Feeding Low Crude Protein Rations to Dairy Cows – What Have We Learned?

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Introduction

Dairy producers should consider lowering ration crude protein (**CP**) levels in rations for two primary reasons. One is to improve profitability by increasing the efficiency of converting feed nitrogen (**N**) intake to milk N output while at least maintaining milk production. This usually also reduces purchased feed cost and increases income over feed cost and/or income over purchased feed costs. A second reason is that feeding lower CP rations decreases the excretion of N to the environment and lowers ammonia emissions. This can decrease the number of acres needed for land application of manure. When ammonia emission regulations are implemented, this will lower animal ammonia emissions. This adjustment provides a win-win situation for both the dairy industry and society. On many farms, there is an opportunity to lower ration CP by 0.5 to 1.5 units with minimal risk of lowering milk production. This can have significant implications on both farm profitability and nutrient management practices. There are a limited number of commercial dairy farms that have already made the step of feeding lower CP rations. These farms may have limited opportunity to further lower ration CP. However, they demonstrate that lower CP rations can be used in herds while maintaining high levels of milk production.

Nitrogen Use in Dairy Cattle

Even though N metabolism in the dairy cow seems 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 milk and milk protein production or it is excreted via urine and feces. The dairy cow has a limited ability to store N compared with energy. Milk N efficiency (**MNE**) is one index that can be used to assess the efficiency of N use in the dairy cow. This index is simply the ratio of the quantity of N excreted via the milk divided by the quantity of feed N consumed. The MNE values observed in commercial dairy herds usually ranges between 20 and 35%. This implies that 65 to 80% of the consumed N is excreted in the manure. As ration CP increases, the MNE value tends to decrease. Table 1 contains information from a study in which rations ranging from 13.5 to 19.4% CP were fed to lactating dairy cows (Olmos Colmenero and Broderick, 2006). The key points from this table are:

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1. The quantity of N excreted in the milk was relatively constant at the levels of ration CP used in this trial. Daily milk production of cows on this trial was about 80 lbs/cow/day.

2. Total manure N excreted per day increased as ration N intake went up.

3. The portion of the total manure N found in the fecal portion varied little with increasing ration CP levels.

4. As total N excretion went up with higher levels of ration CP, urinary N was the main route of excreting this excess N.

5. Milk N efficiency decreased as ration CP increased.

Research Results

A large number of studies have been conducted examining reduced CP concentrations in the ration and milk production. Many of these have been partial lactation experiments rather than full lactation studies. A study in Sweden concluded that rations with 16 to 17% CP were adequate for early lactation cows when diets were balanced including rumen degradable (**RDP**) and undegradable (**RUP**) proteins (Nadeau et al., 2007). A study in Wisconsin reported that diets containing 16.1% CP resulted in similar milk and milk protein yields compared with a ration with 18.8% CP (Leonardi et. al, 2003). This study use mid-lactation cows averaging approximately 90 lbs of milk per day. There was no difference in milk production between rations containing 15 or 18% CP in cows producing 98 to 105 lbs of milk per day (Bach et. al., 2000). Lowering the ration CP from 17.5 to 16.4% did not alter milk production for cows averaging 99 to 108 lbs of milk per day (Wattiaux and Karg, 2004). Recent studies at Cornell University have reported milk production of 88 to 110 lbs per day when corn silage based rations containing 14 to 15% CP were fed (Recktenwald and Van Amburgh, 2006: Hofheer et. al. 2010)

A full lactation study was conducted comparing 4 protein feeding strategies (Wu and Satter, 2000). Each cow was fed 2 totally mixed rations (**TMR**) during lactation. Ration CP concentrations during weeks 1 to 16 and 17 to 44 of lactation were 15.4 to 16 (A), 17.4 to 16 (B), 17.4 to 17.9 (C) and 19.3 to 17.9% (D). Cows fed rations B, C and D had similar milk production (25,500 to 26,000 lbs) whereas cows on ration A averaged 23,500 pounds of milk. Total lactation N intakes were 416, 470 and 471 lbs/cow for rations B, C and D. Total N excreted in the manure was 308 (B), 357 (C) and 354 (D) lbs/cow. Cows fed rations C and D consumed about 54 lbs more N per year than cows on ration B but excreted and extra 50 lbs. of N in the manure. Basically, all of the extra N consumed by cows on rations C and D was excreted in the manure and not used by the cow.

