J. Dairy Sci. 89:1704–1712

Effect of Dietary Crude Protein Concentration on Milk Production and Nitrogen Utilization in Lactating Dairy Cows[1]

J. J. Olmos Colmenero*[2] and G. A. Broderick†[3]
*Department of Dairy Science, University of Wisconsin, Madison 53706
†Agricultural Research Service, USDA US Dairy Forage Research Center, 1925 Linden Drive West, Madison, WI 53706

ABSTRACT

Forty lactating Holstein cows, including 10 with ruminal cannulas, were blocked by days in milk into 8 groups and then randomly assigned to 1 of 8 incomplete 5 × 5 Latin squares to assess the effects of 5 levels of dietary crude protein (CP) on milk production and N use. Diets contained 25% alfalfa silage, 25% corn silage, and 50% concentrate, on a dry matter (DM) basis. Rolled high-moisture shelled corn was replaced with solvent-extracted soybean meal to increase CP from 13.5 to 15.0, 16.5, 17.9, and 19.4% of DM. Each of the 4 experimental periods lasted 28 d, with 14 d for adaptation and 14 d for data collection. Spot sampling of ruminal digesta, blood, urine, and feces was conducted on d 21 of each period. Intake of DM was not affected by diet but milk fat content as well as ruminal acetate, NH_3, and branched-chain volatile fatty acids, urinary allantoin, and blood and milk urea all increased linearly with increasing CP. Milk and protein yield showed trends for quadratic responses to dietary CP and were, respectively, 38.3 and 1.18 kg/d at 16.5% CP. As a proportion of N intake, urinary N excretion increased from 23.8 to 36.2%, whereas N secreted in milk decreased from 36.5 to 25.4%, as dietary protein increased from 13.5 to 19.4%. Under the conditions of this study, yield of milk and protein were not increased by feeding more than 16.5% CP. The linear increase in urinary N excretion resulted from a sharp decline in N efficiency as dietary CP content increased.
Key words: dietary crude protein, milk production, nitrogen utilization

INTRODUCTION

Producers often feed high CP diets to ensure a sufficient supply of the MP required for maximal milk and protein production of dairy cows. A survey of 6 Wisconsin dairy farms with mean rolling herd averages of 14,140 kg indicated lactating cows were fed diets averaging 19.1% CP of DM, with a range from 18.0 to 21.5% (Gunderson et al., 1998). However, several studies have reported no improvement in milk and protein production when dietary CP was increased from 16.1–16.7% to 18.4–18.9% (Cunningham et al., 1996; Broderick, 2003; Leonardi et al., 2003).

It is well established that, as the CP content of the diet increases, the amount of protein degraded in the rumen also increases. If RDP exceeds microbial needs, then large amounts of NH_3 are produced, absorbed into the blood, converted to urea in the liver, and excreted in the urine. In the manure, urinary urea can be rapidly hydrolyzed to NH_3 and lost by volatilization to the environment (Muck, 1982). Overfeeding CP also reduces profit margins because of the relatively high cost of protein supplements and the poor efficiency of N use by dairy cows fed high protein diets (Broderick, 2003).

Although a wide range of RDP values have been reported for solvent-extracted soybean meal (**SSBM**), the most common protein source fed to dairy cows in the United States, an overall mean of about 65% is given by NRC (2001). Substitution of high RUP sources in dairy diets often has been used to increase MP flow to the small intestine. However, reviews by Santos et al. (1998) and Ipharraguerre and Clark (2005) summarized data showing that adding RUP to the diet, at the expense of SSBM, often had little effect on MP supply because of depressed ruminal formation of microbial NAN. A recent trial indicated that omasal flow of bacterial and total NAN decreased linearly, despite increased flow of nonmicrobial NAN, when lignosulfonate-treated soybean meal replaced SSBM in the diet (Reynal and Broderick, 2005).

Therefore, the objective of this study was to determine the optimum CP content of the diet required to maximize production of milk and protein at minimal N excretion by cows fed diets formulated from typical US ingredients.

Received June 6, 2005.
Accepted January 4, 2006.
[1]Mention of any trademark or proprietary product in this paper does not constitute a guarantee or warranty of the product by the USDA or the Agricultural Research Service and does not imply its approval to the exclusion of other products that also may be suitable.
[2]Present address: Centro Universitario de los Altos, Universidad de Guadalajara, Carretera a Yahualica Km. 7.5, Tepatitlan de Morelos, Jalisco, Mexico CP 47600.
[3]Corresponding author: gbroderi@wisc.edu

Table 1. Composition of feeds[1]

