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Effects of dietary crude protein concentration on late-lactation dairy cow performance and indicators of nitrogen utilization

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ABSTRACT

The objectives of this study were to measure performance responses and to evaluate indictors of N utilization in late-lactation cows fed diets with incremental reductions in crude protein (CP) concentration. Holstein cows (n = 128; 224 ± 54 d in milk) were stratified by parity and days pregnant (86 ± 25 d) and randomly assigned to 1 of 16 pens in a randomized complete block design. For 3 wk, all cows received a covariate diet containing 16.9% CP [dry matter (DM) basis]. For the subsequent 12 wk, pens were randomly assigned to 1 of 4 treatments that contained 16.2, 14.4, 13.1, or 11.8% CP (DM basis). Diets were offered once daily and contained 32.5% corn silage, 32.5% alfalfa silage, 13.5% high-moisture corn, and 21.5% concentrate mix. A reduction in dietary CP was achieved by replacing soybean meal with soy hulls in the concentrate mix (DM basis). Dry matter intake, milk urea N (MUN; mg/dL), and the yield of milk urea N (g/d) decreased linearly with dietary CP. Compared with a 16.2% CP diet, a 14.4% CP diet did not alter milk yield throughout the study, but the 13.1 and 11.8% CP diets reduced milk yield after 4 and 1 wk, respectively. Furthermore, milk protein percentage was reduced for all dietary CP less than 16.2%, but this negative effect was temporary and disappeared after 7 wk for the 14.4% CP diet. In contrast, MUN adjusted to a new steady state within 1 wk for all dietary treatments. Modeling quadratic responses with a plateau led to predictions of no reduction in fat- and protein-corrected milk (32.6 kg/d) and yields of fat (1.31 kg/d), lactose (1.49 kg/d), and true protein (1.12 kg/d) until dietary CP decreased below 15.5, 15.3, 15.9, and 16.2%, respectively. In this study, MUN and the yield of MUN were highly correlated with N intake, milk protein yield, and fat- and protein-corrected milk. Surprisingly, N use efficiency (milk protein N/intake N) was not correlated with any variables related to N utilization and reached an apparent upper limit of approximately 30%. Although this observation may be associated with feeding diets deficient in metabolizable protein, late-lactation cows in this study adjusted to low dietary CP concentration better than anticipated as milk production was 2.6, 3.6, 6.4, and 8.0 kg/d higher than National Research Council (2001)-predicted metabolizable protein-allowable milk for dietary CP of 16.2, 14.4, 13.1, and 11.8%, respectively.

Key words: late lactation, nitrogen use efficiency, milk performance, milk urea nitrogen

INTRODUCTION

Pressure on the dairy industry to reduce its environmental impact (Steinfeld et al., 2006) has fueled interest in feeding low-CP diets. Overfeeding dietary CP contributes to low N use efficiency (**NUE**, calculated as milk protein N/intake N; Bequette et al., 2003; Huhtanen and Hristov, 2009) and an undesirable effect on water and air quality because of increased urinary urea N excretion, which is a labile form of N (Broderick, 2003; Hristov et al., 2004; Burgos et al., 2007). Excess dietary CP may also increase feeding costs and negatively affect farm profit margins (Godden et al., 2001). Furthermore, the high volatility in energy (corn grain) and protein (soybean) prices and the abundance of economical by-products with moderate CP concentrations (e.g., distillers grains) create challenges in formulating balanced rations that simultaneously minimize cost and dietary CP concentration. Results from recent studies have suggested that yields of milk and protein were not increased by feeding more than 16.5% CP (Broderick, 2003; Ipharraguerre and Clark, 2005; Colmenero and Broderick, 2006). Although some