Field Trial Data

Two dairy herds in New York were used in a field trial to examine the use of the Cornell Net Carbohydrate and Protein System (CNCPS 6.1) model to lower ration CP levels (Higgs, 2009). The changes made in the N portion of the CNCPS model used in this trial have been previously described (Van Amburgh et.al. 2007). The herds used were selected in cooperation with the nutritionist working with these herds. One herd used a nutritionist from a major feed company and the other herd used an independent consultant. The initial high group rations were evaluated and ration adjustments suggested that could be made to lower ration CP levels. Rations were adjusted monthly over the 8-month period of the trial. The study period was from September, 2008 to April, 2009. Ration changes were not implemented unless the herd nutritionist agreed with the changes suggested as a result of the CNCPS model runs. The goal of this trial was to lower ration CP, improve the efficiency of N use and validate field use of the CNCPS 6.1 model. Milk income and feed costs were calculated using constant values typical of New York prices for April, 2009. There were a number of feed and forage changes made on both farms during the course of the trial as inventories, quality and silos changed. Both farms also replaced a portion of the purchased corn meal with farm produced high moisture corn during part of the trial. Monthly dairy herd improvement (**DHI**) milk production was evaluated with milk component data obtained for each farm. Herd daily milk components, including milk urea N (**MUN**), were provided by the milk processor.

Table 2 contains an overview of the results for each farm. Farm A had about 400 milking cows whereas farm B had about 600 cows. Key points from this table are:

1. There was an increase in % milk true protein in both herds. This most likely was related to the decrease in dietary fat and increase in dietary starch.

2. The concentration of MUN decreased by about 2 units in these herds.

3. Ration CP was reduced about 1 percentage unit.

4. The concentrations of fat in the rations were lowered and of starch increased as ration CP was lowered.

5. Ration metabolizable protein (**MP**) was decreased in Herd A. The MP changed very little for Farm B even though ration CP decreased.

6. Manure N and urinary N decreased in both herds. This is expected to reduce the ammonia emission potential of these herds.

7. Milk N (as % of N intake) increased about 2 to 3 units. This is an index of improved efficiency of N use. The ratio of milk N to urinary N also increased. This is another indication of improved N use and less N excretion.

8. Both total and purchased feed costs were reduced in both herds.

9. Income over feed cost and income over purchased feed cost increased in both herds.

10. There are additional opportunities to further improve N utilization in both herds. Balancing for amino acids would be the next logical step in both herds. However, there are some daily management considerations that need to be addressed before trying to go the next step in these herds to lower the risk of decreasing milk production.

Dairy Herds Feeding Lower Crude Protein Rations

As we started to select herds for the field trial, a number of herds already feeding lower CP rations were identified. It could be difficult to make additional decreases in ration CP or N in these herds. However, it was decided to put the information together for these herds to gain insights into the rations being used. Table 3 contains data on a number of herds feeding lower CP (<16%) rations. The information on these herds was provided by the feed industry person working with the herds. The herds in Table 3 are from Wisconsin, Michigan, Pennsylvania and New York and were provided by 9 different nutritionists or consultants. All of these herds feed total mixed rations. Some key observations from the information in Table 3 are:

1. Milk production per cow is high (> 80 lbs/day) for most herds. The ration for herd D is the high group ration for that farm.

2. Concentration of MUN consistently < 12 mg/dL except for herd N.

3. Most herds feed high (> 55%) forage rations.

4. Ration fat concentrations tend to be moderate whereas nonfibrous carbohydrates and starch are at the upper end of the recommended range in most rations.

5. Corn silage is primary forage in these herds.

6. The efficiency of N use is high in these herds. Milk N efficiency ranged from 28 to 38% of the intake N.

7. There is a wide variation in the amino acid balance in these herds. In most cases, this appears to be an area of opportunity for future consideration.

8. This information does verify that reduced CP rations can be fed in commercial dairy herds and support high milk production, concurrent with improvements in efficiency of N use and reductions in N excretion to the environment.