Item	Alfalfa silage		Corn silage		RHMSC		SSBM		RSB	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DM, %	44.2	5.8	41.2	2.7	72.4	1.6	91.1	0.9	97.7	0.5
CP, % of DM	22.9	1.2	7.23	0.60	8.44	0.62	52.0	2.7	40.0	0.7
Ash, % of DM	10.7	0.8	4.13	0.36	1.95	0.28	7.52	0.19	5.40	0.58
NDF, % of DM	35.8	4.4	36.1	2.1	8.32	0.75	8.06	0.46	23.9	0.9
ADF, % of DM	27.0	3.8	18.3	0.8	1.97	0.18	4.57	0.41	4.04	1.40
Neutral detergent insoluble CP, % of DM	1.41	0.76	0.28	0.03	0.18	0.08	0.26	0.10	3.30	0.50
pH	4.71	0.22	3.89	0.08	4.38	0.07	—	—	—	—
NPN, % of total N	46.3	6.9	55.9	7.6	31.3	4.6	—	—	—	—
NH_3 N, % of total N	6.48	3.55	8.69	1.76	3.64	1.27	—	—	—	—
Free AA N, % of total N	25.9	4.7	36.3	6.3	20.3	2.9	—	—	—	—
Unidentified NAN, % of total NPN	14.0	1.9	10.9	1.6	7.32	1.18	—	—	—	—

[1]RHMSC = Rolled high-moisture shelled corn; RSB = roasted soybeans; and SSBM = solvent-extracted soybean meal.

MATERIALS AND METHODS

Experimental Procedure

Thirty-eight multiparous and 2 primiparous Holstein cows (8 multiparous and 2 primiparous cows were ruminally cannulated) averaging 120 DIM (SD 76), 2.5 parity (SD 1.1), 589 kg of BW (SD 58), and 41 kg of milk/d (SD 6) were blocked by DIM into 8 groups (2 groups of ruminally cannulated animals) then randomly assigned to 1 of 8 diet sequences in an incomplete 5 × 5 Latin square (5 diets and 4 periods). This design, rather than a complete 5 × 5 Latin square, was used because there was insufficient alfalfa and corn silage to complete a fifth period. The duration of each experimental period was 28 d with 14 d for diet adaptation and 14 d for collection of data. Cows were held in tie stalls for the duration of the experiment, had free access to water, and were weighed on 3 consecutive days at the beginning and at the end of each period. All animals were injected with recombinant bST (500 mg of Posilac; Monsanto, St. Louis, MO) every 14 d starting on the first day of the experiment. Animal care and experimental procedures met the requirements of the Institutional Animal Care and Use Committee of the UW-Madison (Research Animal Resources Center protocol # A-07-3400-A00286). Two intact cows had sharp drops in milk yield during the last 2 wk of period 1 and were removed from the experiment; one ruminally cannulated cow was removed from the trial after period 3 for health reasons unrelated to the experiment.

The experimental diets were fed as TMR and contained 25% alfalfa silage, 25% corn silage, and 50% of a concentrate (DM basis) formulated principally from rolled high-moisture shelled corn (**RHMSC**), SSBM, and roasted soybeans. Dietary CP was increased in increments of approximately 1.5 percentage units, from 13.5 to 19.4%, by replacing RHMSC with SSBM. Cows were fed once daily at about 1600 h and feed offered was adjusted daily to yield 5 to 10% orts. Samples of individual feeds and orts (about 0.5 kg) were taken daily, and stored at –20°C. Weekly composite samples from feeds and orts were dried at 60°C for 48 h and the as-fed composition of the diets was adjusted every week. Weekly feed composites were ground through a 1-mm screen (Wiley mill, Arthur H. Thomas, Philadelphia, PA) and analyzed for DM at 105°C (AOAC, 1980) and for total N (Leco 2000; Leco Instruments, Inc., St. Joseph, MI) to adjust diets to the desired CP content (total N × 6.25) every week. Intake of DM was corrected for orts and recorded daily throughout the experiment. Feed samples were analyzed sequentially for NDF and ADF (Van Soest et al., 1991) using heat-stable amylase and sodium sulfite (Hintz et al., 1995) in an Ankom Fiber Analyzer (Ankom Technology Corp., Fairport, NY). The N content of NDF residues was analyzed by combustion assay (Leco Instruments Inc.). Ash and OM contents of feeds were also measured (AOAC, 1980). Weekly samples of alfalfa silage, corn silage, and RHMSC were thawed, water extracts were prepared (Muck, 1987), and pH was measured. Extracts were then deproteinized and analyzed for NPN as described by Muck (1987), and for NH_3 and total free AA by flow-injection analysis as described by Broderick et al. (2004). Chemical composition of the principal dietary ingredients and the composition of the diets, reported in Tables 1 and 2, are averages from wk 3 and wk 4 of all 4 experimental periods.

Cows were milked twice daily and milk weights were recorded at each milking. On d 20 and 27 of each period, a.m. and p.m. milk samples were collected, preserved with 2-bromo-2-nitropropane-1,3-diol, and analyzed for fat, true protein, lactose, SNF, and MUN content by infrared methods (AgSource Laboratory, Verona, WI). On d 22 of each period, samples of rumen fluid were collected from 2 locations in the midventral ruminal sac of cannulated cows starting at 0 (just before feeding), 1, 2, 4, 8, 12, 18, and 24 h after feeding. Samples were