Maintaining Milk Yield while Lowering Dietary Protein Content

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Take Home Messages

- Feeding lower crude protein rations provides an opportunity to improve profitability and decrease nitrogen excretion to the environment.
- Dairy cattle partition intake nitrogen into milk or manure.
- The portion of intake nitrogen excreted in milk ranges from 20 to 40%. This means that 60 to 80% of intake N is excreted in manure.
- Ration crude protein content is a poor predictor of milk production. Metabolizable protein (MP) is a much better predictor.
- Formulating and evaluating rations on a metabolizable basis requires the use of ration models.
- Both research and on-farm data indicate that rations containing < 16.5% crude protein can support daily milk production of > 40 kg.

Introduction

Dairy producers should consider lowering ration crude protein (CP) levels in rations for two primary reasons. The first is to improve profitability by increasing the efficiency of converting feed nitrogen (N) to milk N output while at least maintaining milk production. This adjustment usually lowers purchased feed costs and increases income over feed cost. The second reason is that feeding lower CP rations decreases the excretion of N to the environment. This can lower the number of acres required for land application of manure when using N application guidelines. Feeding lower CP rations will also decrease ammonia emissions which will be regulated on U.S. dairy farms in the near future. One paper estimated that lowering ration CP to 16% could decrease ammonia emissions by 20% (Kebreab et al., 2002). These adjustments provide a win-win situation for both the dairy industry and society.

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Nitrogen Use in the Dairy Cow

Even though N metabolism in the dairy cow is complex, it can be broken down to a few key points. Nitrogen consumed in the feed is either used as a nutrient source to support productive functions (maintenance, growth, pregnancy, milk) or is excreted via urine and feces. The dairy cow has a limited ability to store N in the body as labile reserves. Milk N efficiency (MNE) is one index that can be used to assess the efficiency of N use in the cow. This index is simply the ratio of the quantity of N excreted in milk as a percent of the feed N consumed. Assume that a dairy cow consumes 600 g of diet N and excretes 180 g of N in the milk. This cow would have a MNE of 30%. The maximum reported MNE in research studies is 40-45%. The MNE values observed in commercial dairy herds range from 20-35%. This implies that 65 to 80% of the feed N is excreted via manure. As ration CP levels increase, the MNE value generally decreases. A recent meta-analysis concluded that diet CP was the most important factor that determined MNE (Huhtanen and Hristov, 2009).

Table 1 contains information from a research trial in which rations ranging from 13.5 to 19.4% CP were fed to cows averaging about 36-38 kg of milk/day (Olmos et al., 2006). Key points from this trial are:

- Daily N intake increased as ration CP levels increased.
- Milk N excretion changed very little as ration CP increased.
- Total manure N excreted per day increased as ration N intake increased.
- Daily fecal N excretion changed very little as ration CP increased
- As total manure N excretion increased, a higher proportion of the total excreted N was in the urinary component.
- MNE efficiency decreased as ration CP increased.

Table 1. Nitrogen intake and excretion from rations varying in CP level

Ration CP,%	13.5	15	16.5	17.9	19.4
N intake, g/day	483	531	605	641	711
Milk N, g/day	173	180	185	177	180
Total manure N, g/day	309	316	376	410	467
Fecal N, g/day	196	176	186	197	210
Urinary N, g/day	113	140	180	213	257
Urinary N, % of manure N	36.5	44.3	47.8	52	55
MNE, %	36.5	34	30.8	27.5	25.4

Source: Olmos Colmenereo and Broderick, 2006

▪ What about Research Results?

The literature is filled with large numbers of trials evaluating the effect of dietary CP levels on milk production. Only a limited number of these have been done with high producing dairy cattle (>40 kg milk/day). Many of these trials are short-term or partial lactation trials. A trial from Wisconsin reported similar milk and milk protein yields when diet CP was lowered from 18.8 to 16.1% (Leonardi et al., 2003). The cows in this trial were mid-lactation cows averaging about 40 kg milk/day. There was no difference in milk production between rations containing 18 or 15% CP in cows producing 44 to 47 kg of milk per day (Bach et al., 2000). Lowering ration CP from 17.5 to 16.4% did not alter milk production for cows producing an average of 47.7 kg/day (Wattiaux and Karg, 2004). Recent trials at Cornell have reported milk production levels of 40 – 50 kg/day when corn silage based rations containing 14 to 14.5% CP were fed (Reckentwald and Van Amburgh, 2006; Hofheer et al., 2010).