Challenges to Lowering Ration Crude Protein 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 feed industry professionals and consultants. They vary the safety factor based on their evaluation and assessment of the consistency of forages and daily feeding management practices. In 2006, we surveyed a number of New York feed industry personnel for the challenges they felt needed to be considered as ration CP levels are lowered. The primary factors they listed were:

1. Consistency and quality of daily on-farm feed mixing and feeding management.
2. Daily variations in forage quality and dry matter.
3. Herds feeding total mixed rations versus component fed herds.
4. Lack of on-farm forage dry matter determinations and the use of this information for adjusting the quantity of feeds added to the mixer wagon.
5. Herd grouping and ration strategies.
6. The increasing level of soluble protein in home-produced forages.
7. The increased use of baleage on some farms.
8. Accuracy of the forage samples and the forage lab analyses.
9. Limited availability of MUN values as a monitoring tool.
10. Are our ration formulation tools accurate enough to crank down ration CP?
11. The need to gain experience and a comfort level in lowering CP in rations and observing herd responses.
12. Lack of "real" farm information from herds that have successfully adopted reduced CP rations.

What Do We Balance For?

Crude protein is the term that has been used to formulate and evaluate dairy rations for many years. However, a number of refinements have been added over the years to increase the usefulness of the CP system. These include considering soluble protein, RDP and RUP. The recent Dairy NRC publication indicates that MP should replace CP for ration formulation (NRC, 2001). Metabolizable protein is basically the sum of microbial protein and RUP. The NRC committee examined the relationship between ration CP and milk production using 393 treatment means from 82 published research trials. Ration CP % accounted for only 29% of the variation in milk production in these studies.

Dairy cattle do not have a CP requirement but do need absorbable amino acids to meet requirements to support lactation, pregnancy, maintenance and growth. A more biologically correct way to balance rations is using the MP approach. This is outlined in more detail by Varga (2007). Balancing for MP requires the use of computer models.

What about Ammonia Emissions?

Ammonia emissions from dairy farms are receiving attention due to air quality concerns. More importantly, ammonia emissions represent losses of N from the farm and are an indication of lower efficiency of N use from the feeding program. Nationally, the dairy sector represents about 23.6% of the total ammonia emissions from animal agriculture (USEPA, 2004). Dairy cattle don't emit ammonia directly but rather by conversion of the urea-N in urine being converted to ammonia by action of the urease enzyme contained in the fecal portion of the manure. Yearly ammonia emission factors for dairy cattle used in different parts of the world range from 45 to 83.8 lbs./cow/year (Aneja et. at., 2008). Yearly ammonia emission factors for 4 of the dairy herds in the National Air Emissions Monitoring Study ranged from 28 to 36 lbs/cow/year (Gooch, 2010). Additional information on ammonia emissions from dairy cattle is available (Chase, 2011). An interesting possibility is using milk urea nitrogen as a way to monitor ammonia emissions from dairy cattle (Powell et. al., 2011).

Whole Farm Implications

Improving the efficiency of N use and lowering N excretion to the environment has significant implications for whole farm management. A reduction in yearly N excretion of 50,000 lbs for a 1,000 cow herd would be calculated using the data from the Wu and Satter (2000) study described earlier in this paper. This would greatly alter the acres required for manure spreading if manure application rates are based on N. A paper presented at the 2002 Cornel Nutrition Conference predicted changes in yearly N air emissions for a dairy herd (Jonker et. al., 2002). The herd used had 320 milking and dry cows, 290 replacement heifers and milk production of 26,000 lbs./cow/year. Table 4 contains the results from this paper.

Conclusions

Both research and on-farm trials indicate that many herds have an opportunity to lower ration CP levels without altering milk production. The following points should be kept in mind as you consider implementing this on herds that you work with.

1. Is this herd a candidate for lowering ration CP level:
    a. Is the current ration CP > 16.5%?
    b. Are the herd MUN concentrations > 12 mg/dL?

2. How consistent are the daily feeding and feeding management procedures?

3. How consistent are forages and forage dry matters on a daily basis?

4. Do both you and the dairy producer believe that this approach will work?

5. How will you monitor the potential responses to adjustments in ration CP levels?

I feel that many of our herds have the potential to reduce the ration CP concentrations by at least 0.5 to 1 unit without impacting herd milk production. However, there can be significant economic and environmental impacts of these changes.

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Table 1. Nitrogen intake and excretion from cows fed rations varying in CP content[1]

	Ration CP, %				
Item	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
Milk N, % of N intake	36.5	34	30.8	27.5	25.4

[1] Olmos Colmenero and Broderick (2006).

