same amount of RDP and RUP. The four treatments formed over the entire lactation were as follows: 15.4→16.0% CP, 17.4→16.0% CP, 17.4→17.9% CP, and 19.3→17.9% CP. The change from one level to the other took place at the beginning of wk 17 of the 44-wk lactation. Higher than anticipated protein content of alfalfa silage fed in week 17 to 44 resulted in CP levels slightly higher than intended. All cows were administered bST biweekly starting at wk 9 of lactation.

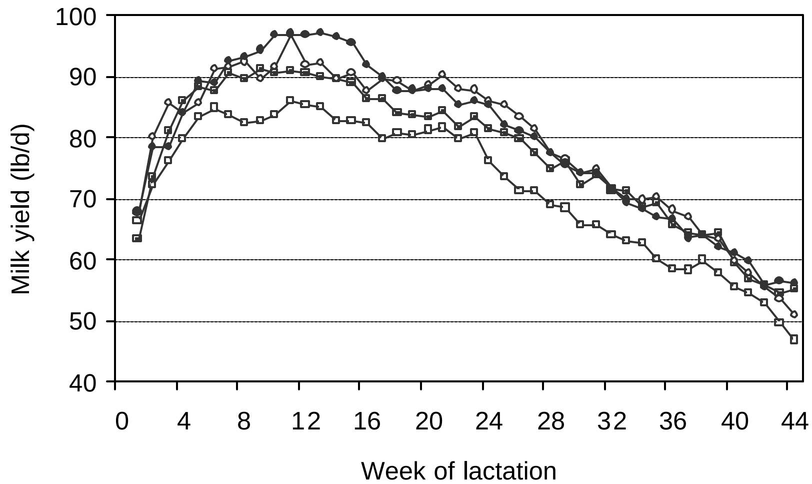

Figure 2. Lactation curves of cows fed diets containing different levels of CP: 15.4% during lactation wk 1 to 16 and 16% during wk 17 to 44 (□), 17.4% during wk 1 to 16 and 16% during wk 17 to 44 (¦), 17.4% during wk 1 to 16 and 17.9% during wk 17 to 44 (o), and 19.3% during wk 1 to 16 and 17.9% during wk 17 to 44 (•).

The lactation curve of the trial (Figure 2) clearly shows that 15.4-16.0% CP was a deficient treatment. The curve for cows fed the highest protein (19.3%) appears to achieve the greatest peak. Furthermore, around the week the dietary protein level was reduced from 19.3 to 17.9% (wk 16 to 18), a dramatic decrease in milk yield occurred for that group. A similar decrease in milk yield was also observed when the dietary CP level was decreased for the cows in the 17.4-16.0% CP group, relative to the group of the cows in the 17.4-17.9% CP treatment. This observation suggests that 16.0% CP was not providing sufficient protein for cows producing about 88 lb/d of milk at wk 17 of lactation. It was not until milk yield had decreased to about 75 lb/d at wk 30 that milk yield of these two groups became similar. Surprisingly, increasing dietary CP from 17.4 to 19.3% failed to enhance milk yield during wk 1 to approximately wk 7 postpartum. All these observations indicated that except for the first few weeks and the late part of the lactation, a high protein diet was beneficial for the majority of the lactation.

The above pattern of milk production and protein requirement is no doubt related to modern cows' production potential and the use of bST. The lower panel of Figure 3 is a constructed composite lactation curve that attempts to reflect the highest milk yields obtained from the top treatments during the different segments of lactation while using the least amount of dietary protein needed to support that maximum production. The synthesized lactation would result in 24,640 lb milk. Compared with the lactation curve considered typical 15 yr ago [upper panel of Figure 3, adopted from NRC (1989)], modern cows receiving bST have broader peak lactation and a more sustained lactation. The use of bST has had the effect of extending the period of peak milk production, and this will sustain the demand for high protein intake over a prolonged period.