A full lactation trial was conducted comparing 4 protein feeding strategies (Wu and Satter, 2000). Each cow was fed 2 total mixed rations during lactation. Ration CP levels during weeks 1-16 and 17-44 of lactation were 15.4-16 (A), 17.4-16 (B), 17.4-17.9 (C) and 19.3-17.9 (D). Cows fed ration A produced significantly less 3.5% fat corrected milk (10,690 kg) than cows fed the other rations. There were no statistical differences in 3.5% fat corrected milk production between the other 3 rations. Milk production ranged from 11,559 to 11,804 kg/lactation for rations B, C and D. Total lactation N intakes were

178, 189, 214 and 214 kg for rations A, B, C and D. Manure N excretion for the total lactation was 127, 140, 162 and 161 kg/cow for ration A, B, C and D. Cows fed rations C and D consumed about 25 kg more N per year than cows on ration B. However, cows on ration C and D also excreted about 22 kg more N in the manure than cows fed ration B. The majority of the extra N consumed by cows on rations C and D was excreted in the manure and was not used by the cow to produce milk.

▪ Does This Work on Dairy Farms?

A field trial was conducted in western New York using 2 commercial dairy herds (Higgs, 2009). The goal was to evaluate the changes made in the N component of the Cornell Net Carbohydrate and Protein System (CNCPS) 6.1 model (Van Amburgh et al., 2007). The herds were selected in cooperation with nutritionists working with the herds. The initial rations in both herds were evaluated with the CNCPS 6.1 model and potential ration adjustments discussed with both the dairy producer and nutritionist. In this trial, we formulated the rations for the high group in each herd. The other rations continued to be formulated by the herd nutritionist. This trial was done over an 8-month period starting in September, 2008. Rations were evaluated and reformulated at least monthly during this trial. No suggested ration adjustments were implemented unless the herd nutritionist agreed. Our objective was to lower ration CP, improve MNE, decrease nutrient excretion and increase income over feed cost. Milk income and feed costs used in all calculations were based on April, 2009 prices. There were a number of feed and forage changes made on each farm during the trial. These were based primarily on changes in feed and forage inventory, silo changes and different forage crop years. Both herds replaced some of the purchased corn meal with home produced high moisture corn during a portion of the trial. Monthly DHI herd data and daily bulk tank milk component values were obtained. Table 2 contains an overview of the results for each farm. On both farms, lowering ration CP resulted in improved efficiency of N use, decreased MUN levels and improved income over feed costs while maintaining herd milk production. There are still additional opportunities on both farms to further decrease ration CP. Improving the amino acid balance is one area to consider. The second is to work with the farms to improve the consistency of daily feeding management practices.

Harrison (2004) reported that lowering ration CP from 17.8 to 16.9% did not alter milk production in a herd producing about 45 kg of milk per cow per day. Manure N excretion was calculated to decrease 12% when ration CP was decreased .Income over feed cost was 12 cents/cow/day higher for the lower CP ration. Varga (2007) reported that lowering ration CP from 18 to 16% improved nitrogen efficiency by 4.6%.

Table 2. Field Trial Results

Item	Herd A – Initial Ration[a]	Herd A – Final Ration	Herd B – Initial Ration	Herd B – Final Ration
Herd milk, kg/day	35.8	36.3	37.2	36.3
Milk fat, %	3.58	3.63	3.56	3.63
Milk true protein, %	3.03	3.11	2.96	3.07
MUN, mg/dl	14.8	12.5	14.5	12
Forage, % of DM	54	57	60	48[b]
Corn silage, % of forage DM	59	71	53	60
Ration CP, %	17.5	16.6	17.7	16.9
NDF, % of DM	32.5	33.6	31.3	33.2
Starch, % of DM	23	27.6	23.6	26.3
Fat, % of DM	4.3	3.8	5.4	4.2
Total MP, g/day	2950	2769	2646	2690
N intake, g/day	697	641	655	629
Manure N, g/day	500	441	469	441
Fecal N, g/day	250	237	233	231
Urinary N, g/day	250	204	236	210
MNE, %	28	31	28	30
Milk N:Urine N	0.78:1	0.98:1	0.78:1	0.90:1
Feed cost, $/cow/day	5.88	5.43	6.14	5.97
Purchased feed, $/cow/day	3.55	2.96	3.73	3.42
IOFC, $/cow/day	3.08	3.83	3.01	3.22
IOPFC,$/cow/day	5.41	6.30	5.42	5.77

