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Feeding Protein to Meet Dairy Cow Nutrient Requirements Can Result in Cheaper, Environmentally Friendly Rations

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Animal agriculture is facing the significant issue of managing excreted nutrients, and researchers are designing programs to address the issue. The intense management of animals in the poultry, swine, and dairy industries can contribute to environmental pollution. Although there are more beef than dairy cattle in Virginia, beef cattle are typically maintained on pasture and dispersed over a greater area. Feed management in dairy cows to reduce nutrient consumption has been identified as being very effective in reducing output of potentially polluting nutrients such as nitrogen and phosphorus.

Nitrogen Excretion

Ruminant animals absorb protein directly as amino acids or convert it into microbial protein that is digested and absorbed. Both in turn are used as a source of amino acids for milk protein production or other processes. In reverse, protein digestion results in nitrogen that in excess of requirements is excreted by the animal. The table below shows the distribution of excreted nitrogen in lactating dairy cows fed three concentrations of crude protein. Units are expressed as grams (g) of nitrogen (N) per cow per day.

As nitrogen intake increases, so does its excretion in both the urine and feces, but the increase is greatest in the urine. At 12 percent protein in the ration, the percent of excreted nitrogen in the urine is 39 percent, compared to 44 percent at 15 percent protein and 53 percent at 18 percent protein. The bottom line is the majority of excess fed nitrogen is excreted via the kidneys in urine. In addition, much of the nitrogen in urine is in the form of urea, which is broken down to ammonia and partially volatilized into the atmosphere. It is interesting to note that efficiency of nitrogen utilization (excreted N divided by N intake) was similar across all three protein levels. In this study, milk production was 45 pounds per cow per day and the nitrogen excreted in the milk was approximately 100 grams per cow per day and was not affected by the amount of protein in the ration. However, the amount retained by the cow increased with increased protein in the ration, going from 16 to 43 to 55 grams at 12 percent, 15 percent, and 18 percent protein.

A recent study from the University of Wisconsin looked at the effect of protein source on nitrogen excretion. Alfalfa and corn silages were fed in equal proportions

Table 1: Distribution of excreted nitrogen in lactating dairy cows fed three concentrations of crude protein.

	Intake N, g/day	Urine N, g/day	Fecal N, g/day	Total Excreted, g/day	Excreted/Intake, %
12% protein	359	99	158	257	72
15% protein	449	138	179	317	71
18% protein	582	228	199	427	73

Source: Tomlinson et al. 1996. American Society of Agricultural Engineers.

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at 50 percent of ration dry matter. Solvent (high protein degradability, HD) and expeller (low protein degradability, LD) soybean meals were varied to alter the ratio of rumen degradable to undegradable protein. Both soybean meals were fed in all four diets; only the proportion changed, with the HD diets having the majority solvent soybean meal and the LD diets having more of an equal mixture of solvent and expeller meals.

As shown in table 2, dry matter intake and milk were increased with the addition of expeller soybean meal on both the LD and HD diets. Milk nitrogen in grams per day was also increased by addition of expeller soybean meal, indicating more amino acids were available for milk protein synthesis. Milk urea nitrogen was not different but did tend to be higher on higher protein diets. Table 3 contains information on nitrogen excretion from this experiment.

Clearly, if more nitrogen or protein than needed is consumed, more nitrogen is excreted. In this study, approximately two-thirds of the consumed nitrogen was excreted in urine or feces. This study also demonstrated that as more expeller soybean meal, which was lower in rumen degradability than solvent soybean meal, was fed, the dry matter intake and milk production increased. The opposite was true when solvent soybean meal was fed in excess. Therefore, the protein source is as important as the level of ration protein. In addition, there were differences in excreted nitrogen based on the age or lactation number. First-lactation cows excreted additional nitrogen while multiple-lactation cows retained more of the nitrogen. The authors concluded that first-lactation cows should have balanced rations without excessive protein content, especially when they contain highly degradable protein sources. A separate first-calf heifer group would be required.

Milk Urea Nitrogen as a Tool

Dietary protein that does not end up in the feces or milk is converted to urea and can be excreted in the urine. Urea is a small molecule that travels in the aqueous (water) phases of the cow and appears in the blood, urine, and milk. Because milk urea nitrogen (MUN) is a breakdown product of protein whose concentrations in the aqueous phases is proportional to protein degradation, it can be used to monitor protein status of cows. Feeding protein in excess of needs for milk protein synthesis and animal growth will result in elevated MUN. Conversely, feeding too little protein will compromise milk production and will be associated with low MUN. A report by Wattiaux (*Hoard's Dairyman*, 2005) indicates that a MUN of 11.5 to 12 mg/dl is associated with a ration protein level of 16.5 percent. This can indicate an optimal situation that does not reduce milk production while avoiding excess urinary nitrogen. Wattiaux estimates that there is a 2-mg/dl change for each one-percentage unit change in protein when rations contain 15 percent to 18.5 percent protein. Herds with a MUN above 14 mg/dl would have increased urinary excretion of nitrogen.

Table 2: Effect of HD vs. LD diets on milk nitrogen.

	DM intake, lbs./day	Milk, lbs./day	Milk N, g/day	Milk N, % intake	Milk urea nitrogen, mg/dl
17.0% protein (LD)	50	85	177	29	11.9
18.0% protein (LD)	54	89	189	27	12.5
17.6% protein (HD)	46	82	169	28	12.6
18.7% protein (HD)	52	85	181	25	13.4

Source: Flis and Wattiaux. 2005. Journal of Dairy Science.

Table 3: Effect of HD vs. LD diets on nitrogen excretion.

