



Feeding Low Protein Diets to Dairy Cows

Discussion of benefits to feeding diets with lowered protein content while meeting true animal requirements for metabolizable protein.

 ARTICLES



Introduction

The role of dietary protein in the nutrition of the dairy cow and overall farm sustainability can be summarized as: (1) effects on dry matter

intake (DMI), milk yield, and milk composition, (2) effects on feed costs, (3) environmental effects, and (4) possible effects on reproduction efficiency. Feeding diets with lowered protein content reduces nitrogen input, improves nitrogen utilization efficiency, and reduces nitrogen losses from manure. Reducing dietary protein also benefits the producer by reducing feed cost and improving overall farm profitability. There are many examples where decreasing protein concentration in dairy diets dramatically decreased manure nitrogen losses without affecting animal production. These interventions, however, have to be balanced with the risk of loss in milk production. If the true animal requirements for metabolizable protein are not met, long-term production cannot be sustained. Dietary protein should not be reduced in diets that do not meet the requirements of the animal for other nutrients, particularly energy.

The NRC (2001) definition for metabolizable protein is: digestible protein (digestible total amino acids) that is provided to the animal through ruminally synthesized microbial protein and feed protein that escapes ruminal degradation (but is digested and absorbed in the small intestine).

How Low Can We Go?

How much can metabolizable protein in a diet be decreased before production is affected? In some cases, dietary crude protein (CP) as low as 12% did not affect milk production in dairy cows, although nutrient digestibility and microbial protein synthesis in the rumen were depressed (Aschemann et al., 2012). In that study, however, cows were relatively low producers (about 64 lbs/d) and intake was restricted, meaning the important effect of protein on feed intake could not be demonstrated. In some trials, although not statistically significant effects, metabolizable protein-deficient diets showed clear numerical trends for decreased DMI and/or milk production. For example, Olmos Colmenero and Broderick (2006) fed diets varying in CP content from 13.5 to 19.4% [rumen-degradable protein (RDP) increased from 9.3 to 12.7% and rumen-undegradable protein (RUP) from 4.2 to 6.7%]. Dry matter intake and milk yield were not affected statistically in this trial, but the 13.5% CP diet resulted in about 1.5 lbs/d less DMI ($P > 0.22$) and 4.4 lbs less milk ($P = 0.10$) compared with the 16.5% CP diet.

Trials with high producing dairy cows at Penn State have shown a variable effect of decreasing dietary CP or metabolizable protein on DMI. In trials where DMI was decreased when feeding the metabolizable protein deficient diets, milk production also decreased (Lee et al., 2011a; Lee et al., 2012a). On the contrary, when DMI did not decrease, milk production was also not different from diets with adequate metabolizable protein (Lee et al., 2012b; Giallongo et al., 2014). In all trials to date, total tract apparent neutral detergent fiber (NDF) digestibility was decreased (6 to 20%) by the low CP, metabolizable protein deficient diets. Interestingly, this did not affect milk production or milk fat content (although the cows did not quite reach the same production as cows fed excess metabolizable protein; Lee et al., 2012b). This could be a result of the high DMI in these trials. It appears that production losses with low-protein diets are caused by: (1) depressed DMI due to impaired rumen function or physiological regulation of intake, (2) deficiency of RDP, which may cause decreased fiber digestion, and (3) insufficient supply of key amino acids limiting milk protein synthesis.

The effect of low protein diets on feed intake is critical and must always be considered (Lee et al., 2012a). For example, an analysis of the literature from a few years ago (31 studies published in the *Journal of Dairy Science* from 1995 to March 2008 that investigated CP level in the diet; Huhtanen and Hristov, 2009) showed increased milk protein yield with increasing dietary CP in 7 experiments. In 5 of these 7 experiments, however, the effect on milk protein

yield was through increased DMI. Only in 2 trials was milk protein yield significantly increased with increasing dietary CP concentration without an effect on DMI.

Strategies for Feeding Low Protein Diets

The dairy NRC (2001) model predicts that a diet based on corn silage, alfalfa hay, steam-flaked corn, soybean meal, whole cottonseed, and 0.5% (DM basis) blood meal with about 16% CP and at 55 lbs/d DMI meets the metabolizable protein requirements (and exceeds the NE_L requirements) of a 1,500-lb, 90-days-in-milk cow with milk production of 88 lbs/d and 3.0% true protein. In our experiments at Penn State, a diet based on corn silage, alfalfa haylage, grass hay, whole roasted soybeans, canola meal, and about 6% bypass soybean meal containing 16% CP met the metabolizable protein requirements of cows at a similar level of production. The RDP balance for this diet was on average +3 g/d. If this diet was formulated at 17% CP, by replacing the hay with haylage and including some solvent-extracted soybean meal (partially replacing the bypass soybean meal), the metabolizable protein requirements would still be met but the RDP balance would be +286 g/d. As demonstrated in a number of experiments, RDP excess will increase urinary nitrogen and urea losses and, consequently, ammonia emissions from manure (van Duinkerken et al., 2005; Agle et al., 2010). In the study by Olmos Colmenero and Broderick (2006), for example, urinary urea-nitrogen excretion more than tripled when CP content of the diets increased from 13.5 to 19.4%. Decreasing RDP balance to about -200 g/d resulted in a 40% decrease in the ammonia-emitting potential of manure in the study by Lee et al. (2012b).

