Feeding Metabolizable Protein-Deficient Rations is a Reality with Rumen Protected Amino Acid Supplementation

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Protein feeds are usually the most expensive ingredients in dairy rations. Reducing feed cost by feeding less protein is an attractive strategy to increase income-over-feed-costs (**IOFC**) and farm profitability. An on-farm study with 12 Pennsylvania dairies (169 ± 50 cows) demonstrated the opportunity to decrease dietary crude protein (**CP**) concentration and increase IOFC without affecting milk production or composition (Hristov et al, 2012). As shown in Fig. 1, over a 2-yr period, dietary CP decreased by about 1%-unit and IOFC increased by $0.61/cow/d. Milk yield [32.2 vs. 32.5 kg/d (70.8 and 71.5 lb/d); *P* = 0.8] and milk composition were not different between the High- and Low-protein periods.

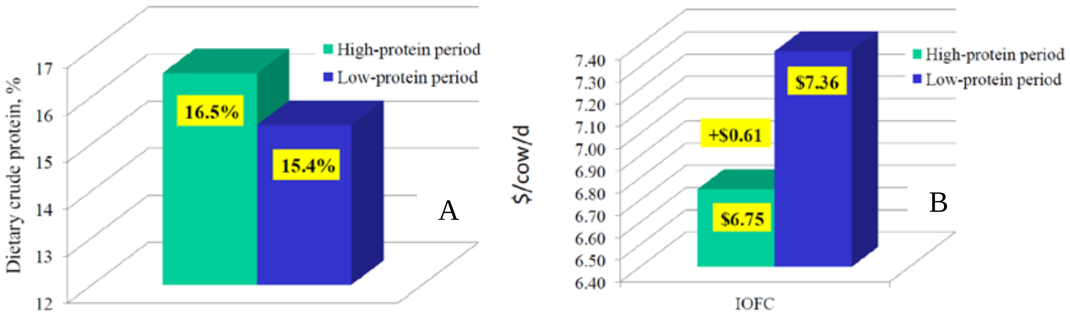

Figure 1. Average ration crude protein (panel A) and IOFC (panel B) in commercial dairies during a 2-yr period, before (High-protein period) and after (Low-protein period) dietary protein reduction (data from Hristov et al., 2012).

Another important implication of reducing dietary CP is reduction of ammonia and potentially nitrous oxide emissions from manure during storage and soil application (Hristov et al., 2011, 2013). In the above-mentioned on-farm project, the ammonia emitting potential of manure (based on evaluation of manure emissions in standardized conditions) was on average 23% lower ($P < 0.001$) for manure from the Low- vs. High-protein periods (292 vs. 378 mg/m^2/h). The mechanism of reducing ammonia emission with low-CP diets is through a reduction in urinary urea excretion. It is well documented that urea in urine is the most important source of ammonia emitted from cattle manure (Lee et al., 2011a), emphasizing the importance of reducing urinary N losses and/or shifting N excretion from urine to feces. Because CP intake is the primary factor determining milk N efficiency, cows fed diets with reduced dietary CP have increased N utilization efficiency (Olmos Colmenero and Broderick. 2006; Huhtanen and Hristov, 2009).

Interventions aimed at reducing dietary CP concentration, however, have to be balanced with the risk of lost production. If animal requirements for metabolizable protein (**MP**) are not met, production cannot be sustained. Milk production of high-producing dairy cows, for example, was reduced with diets containing around 14% CP (Lee et al., 2011b; Lee et al., 2012a). Production losses with low-protein diets can be caused by: (1) depressed dry matter intake (**DMI**) due to impaired rumen function or physiological regulation of intake, (2) deficiency of ruminally-degradable protein (**RDP**), and/or (3) insufficient supply of key amino acids (**AA**) limiting milk protein synthesis. The effect of low-protein diets on feed intake is critical and must always be considered (Lee et al., 2012a). In some cases, dietary CP as low as 12%, did not affect milk production of dairy cows, although nutrient digestibility and microbial protein synthesis in the rumen were depressed (Aschemann et al., 2012). In the latter study, however, intake of the cows was restricted and the important effect of protein on DMI could not be demonstrated. Supplementation with rumen-protected (**RP**) AA limiting milk production and milk protein synthesis may compensate for the deficiency of MP. In some cases, this was a successful strategy (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). This uncertainty of the impact of low-protein diets on milk production can jeopardize efforts for promoting environmentally-sustainable practices to the dairy industry. Thus, it is important to elucidate the mechanisms by which dietary protein and postruminal AA supply regulate feed intake and milk production in dairy cows, so the effect of protein feeding on animal production can be successfully predicted.