	Intake N, g/day	Urine N, g/day	Fecal N, g/day	Total Excreted, g/day	Excreted/ Intake, %
17.0% protein (LD)	618	194	209	403	65
18.0% protein (LD)	707	213	232	445	63
17.6% protein (HD)	596	202	190	392	66
18.7% protein (HD)	712	223	208	431	61

Source: Flis and Wattiaux. 2005. Journal of Dairy Science.

Factors that can influence MUN concentrations are:

- **Protein intake** (both rumen degradable and undegradable),
- **Energy intake** (especially rumen available energy needed to capture rumen available N),
- **Heat damage** (resulting in reduced protein and energy digestibility),
- **Consumption of water** (dehydration increases MUN), and
- **Feed sorting**.

Air Emissions

Air emissions are becoming an issue with animal production units and ammonia is one of the primary concerns. The industrial standard limits ammonia release to a maximum of 100 pounds of ammonia per day into the atmosphere. Rotz (*Hoard's Dairyman*, 2005) estimates emission rates of ammonia on dairy farms range from 0.18 to 1 pound/cow/day, depending on the type of housing and manure handling system. The 0.18-pound emission rate would mean a 550-cow herd would be needed to produce 100 pounds of ammonia but at the 1-pound rate, only 100 cows would be needed. In addition to feeding excess protein, factors such as temperature (high temperature results in more emissions), manure pH (high pH results in more volatilization), and manure handling impact ammonia volatilization. The majority of excess nitrogen is excreted in the urine, which is most prone to volatilization. A management strategy to reduce ammonia emissions would be to fine-tune the ration to avoid feeding excess protein. Covered manure storage and manure injection into the soil are also recommended ways of reducing nitrogen emissions.

Level of Protein and Rumen Degradibility

How much protein is needed for lactating dairy cows? Certainly the 12 percent protein in the experiment previously described would not be adequate for most modern dairy cows. Could less than 18 percent be used with no loss of milk production? In some cases it seems possible if there is the proper balance of rumen degradable (RDP) and undegradable (RUP) protein in combination with adequate rumen available energy. Typically, rations for lactating cows have 60 percent to 64 percent of the protein as RDP and 36 percent to 40 percent as RUP. The calculation of nonfiber carbohydrates (NFC = (100 - (crude protein + fat + (NDF – NDF crude protein) + minerals) in a ration indicates rumen available energy. Usually rations have 35 to 40 percent NFC in the dry matter. Rations balanced within these parameters can sometimes contain less protein without negative production impacts, especially if dry matter intake is maintained at desirable levels. Also, it appears age or the lactation number should be considered when managing the lactating herd. Keeping first-lactation cows apart from the rest of the herd has merit from both a social as well as a nutritional and environmental standpoint. A lower protein level is warranted when feeding first-lactation cows relative to older cows because they are usually lower producing and thus have lower protein requirements.

Dry Matter Intake

Since the nutrients consumed are in the dry matter, it is important to know dry matter intake to calculate actual protein or nitrogen intake. In Table 4 are whole-herd projections for the 2001 NRC for 1,400- and 900-pound cows producing 4.0 percent and 5.0 percent fat milk respectively and varying in milk production. It is best to know what the actual dry matter intake is for the herd or by groups. This is the amount fed minus the refusals. Accomplishing this requires knowing the dry matter content of feedstuffs or the overall ration. Table 4 represents the expected dry matter intake for herds or groups of cows and is not for individual animals because days in milk can have an impact.

Best Management Practices to Prevent Overfeeding Protein

1. Balance ration for total protein, rumen degradable (60 percent to 64 percent of total protein) and undegradable (36 percent to 40 percent) protein, and rumen available energy as measured by nonfiber carbohydrates (35 percent to 40 percent or ration dry matter) or starch as well as total energy.
2. Monitor dry matter intakes weekly on all groups and calculate nitrogen intakes relative to requirements.
3. Analyze feeds each month for total protein and degradable protein. If heat damage is suspected, measure acid detergent insoluble nitrogen (ADIN) or acid detergent crude protein (ADFCP). Levels exceeding 10 percent of the total protein indicate overheating.
4. Group cows by production and feed accordingly.
5. Prevent feed sorting by feeding a ration properly mixed with uniformity of feed delivered; particle size separation at different feed bunk locations can be monitored by using a particle size separator.
6. If bulk tank MUN is above 14 mg/dl, consider modifying the ration; rations below 12 are considered best from an environmental standpoint.
7. If bulk tank MUN is below 8 mg/dl, protein consumption may be low or feeds may be heat damaged.

Recommended Protein Levels

Most people think in terms of percentages or concentrations of protein in the ration; therefore, the authors give in Table 5 their interpretation of the material provided by the Feed Management Education Project coordinated by Joe Harrison of Washington State University. As more of the best management practices (BMPs) are followed, the concentration of protein in the ration can usually be reduced as long as cows are eating acceptable amounts of dry matter. If dry matter intakes are restricted, higher levels of protein may be warranted.

Table 4: Whole-herd projections of dry matter intake

Milk, lbs/cow/day	30	40	50	60	70	80	90
Dry matter intake, lbs./day							
900 lbs body weight	30.5	34.6	38.6	42.7	46.8	50.8	54.9
1400 lbs body weight	36.2	39.7	43.2	46.7	50.3	53.8	57.3

Source: National Research Council. 2001.

Table 5: Relation of BMP used to protein concentrations.

	Use majority of BMPs	Use less than half of BMPs	Don’t use BMPs
High group	16-16.9% CP	17-17.9% CP	18-18.5% CP
Medium/low group	13-13.9%	14-14.9%	15-15.9%
Dry cows	11-11.9%	12-12.9%	13-13.9%

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