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Effect on Production of Replacing Dietary Starch with Sucrose in Lactating Dairy Cows[1]

G. A. Broderick,*[2] N. D. Luchini,†[3] S. M. Reynal,‡[4] G. A. Varga,§ and V. A. Ishler§
*Agricultural Research Service, USDA, US Dairy Forage Research Center, 1925 Linden Drive West, Madison, Wisconsin 53706
†Conti-Group Inc., 745 Riverside Drive, Chicago, IL 60606
‡Department of Dairy Science, University of Wisconsin, Madison 53706
§Animal Science Department, Pennsylvania State University, University Park 16802

ABSTRACT

Replacing dietary starch with sugar has been reported to improve production in dairy cows. Two sets of 24 Holstein cows averaging 41 kg/d of milk were fed a covariate diet, blocked by days in milk, and randomly assigned in 2 phases to 4 groups of 6 cows each. Cows were fed experimental diets containing [dry matter (DM) basis]: 39% alfalfa silage, 21% corn silage, 21% rolled high-moisture shelled corn, 9% soybean meal, 2% fat, 1% vitamin-mineral supplement, 7.5% supplemental nonstructural carbohydrate, 16.7% crude protein, and 30% neutral detergent fiber. Nonstructural carbohydrates added to the 4 diets were 1) 7.5% corn starch, 0% sucrose; 2) 5.0% starch, 2.5% sucrose; 3) 2.5% starch, 5.0% sucrose; or 4) 0% starch, 7.5% sucrose. Cows were fed the experimental diets for 8 wk. There were linear increases in DM intake and milk fat content and yield, and linear decreases in ruminal concentrations of ammonia and branched-chain volatile fatty acids, and urinary excretion of urea-N and total N, and urinary urea-N as a proportion of total N, as sucrose replaced corn starch in the diet. Despite these changes, there was no effect of diet on microbial protein formation, estimated from total purine flow at the omasum or purine derivative excretion in the urine, and there were linear decreases in both milk/DM intake and milk N/N-intake when sucrose replaced dietary starch. However, expressing efficiency as fat-corrected milk/DM intake or solids-corrected milk/DM intake indicated that there was no effect of sucrose addition on nutrient utilization. Replacing dietary starch with sucrose increased fat secretion, apparently via increased energy supply because of greater intake. Positive responses normally correlated with improved ruminal N efficiency that were altered by sucrose feeding were not associated with increased protein secretion in this trial.
Key words: alfalfa silage, nonstructural carbohydrate, sucrose, starch

INTRODUCTION

Diets based on alfalfa silage and most other hay-crop silages contain high levels of NPN and other sources of RDP (Muck, 1987; McDonald et al., 1991). When such diets are fed, the rate of ruminal energy fermentation may be too slow to allow ruminal organisms to synthesize protein from the rapidly available RDP (Kim et al., 1999a). Under these circumstances, increasing the rate of carbohydrate fermentation could result in more effective capture of RDP and improved supply of MP to the dairy cow. There is in vitro evidence of enhanced net yield of ruminal microbial protein from sugar fermentation (Stokes et al., 1991). Sugars were more rapidly fermented in the rumen than starch (Chamberlain et al., 1993), confirming their effectiveness as supplements for alfalfa silage diets. The Cornell Net Carbohydrate and Protein System (e.g., NRC, 1996) indicated that the organisms fermenting soluble sugars could contribute approximately 18% more microbial protein than those fermenting the starches in high-moisture corn. Our objective was to assess whether it was advantageous for the lactating dairy cow to increase dietary sugar content. Therefore, we formulated an alfalfa silage-based control diet containing a large amount of corn starch and assessed the effect on production and ruminal metabolism of incremental replacement of the starch with sucrose.

MATERIALS AND METHODS

Lactation Trial

Two sets of 24 multiparous Holstein cows, with mean (SD) parity 3.2 (1.4), 641 (58) kg of BW, 77 (53) DIM,

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[2]Corresponding author: glen.broderick@ars.usda.gov
[3]Current address: Adisseo USA Inc., 1508 Culpepper Dr., Naperville, IL 60540.
[4]Deceased June 25, 2007.