[a] Herd A = 400 cows, herd B = 600 cows
[b] Total forage fed in herd B was reduced due to forage inventory constraints.
[c] Definitions: IOFC= income over feed costs; IOPFC= income over purchased feed costs

■ Dairy Herds Feeding Lower CP Rations

A second approach was to obtain information from a group of herds that had already been feeding lower CP rations. We worked with feed industry professionals to obtain detailed feeding information on a number of herds. Our target was herds producing > 36 kg of milk/day and feeding rations <16% CP. To date, we have > 16 herds in this dataset. All are Holstein herds fed total mixed rations. Table 3 contains the information on a subset of these herds. Some of the key observations from this information are:

- Milk production is > 38 kg/cow/day in these herds. The ration listed for Herd B is the High group ration in this herd.
- 2 of these herds do not use any animal protein sources in the ration.
- Corn silage is the primary forage in these herds with the exception of Herd C. This herd feeds primarily grass silage.
- There is a wide variation in amino acid balance in these herds. A number of these herds have an opportunity to fine tune rations by balancing amino acids. This should provide an opportunity to lower ration CP and improve the efficiency of N use.

Table 3. Commercial Dairy Herd Rations

Item	A	B	C	D	E	F
Cows	140	920	250	180	108	700
Milk, kg	41	52.6[a]	38.5	43	40	40.5
Milk fat,%	3.65	3.3	3..8	3.6	3.6	3.5
Milk TP,%	3.1	3	3.1	3.1	3.2	3.1
MUN, mg/dl	8-10	8	-	8-9	12	7-9
Ration CP,%	14.3	15.9	15.7	15.8	15.5	16.2
MP, % of DM	10.5	12.2	11.1	11.2	11.1	12.1
MP, g/day	2600	3322	2710	2744	2720	2779
Lysine, % of MP	6.42	6.86	5.6	5.9	6.23	6.6
Methionine, % of MP	2.1	2.74	1.9	1.9	2	2.8
Lys:Meth	3.05:1	2.5:1	2.9:1	3.1:1	3.1:1	2.3:1
NDF, %	31.4	31	36	33.4	31	32
Forage NDF, % of BW	0.99	0.94	0.9	0.99	0.86	0.88
NFC, %	42.4	41	34	39	42	39
Starch, %	29.3	28.3	23	29	27	27.6
Sugar, %	5	5.5	3.7	2.9	3.1	5.1
Fat, %	4.4	5.2	6.5	5.3	3.8	5.4
Animal protein source	Yes	Yes	No	Yes	No	Yes
Forage, % of ration DM	59	60	42	53	60	53
Corn silage, % of forage DM	53	68	6	58	72	64
MNE, %	36	38	34	35	35	35

[a] High group ration in this herd

▪ Challenges to Lowering Ration CP in Dairy Herds

There are always considerations and risks involved when altering rations and nutrition management programs on dairy farms. The size of the “safety factor” used in formulating rations is a tool routinely used by nutritionists. They adjust the size of the safety factor based on their evaluation and assessment of the daily consistency of forages and feeding management practices. In 2006, we surveyed feed industry personnel for the challenges they felt needed to be considered if they were going to formulate lower CP rations. The primary factors they identified were:

- Consistency and quality of daily on-farm mixing and feeding management.
- Daily variations in forage quality and dry matter.
- Feeding system (TMR's versus component fed herds).
- Lack of on-farm forage dry matter determinations and the use of this data to adjust the quantity of feeds mixed and fed.
- Herd grouping and ration strategies.
- High levels of soluble protein in home-produced silages.
- Increased use of baleage on some farms.
- Accuracy of taking forage samples and forage lab analyses.
- Limited availability of MUN as a monitoring tool.
- Are the ration formulation programs accurate enough to feel comfortable in lowering ration CP levels?
- The need to gain experience and develop a comfort level in lowering ration CP and observing herd responses.
- Lack of "real" farm information from herds that have adopted this practice.

What Do We Balance For?