Inaccurate estimation of feed RDP, unaccounted physiological mechanisms such as urea recycling, and improved efficiency of conversion of MP to milk protein (Doepel et al., 2004; Huhtanen and Hristov, 2009) as diets become increasingly deficient in MP are likely responsible for the observed underprediction of milk yield in cows fed MP-deficient diets in a series of experiments conducted at Pennsylvania State University. In these experiments, urinary N losses, blood urea, and milk urea N were consistently decreased compared with the control, MP-adequate diets (Lee et al., 2011b, 2012a,b). In some experiments, however, DMI, milk production, and milk protein concentration were decreased with the MP-deficient diets. Supplementation with RPAA (Met and Lys) appeared to alleviate some of these negative effects, but the trends for depressed DMI and milk production still existed (Lee et al., 2012b).

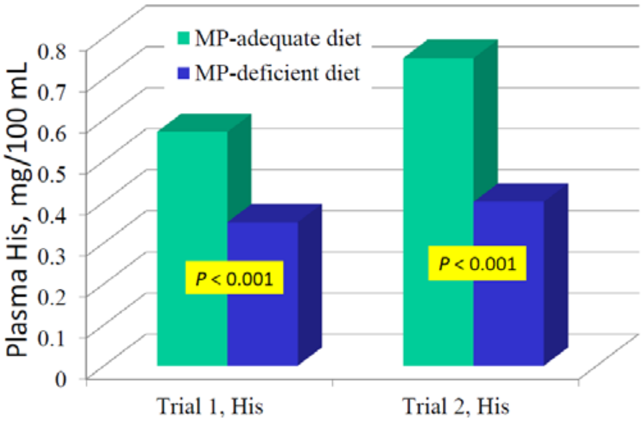

Figure 2. Effect of dietary metabolizable protein (MP) supply on blood plasma His concentration in lactating dairy cows (Exp. 1; SEM = 0.053, *P* = 0.001; Exp. 2; SEM = 0.042, *P* < 0.001). The MP-adequate diets met MP requirements of the cows and the MP-deficient diets were about 12 to 15% deficient in MP according to NRC (2001) (data from Lee et al., 2012a,b).

Analysis of the data from these long-term, continuous design studies showed a clear trend for decreased blood plasma His concentrations with the MP-deficient, compared with the control diets (Fig. 2). Further, analysis of rumen bacterial samples from unrelated experiments conducted at Pennsylvania State University indicated about 27% lower His than Met concentration in bacterial protein. Microbial protein is an increasingly important source of AA for the cow when MP-deficient diets are fed. Therefore, based on the plasma His and ruminal bacterial AA composition data, we hypothesized that His may become a limiting AA in high-producing dairy cows fed corn silage- and alfalfa haylage-based diets deficient in MP. Indeed, His has been identified as the first limiting AA in lactating cows fed grass silage-based diets with low inclusion of plant protein supplements (Kim et al., 1999; Vanhatalo et al., 1999), but has not been implicated as a limiting AA in dairy cows fed typical North American, corn and alfalfa silage-based diets.