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of these findings have been obtained with peak- or mid-lactation cows in Latin square trials with 2 wk of dietary adaptation periods (Broderick, 2003; Colmenero and Broderick, 2006), Law et al. (2009) suggested that when substantial changes in dietary CP were applied, cows' responses to dietary shifts did not always stabilize within 2 wk. Furthermore, these authors reported that reducing dietary CP at 151 DIM from 17.3 to 14.4% of DM had no detrimental effect on milk yield (**MY**) in the later part of the lactation. Therefore, the optimal dietary CP that sustains MY in late lactation may be lower than commonly practiced (Kaiser and Shaver, 2006) or recommended by NRC (2001), which predicts a curvilinear decline in MY with declining dietary CP concentration below approximately 16.5%. Thus, in this trial, a randomized complete block design was used to determine responses of late-lactation cows to substantial reductions in dietary CP concentration over a 12-wk period. Our main hypotheses were that (a) milk performance and N-related responses would be quadratic; (b) significant treatment × week interactions would be detected, reflecting differential changes in response variables over time depending on the extent of reduction in dietary CP concentration; and (c) changes in indicators of N utilization (e.g., MUN) would closely reflect changes in cows' responses to decreasing dietary CP. Thus, our objectives were (a) to determine the pattern of the responses to incremental reductions in dietary CP concentration in late lactation and, when applicable, search for the minimal dietary CP concentration that maintains maximal performance; (b) to identify and explore response variables for which there was a treatment × time interaction; and (c) to determine correlations among performance responses and indicators of N utilization.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee of the College of Agricultural and Life Sciences of the University of Wisconsin–Madison approved the experimental protocol for this study, which was conducted from September to December 2013 at the University of Wisconsin–Madison Emmons Blaine experimental station (Arlington, WI).

Cows, Diet, and Experimental Design

A total of 128 Holstein cows greater than 150 DIM (224 ± 54; mean ± SD) were stratified by parity (2.5 ± 1.3 lactations) and days pregnant (86 ± 25 d) and randomly assigned to 1 of 16 pens (experimental units), each including 2 primiparous and 6 multiparous cows. The study was initiated with a 3-wk covariate period in which all cows were fed a diet containing 16.9% CP (DM basis). For the subsequent 12 wk (experimental period), pens were blocked by 1 of 2 barn wings and randomly assigned to 1 of 4 dietary treatments that contained 16.2, 14.4, 13.1, and 11.8% CP (DM basis; Table 1). Diets were mixed and fed once daily at 0700 h as a TMR containing approximately 65% forage (32.5% corn silage and 32.5% alfalfa silage), 13.5% high-moisture corn, and 21.5% concentrate mix (DM basis). The CP reduction in the diet was achieved by replacing soybean meal with soy hulls in the concentrate mix, which was prepared at the University of Wisconsin Feed Mill (Arlington, WI; Table 2). Diets were offered ad libitum, allowing for 5 to 10% refusal. The amount of each feed ingredient in the TMR was adjusted weekly for change in percentage of DM in forages.

Feed Sampling and Analysis

Samples of feed ingredients (corn silage, alfalfa silage, high-moisture corn, and concentrate mixes), TMR, and refusals were obtained weekly, dried at 60°C for 48 h in a forced-air oven, and ground through a 1-mm screen (Wiley mill; Arthur H. Thomas, Philadelphia, PA). To monitor CP (total N × 6.25) concentration of the TMR, ground samples of feed ingredients and TMR were analyzed weekly for total N (method 990.03, AOAC International, 2000; Leco FP-2000 Nitrogen Combustion Analyzer, Leco, St. Joseph, MI). Weekly samples were dried at 105°C for 24 h to determine absolute DM, and dried samples were used to determine ash (method 942.05; AOAC International, 2006). Nutrient composition was determined on wk 2 and 3 composite samples of the covariate period and monthly composite samples during the experimental period. The NDF procedure included α-amylase and sodium sulfite (Van Soest et al., 1991). Acid detergent fiber and ADL were determined according to AOAC (1990) method 973.18. Determination of NDIN and ADIN was done by pelleting the F57 Ankom bags (Ankom Technology, Macedon, NY) containing the NDF and ADF residues before N analysis as described previously. Dairyland Laboratories Inc. (Arcadia, WI) analyzed samples for starch (Bach Knudsen, 1997; YSI Biochemistry Analyzer, YSI Inc., Yellow Springs, OH) and 48-h in vitro NDF digestibility (Holden, 1999; Ankom Daisy Incubator, Ankom Technology). The same laboratory also analyzed a single covariate and a single experimental composite sample for ether extract (method 942.05; AOAC International, 2006). Daily DMI and N intake were determined on a pen basis using absolute DM percentages and weights of as-fed TMR offered and refused, which were obtained from Feed Supervisor Software (Supervisor Systems, Dresser, WI).