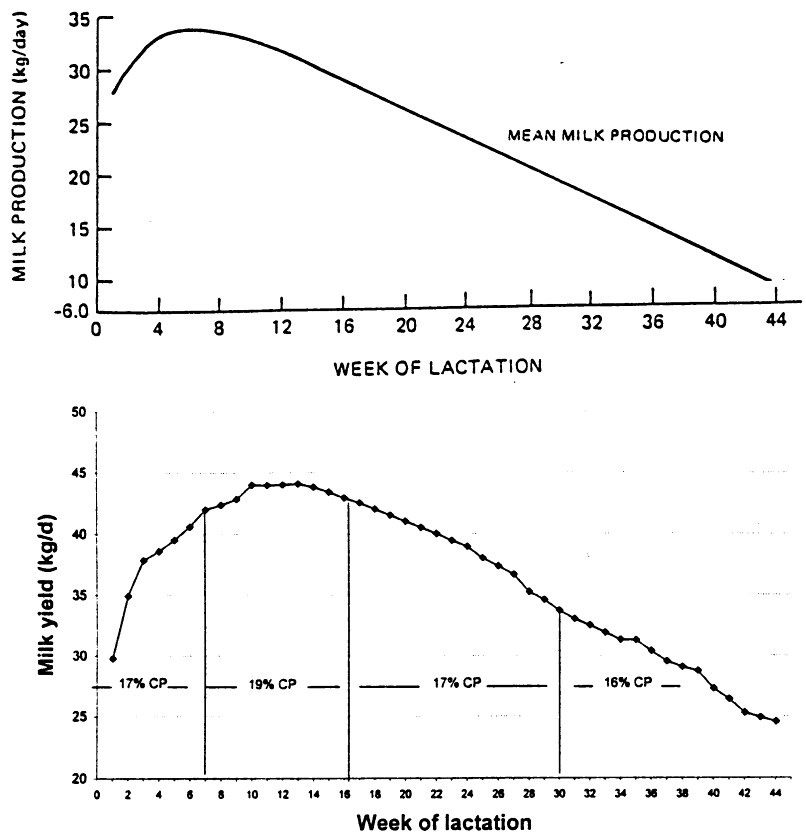

Figure 3. Lactation curve attained with treatments of different dietary protein levels that resulted in the highest milk yields during different stages of lactation in a 2000 study (lower panel) compared to the lactation curve considered typical 15 years ago (upper panel, NRC, 1989).

Milk yield for the 308-d lactation for the 17.4-16.0% CP treatment was about 1700 lb more than that for the 15.4-16.0% CP treatment, and similar to the yields for the 17.4-17.9 and 19.3-17.9% CP treatments (Table 2). Overall, milk yield averaged 24,240 lb for the 308-d lactation for the three highest protein groups. Estimated N excretion largely reflected N intake. The efficiencies for converting feed N to milk N, ranging from the lowest to the highest dietary protein treatments, were 28.8, 25.9, 24.0 and 24.7%. The lowest protein treatment resulted in the highest efficiency for converting dietary N to milk N, but this treatment was clearly deficient in protein. Based on this experiment, it will be difficult to increase the efficiency of converting feed N to milk N by feeding less protein, when based on total lactation averages, much above 30% and still maintain acceptable milk production levels.

This experiment suggests that 17-18% CP is adequate and would allow higher net profit than feeding higher protein. The period that requires the highest protein is not the first few weeks of lactation, as generally thought, but from approximately wk 8 to wk 30. An increase in peak production from feeding more than 17-18% CP is possible, but may not be optimal considering net profit and N excretion. The level can be reduced at around wk 30 to about 16%. Dietary protein level can be manipulated, but the room is quite limited for the most part of the lactation; early and late stages of lactation might provide the best opportunity for reducing the level of dietary protein.

Table 2. Milk yield, intake N, milk N, and manure N of cows fed diets varying in CP content during 308-d lactation.

	Dietary CP (%)				
Item	15.4-16.0 (n = 15)	17.4-16.0 (n = 15)	17.4-17.9 (n = 14)	19.3-17.9 (n = 14)	SEM
	------------- (lb) -----------------				
Milk yield	22,123	23,830	24,409	24,490	768
Intake N	392	416	470	471	8.8
Milk N	113	108	113	117	3.5
Manure N	278	308	357	355	8.4

Evidence exists to support the above conclusions. Komaragiri and Erdman (1997) showed that cows fed a diet with 20.9% CP did not produce more milk than cows fed a diet with 17.3% CP during the first 6 wk of lactation, but peaked higher, and sustained milk production at a higher level. Eastridge et al. (1998) summarized the recommendations of four ration formulation programs, and all four programs called for the highest level of dietary protein at d 60 of lactation. The levels of dietary CP recommended by the programs for d 60 ranged from 18.1 to 20.0% for cows producing 120 lb milk daily. However, this level of production is probably higher than the herd averages for most of the farms in the U.S.

Table 3 contains a cost analysis of reducing fecal N using the lowest (15.4-16.0 % CP) and the second highest (17.4-17.9% CP) dietary protein treatments. Yearly total income from milk is calculated from milk component yields and prices. Subtraction of feed and management cost leaves a net income of $2842 or $3085 per cow per year for the two groups. Thus, a 2% unit reduction in dietary protein resulted in a net loss of about $245 per cow per year. The reduction in manure N was about 80 lb per cow per year. The cost for reducing manure N

Table 3. Cost of reducing N by feeding less protein.

	Dietary CP (%)	
Item	15.4-16.0	17.4-17.9
Milk, lb/308 d	22,123	24,409
Income from milk, $/308 d[1]	4184	4521
Net income, $/308 d[2]	2842	3085
Difference $/308 d	-243	…
Manure N, lb/308 d	278	357
Difference, lb/308 d	-79	…
Cost of reducing manure N, $/lb	3.09	…
Equivalent of fertilizer N cost[3]	9.0	…

[1]Milk price derived from June 2001 Federal Order One component prices.
[2]Includes management cost = $1.60/d.
[3]Assuming fertilizer N cost = $0.35/lb.

was $3/lb of manure N reduced, which is about 9 times the cost of commercial fertilizer N based on a fertilizer N price of $0.35/lb of N. That seems a big price to pay for nutrient management. However, this cost needs to be considered in terms of the disposal of the extra N, either by spreading on land or removal from the farm. If the costs of removing this excess N exceed $3/lb of N then the producer is better off financially, by reducing the protein content of the ration.