Table 2. Field trial results

	Herd A		Herd B	
Item	Initial Ration	Final Ration	Initial Ration	Final Ration
Milk, lbs/day	79	80	82	80
Milk fat, %	3.58	3.63	3.56	3.63
Milk true protein, %	3.03	3.11	2.96	3.07
Milk urea N, mg/dL	14.8	12.5	14.5	12
Forage, % of ration DM	54	57	60	48
Corn silage,% of forage	59	71	53	60
Ration (DM basis)				
CP, %	17.5	16.6	17.7	16.9
NDF, %	32.5	33.6	31.3	33.2
Starch, %	23	27.6	23.6	26.3
Fat, %	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
Urine N, g/day	250	204	236	210
Milk N, % of N intake	28	31	28	30
Milk N:Urine N	0.78:1	0.98:1	0.78:1	0.90:1
Feed cost, $/cow/day				
Total	5.88	5.43	6.14	5.97
Purchased feeds	3.55	2.96	3.73	3.42
IOFC, $/day	3.08	3.83	3.01	3.22
IOPFC, $/day	5.41	6.30	5.42	5.77

IOFC = income over feed cost.
IOPFC = income over purchased feed cost.

Table 3. Commercial dairy herds feeding reduced crude protein rations

	Farm													
Item	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Cows	1550	108	270	920	140	100	700	100	180	45	220	45	250	53
Milk, lbs/cow/day	88	88	85	116	89	85	89	89	95	80	75	85	85	72
Milk fat,%	3.6	3.6	3.8	3.2	3.65	4	3.5	4	3.6	3.6	3.85	3.7	3.56	3.64
Milk true protein,%	3.05	3.2	3.07	3	3	3	3.1	3.1	3.1	3.1	3.2	3.2	3.03	2.9
Milk urea N, mg/dL	10.6	12	-	8	8-10	9	7-9	9	8-9	8-9	8-9	8-9	10	14
Ration, DM basis														
CP, %	15.9	15.5	15.7	15.9	14.3	16	16.3	15	15.8	15.6	15	15.6	15.5	15.8
MP, g/cow	2625	2720	2961	3306	2599	3016	2792	2760	2744	2305	2256	2419	2739	-
Lysine, % of MP	6.6	6.23	6.4	6.74	6.42	6.17	6.64	6.49	5.77	6.32	6.23	6.31	6.29	6.4
Methionine,% of MP	1.94	1.96	2.05	2.71	2.1	1.77	2.79	1.89	1.85	1.91	1.88	1.91	1.93	1.9
Lysine to methionine	3.4:1	3.18:1	3.12:1	2.5:1	3.05:1	3.5:1	2.38:1	3.4:1	3.12:1	3.3:1	3.3:1	3.3:1	3.3:1	3.3:1
NDF, %	28.9	30.8	30.7	30.9	31.4	31.5	32.2	28.4	32.3	29.3	31.5	29.3	31.5	33.7
Forage NDF, % of BW	0.88	0.86	0.86	0.94	0.99	0.91	0.88	0.99	0.99	0.89	0.78	0.89	1.02	0.94
NFC, %	43.4	41.9	40.6	41.5	42.4	38.1	39.1	44	39.3	41.3	40.7	44.4	42.5	40
Starch,%	28.5	27.1	31.6	28.7	29.3	24	27.6	30	28.7	28.6	27.6	29.5	28.6	29
Sugar, %	3.5	3.1	4.2	5.4	5	3.3	5.1	4.3	3.5	3.7	3.4	4.1	7.4	3.9
Fat, %	4.3	3.8	4.3	5.1	4.4	5.2	5.4	4.7	5.1	5.1	4.8	4	5.2	4.1
Forage, %	57	60.4	48	60	59	57	53	59	51	59	52	59	55	60
Corn silage, % forage	80	72	37	68	53	47	64	49	58	56	49	38	74	46
Milk N, % of N intake	35	35	32	38	36	28	35	31	35	35	35	36	31	32

Table 4. Impact of different technologies on yearly nitrogen air emissions[1]

Technology used	N emissions, lbs/year	Change from baseline, %
Baseline	66,220	
Precision feeding	51,480	-22
Lagoon cover	55,220	-16
Soil incorporation	43,340	-35
Precision feeding + lagoon cover	43,120	-35
Precision feeding + soil incorporation	34,320	-48
Lagoon cover + soil incorporation	28,600	-57
Precision feeding + lagoon cover + soil incorporation	23,540	-65

[1] Jonker et al. (2002).

SESSION NOTES