Crude protein is a term that has been used to formulate and evaluate dairy rations for many years. A number of refinements have been added to increase the usefulness of the CP system. These include considering soluble protein, rumen degraded protein (RDP) and rumen undegraded protein (RUP). The recent Dairy NRC publication suggests using metabolizable protein (MP) to replace CP for ration formulation (NRC, 2001). Metabolizable protein is basically the sum of rumen microbial protein and RUP available in the small intestine. The NRC committee examined the relationship between CP and milk production using 393 treatment means from 82 published research trials. The regression model used contained both dry matter intake and ration CP %. This model accounted for only 29% of the variation observed in milk production. Schwab and Ordway (2004) reported on an analysis that used MP as a predictor of milk yield. They indicated that using MP (g/day) in the prediction model accounted for 65% of the variation in milk yield. This clearly indicates that MP is a better predictor of milk yield than CP. The challenge with using MP is that it is not a tabular value and requires use of specialized model based ration formulation programs. A more detailed discussion on the rationale for using MP is available (Varga, 2007).

▪ How Do We Implement Lower CP Rations on Dairy Farms?

There are a number of logical steps that can be followed to assess the potential of and implement lower CP rations. The concept of feeding lower CP rations is valid but if improperly used can lower milk production and profits. What is a lower CP ration? My simple definition is a ration lower in CP than currently being fed. The following points should be considered when working with a farm to determine the potential for lowering ration CP levels:

1. Mindset – Both the dairy producer and nutritionist need to feel that this concept is correct and could work on this specific farm. If this isn't the case, don't move ahead with lowering ration CP levels.

2. Is this herd a candidate to feed lower CP rations? There are some simple assessments that can be done to answer this question.
    a. Evaluate herd MUN levels – Our goal range is 8 – 12 mg/dl. Herds with higher MUN's do have opportunities to improve the efficiency of N use.
    b. Calculate MNE with the current ration Herds with a MNE < 30% have a real opportunity to improve the efficiency of N use by adjusting the ration. Herds > 30% can still improve the efficiency of N use but they have a smaller opportunity. If MNE is > 35%, the herd is already very efficient in using diet N.
    c. Evaluate the CP level in the current ration. In our New York Precision Feed Management program, our goal is to have ration CP levels < 16.5%. Attaining this level can be difficult in herds feeding high levels of high protein, high RDP grass or legume silages.
    d. Evaluate herd milk true protein levels. Holstein herds with milk TP < 3.1% indicate an opportunity to adjust rations and improve the efficiency of N use.

3. Evaluate the consistency of the forages available on the farm. The more consistent they are in quality, the more comfortable you can be in lowering ration CP with minimal risk of decreasing milk production.

4. The same consistency question needs to be evaluated regarding daily feed mixing, delivery and feed bunk management. As variability increases, the risk of decreasing milk production increases.

5. If possible, balance rations on an MP basis rather than CP. MP is a better predictor of potential milk and milk protein response. This will require using one of the currently available rations models that are

based on MP. These models also provide information on microbial protein synthesis. As ration CP is lowered, more microbial protein needs to be produced in the rumen as a source of amino acids in the intestine.

6. Work closely with your nutrition advisor or consultant to explore possible ration adjustments. Calculate predicted changes in milk production, feed cost and income over feed cost. Does lowering ration CP appear to be a good move?

7. Consider RUP feed selection based on quality, variability and amino acid profile. RUP sources that have a higher and more consistent quality do exist in the feed trade. These products usually cost more per ton since the company producing the product has an added investment in manufacturing this feed. This extra cost needs to be factored in to your calculations to determine potential changes in income over feed cost.

8. Ration formulation guidelines. The following are some general starting points. These will need to be adjusted depending on the specifics of the ration formulation model used.
    a. Feed adequate amounts of forage and effective NDF.
        i. Minimum forage NDF intake > 0.9% of body weight
        ii. peNDF > 23% of total ration dry matter.
    b. Feed carbohydrates – Fermentable carbohydrates are needed in the rumen to provide energy for synthesis of microbial protein.
        i. Starch = 21 – 28%.
        ii. Sugar = 4 – 7%
    c. Feed protein fractions:
        i. RDP = 9 – 11% of total ration dry matter
        ii. RUP = 4 – 7% of total ration dry matter
    d. Microbial protein = 45 – 55% of the total MP required.
    e. Amino acids:
        i. Lysine = 6.6 – 6.8% of MP
        ii. Methionine = 2.2 – 2.3% of MP
        iii. Lysine:methionine ratio = 3:1

9. Monitor the results – An on-farm monitoring system needs to be developed to assess the results of adjusting ration CP levels. Milk protein %, MUN and milk production are the 3 key items to monitor.

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