Long-term (up to 10 weeks), continuous design trials conducted with cows producing 84 to 95 lbs milk/d at Penn State showed that decreasing NRC (2001) estimated metabolizable protein supply to 8 to 13% below requirements may depress DMI and/or decrease milk production. These diets were usually around 14% CP. In one study (Lee et al., 2012b), diets that were 12 to 13% deficient in metabolizable protein (14% CP) but supplemented with rumen-protected amino acids did not result in decreased production. In a recent trial with cows milking around 95 to 99 lbs/d, 5 to 8% metabolizable protein deficient diets also did not result in depressed DMI or milk production (Giallongo et al., 2014). It may be important to point out that in these trials the calculated metabolizable protein balance was based on the actual DMI and production of the cows. The correct way of estimating metabolizable protein requirements - based on actual or potential milk production and composition - may be debated. In some cases,

this could make a difference (for example, if estimated milk production is greater than 10 lbs more than actually produced), although in the Penn State trials, we found it of little relevance.

The first and most important factor for successful reduction of dietary protein close to or below the animal's metabolizable protein requirements is to keep dietary energy balance at or slightly in excess of requirements. Amino acids are inevitably used for glucose synthesis by the cow, but their role as a source of energy to sustain production becomes more important if dietary energy is deficient. In our experience, diets with CP of around 14% are RDP deficient, which is manifested in decreased total tract NDF digestibility. Although we have not measured ruminal fiber degradability, it is safe to assume that a big part, if not all, of the decrease in total tract fiber digestibility occurred in the rumen. We were not able to detect, at least with the indirect method we used, a consistent response in microbial protein syntheses in the rumen with the low CP diets. Overall, our data indicate that diets with RDP of around 9 to 10% (of dietary DM) decrease fiber digestibility, but do not appear to have a consistent effect on ruminal microbial protein synthesis.

The NRC (2001) model over-predicts the effects of metabolizable protein on milk production. In our trials with metabolizable protein deficient diets, the NRC (2001) protein model under-predicted milk response by about 5 lbs per 100 g of metabolizable protein deficiency (Lee et al., 2012b). Similar trends were reported by Lee et al. (2012a); on average, under-prediction of milk yield in the metabolizable protein deficient groups of cows was 22.7 ± 1.7 lbs/d. In a more recent trial with 60 cows in which DMI was not affected by the metabolizable protein deficient diets, milk yield was under-predicted by NRC (2001) on average by 7.7 ± 1.5 lbs/d (Giallongo et al., 2014). Possible reasons for these effects may include overestimation of RDP requirements, sufficient urea recycling, and variable efficiency of conversion of metabolizable protein for metabolic functions (see discussions in Doepel et al., 2004 and Huhtanen and Hristov, 2009).

Diets with CP concentration of 16% or less are not uncommon on commercial dairies in the Northeast. In our on-farm projects (unpublished data from Hristov et al., 2012 and Weeks et al., 2014) total mixed rations (TMR) from dairies that ranged from 60 to 80 lbs milk/d often analyzed below 16 and in some cases below 15 and even 14% CP. While some of this may be due to unrepresentative sampling and other factors that could affect diet composition (TMR mixing, for example), it is apparent to us that on commercial farms, and particularly when feed prices are high, diets may reach critically low levels of CP that may limit production in some herds.

Supplementing Specific Amino Acids

Supplementation with rumen-protected amino acids that are limiting milk production and milk protein synthesis may compensate for metabolizable protein deficiency in dairy cow diets. In some cases, this was a successful strategy to maintain production (Leonardi et al., 2003; Berthiaume et al., 2006; Broderick et al., 2008), but not in others (Socha et al., 2005; Davidson et al., 2008; Benefield et al., 2009). Amino acid supplementation research at Penn State has pointed to histidine as a limiting amino acid in dairy cows fed typical North American diets based on corn silage, alfalfa haylage, corn grain, and soybean or canola meals. Lee et al. (2012a) reported a trend for increased DMI when rumen-protected histidine was added to a 13% metabolizable protein deficient diet supplemented with rumen-protected lysine and methionine. The increased DMI triggered milk and milk protein yield responses. Analysis of rumen bacterial samples from various trials conducted at Penn State indicated about 27% lower histidine than methionine concentration in bacterial protein. Microbial protein is an increasingly important source of amino acids for the cow when metabolizable protein deficient diets are fed, and we proposed that histidine may be a limiting amino acid in high-producing dairy cows fed diets deficient in metabolizable protein. Our analysis indicated that the proportion of histidine in metabolizable protein should be similar to that of methionine, which, for practical purposes, is suggested to be 2.2%. Others have suggested histidine requirements of 2.4 (Doepel et al., 2004), 2.3 (Lapierre et al., 2014), and up to 3.4% (Rulquin and Pisulewski, 2000) of metabolizable protein.