To test our hypothesis, we conducted a long-term (12 wks), continuous design experiment with 48 lactating dairy cows (75 ± 5.6 days in milk). Treatments were:

control, MP-adequate diet (**AMP**; MP balance: +9 g/d); MP-deficient diet (**DMP**; MP balance: -317 g/d); DMP supplemented with RPLys (AminoShure®-L; Balchem Corporation, New Hampton, NY) and RPMet (Mepron®, Evonik Industries AG, Hanau, Germany; **DMPLM**); and DMPLM supplemented with an experimental RPHis preparation (**DMPLMH**; Balchem Corporation). Crude protein content of the AMP and DMP diets was 15.7 and 13.5 to 13.6%, respectively. Apparent total tract digestibility of all measured nutrients, plasma urea-N, and urinary-N excretion were decreased by the DMP diets compared with AMP. Milk N secretion as a proportion of N intake was greater for the DMP diets compared with AMP. Compared with AMP, DMI tended to be lower (*P* = 0.06) for DMP, but was similar for DMPLM and DMPLMH (Table 1). Milk yield was decreased by DMP, but was similar to AMP for DMPLM and DMPLMH, paralleling the trend in DMI. Milk fat and true protein content did not differ among treatments, but milk protein yield was increased by DMPLM and DMPLMH compared with DMP and was not different from AMP. Supplementation of the DMP diets with RPAA increased plasma Lys, Met, and His concentrations. These data clearly identified His as a limiting AA in high-producing dairy cows fed corn silage and alfalfa haylage-based diets, deficient in MP. Urinary N losses were dramatically decreased by the DMP diets. Based on our data and the similar concentration of Met and His in milk protein essential AA (5.5%, according to NRC, 2001), we concluded that MP should contain 2.2% His for lactating dairy cows fed corn silage and alfalfa haylage-based diets (similar to the recommended concentration of Met in MP; Schwab et al., 2005).

Table 1. Effect of metabolizable protein (MP) supply and rumen-protected amino acid supplementation on dry matter intake (DMI) and milk production and composition in dairy cows (data from Lee et al., 2012a).

	Diet					
Item	AMP	DMP	DMPLM	DMPLMH	SEM	*P*-value
DMI, kg/d	24.5	23.0	23.7	24.3	0.43	0.06
Milk yield, kg/d	38.8^{a}	35.2^{b}	36.9^{ab}	38.5^{a}	0.74	<0.01
Milk fat, kg	1.34	1.20	1.21	1.23	0.045	0.10
Milk true protein, kg/d	1.13^{a}	1.01^{b}	1.10^{a}	1.14^{a}	0.025	<0.01

^{a,b,c} Within a row, means without a common superscript letter differ (*P* < 0.05). AMP = MP balanced diet; DMP = MP-deficient diet; DMPLM = DMP supplemented with RPLys (AminoShure®-L) and RPMet (Mepron®); DMPLMH = DMPLM supplemented with an experimental RPHis product (Balchem Corp., NY).

Take-home message:

When coupled with high-quality forages and a well-balanced diet, decreasing CP concentration in lactating cow diets to 16 and even 15% (DM basis) is unlikely to result in loss of production or changes in milk composition in cows producing up to 36 kg/d (80 lb/d) milk, will increase milk N efficiency and IOFC, and will decrease N losses with urine and ammonia emissions from manure. Feeding diets with CP below 15% (MP deficiency of around -15%; NRC, 2001) to cows milking >40 kg/d (>88 lb/d), however, may result in decreased milk and milk protein yields, although milk production will be significantly greater than predicted by NRC (2001). Data from long-term experiments (Lee et al., 2012a; Giallongo et al., unpublished) showed increased DMI with rumen-protected AA supplementation, particularly when His were supplemented (in addition to Lys and Met or Met alone). The increased DMI triggered milk and milk protein yield responses with the AA-supplemented diets. Thus, supplementation of a MP-deficient diet with rumen-protected AA (Met, Lys, and His) has the potential to reduce N losses and gaseous N emissions while maintaining milk production and milk protein yield in dairy cows.

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