Our hypothesis that histidine is a limiting amino acid in North American dairy cows was based on data from Europe with grass silage-based diets (Kim et al., 1999; Vanhatalo et al., 1999) and the consistently lower blood plasma histidine concentrations in long-term trials with metabolizable protein deficient diets conducted at Penn State (Lee et al., 2012a,b). We have to emphasize the importance of experimental design in trials investigating production effects. In contrast to data from long-term experiments (Lee et al., 2012a,b), plasma histidine concentrations were not different in cows fed diets adequate or deficient in metabolizable protein in a parallel Latin square design trial with 21-d experimental periods (Lee et al., 2011b). As discussed by Lapierre et al. (2008), histidine may be unique among the essential amino acids by having labile pools that provide a source of stored histidine during short periods of deficiency (i.e., intramuscular carnosine and anserine, dipeptides containing histidine, and circulating hemoglobin). Carnosine along with hemoglobin as sources of histidine have been discussed in human nutrition, and negative nitrogen balance and decreased

blood hemoglobin have been observed in rats when histidine was omitted from the diet. In dairy cows, the carnosine/hemoglobin mechanism may be sufficient to maintain histidine supplies in short-term experiments.

We have recently conducted a 10-week randomized complete block design trial with 60 cows (87 ± 40 days in milk) with the main objective of investigating the effects of slow-release urea and rumen-protected methionine and histidine supplementation of a metabolizable protein deficient diet on lactation performance (Giallongo et al., 2014). By inclusion of slow-release urea in the diet, we were hoping to address the lower NDF digestibility observed with metabolizable protein deficient diets in our earlier trials. This trial had 5 treatments: a control (meeting metabolizable protein requirements of the cows) and metabolizable protein-deficient diets supplemented with slow-release urea and rumen-protected methionine and histidine. The diets were based on corn silage and contained from 14.8 to 16.7% CP. The metabolizable protein balance (based on NRC, 2001) ranged from +200 to -250 g/d. All diets were deficient in lysine (from -10 to -28 g digestible lysine/d). The diets that were not supplemented with rumen-protected amino acids were also deficient in methionine (from -13 to -17 g digestible methionine/d). The diets not supplemented with histidine were -5 to -8 g/d deficient in digestible histidine. Similar to previous trials, urinary nitrogen and urea excretions were decreased by the diet deficient in metabolizable protein. Dry matter intake was not affected by metabolizable protein level, but tended to be higher for the rumen-protected histidine diet. Yields of milk and milk fat were not affected by treatment. Milk true protein content was increased, and milk protein yield was numerically increased by rumen-protected histidine addition. Cows fed the diet deficient in metabolizable protein (14.8% CP) gained 14 g/d of body weight, whereas cows on all other treatments (control or slow-release urea and rumen-protected amino acids) gained on average 267 g/d. This important observation, which was unlikely to be detected in a short-term trial, suggested that cows on the deficient diet were not gaining weight, whereas cows on the supplemented diets were recovering weight lost in early lactation. The conclusion from this trial was that feeding a 5% metabolizable protein deficient diet did not decrease DMI and yields of milk and milk components. Supplementation with rumen-protected histidine tended to increase DMI and increased milk protein content. These results confirmed our previous data and suggest that histidine may have a positive effect on voluntary feed intake in high-yielding dairy cows. We were not able to show a positive effect of slow-release urea on total tract fiber digestibility.

Conclusions

Dietary protein intake is the most important factor determining, milk nitrogen efficiency, urinary nitrogen losses, and consequently, ammonia emissions from dairy cow manure. Dairy cows producing up to 88 lbs/d can be safely fed balanced diets with 16% (and even 15%) CP without affecting milk production or composition. Diets with CP < 15% (metabolizable protein deficiency of < -12%) will likely result in decreased milk yield, partially through decreased DMI. Low CP diets (i.e., deficient in metabolizable protein) may benefit from supplementation with rumen-protected amino acids limiting production (again, partially through an effect on DMI). Our data demonstrated that histidine is a limiting amino acid in metabolizable protein deficient, corn silage/alfalfa haylage-based diets and long-term trials showed that supplementation of these diets with rumen-protected histidine increased or tended to increase milk yield and milk protein percent and yield, mainly through increasing DMI. Total tract digestibility of NDF will likely be decreased with diets with CP < 16% (RDP \leq 10% of DM).

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Reviewed by Robert A. Patton, Nittany Dairy Nutrition and Antonio Faciola, University of Nevada