Table 1. Composition of major dietary ingredients[1]

Component	Alfalfa silage	Corn silage	HMSC	SSBM
DM, %	42.0	33.3	73.2	89.9
CP, % of DM	21.9	8.5	8.3	54.7
Ash, % of DM	9.8	4.6	1.3	7.0
NDF, % of DM	42.5	43.8	7.9	7.4
ADF, % of DM	33.8	24.9	2.0	4.0
pH	4.6	4.0	3.9	—
NPN, % of total N	63.2	53.4	49.4	—
Ammonia-N, % of total N	10.0	3.7	7.4	—
Total AA-N, % of total N	26.5	22.0	19.9	—
Unidentified-N, % of total N	26.6	27.3	22.1	—
ADIN, % of total N	3.0	1.5	4.2	1.0

[1]HMSC = high-moisture shelled corn; SSBM = solvent-extracted soybean meal.

and 41 (4) kg milk/d, were blocked within sets into 6 groups of 4 by DIM in a feeding trial of randomized complete block design. The first set of 24 cows was used during phase 1 and the second set was used during phase 2 of the trial. Before starting each experimental phase, all cows were fed the same diet for a 2-wk covariate period, and production of milk and milk components was determined for use in statistical analyses. Cows within blocks were then randomly assigned to 1 of the 4 diets and fed only that diet during each 8-wk experimental phase. Care and handling of all experimental animals, including ruminal cannulation of cows used in the ruminal metabolism study, was conducted under protocols approved by the University of Wisconsin Institutional Animal Care and Use Committee.

Forage was from the same source of alfalfa silage and corn silage in all diets. The alfalfa silage was harvested using a conventional mower conditioner, field wilted to about 40% DM, chopped to a theoretical length of 2.9 cm, and ensiled in a large bunker silo after inoculation with 100,000 cfu/g of wet silage (H/MF inoculant, Medipharm USA, Des Moines, IA; Table 1). Corn silage was a brown midrib variety (F657, Cargill Hybrid Seeds, Minneapolis, MN) harvested at about one-half milk line, chopped to a theoretical length of 1.9 cm, field-processed with rolling (roller clearance of 1 to 3 mm), and ensiled in a large upright silo without additives (Table 1). The covariate diet was formulated from these silages, high-moisture shelled corn (rolled to a geometric mean particle size of about 2 mm; Broderick et al., 2001), 48% CP solvent-extracted soybean meal (**SBM**), roasted soybeans, a fat supplement (Energy Booster 100, Milk Specialties, Dundee, IL), corn starch, plus minerals and vitamins (Table 2). The 4 experimental diets were similar except that corn starch was replaced in stepwise increments of 2.5 percentage units with sucrose so that diets ranged from 7.5 to 0% added corn starch and from 0 to 7.5% added sucrose (Table 2). Also, roasted soybeans in the covariate diet were replaced by SBM to reduce dietary RUP to make cows more responsive to changes in microbial protein supply (Table 2). All diets were fed as TMR.

Cows were milked twice daily and individual milk yields were recorded at each milking. Milk samples were collected at 2 consecutive (p.m. and a.m.) milkings midway through wk 2 of the covariate period and midway through wk 2, 4, 6, and 8 of each experimental phase and analyzed for fat, true protein, lactose, and SNF by infrared analysis (AgSource, Verona, WI) with a Foss FT6000 (Foss North America Inc., Eden Prairie, MN) using AOAC (1990) method 972.16. For MUN determination, 5 mL of milk sample from both milkings was treated with 5 mL of 25% (wt/vol) TCA. Samples were vortexed and allowed to stand for 30 min at room temperature before filtering through Whatman no. 1 filter paper. Filtrates were stored at −20°C until MUN analysis by an automated colorimetric assay (Broderick and Clayton, 1997) adapted to flow-injection (Lachat Quik-Chem 8000 FIA, Lachat Instruments, Milwaukee, WI). Concentrations and yields of fat, true protein, lactose, and SNF, and MUN concentration were computed as the weighted means from a.m. and p.m. milk yields on each test day. Yields of 3.5% FCM (Sklan et al., 1992) and SCM (Tyrrell and Reid, 1965) were also computed. Efficiency of conversion of feed DM was calculated for each cow over each 2-wk interval of the experimental phase by dividing mean yield of actual milk, FCM, and SCM by mean DM intake. Similarly, efficiency of utilization of feed N was computed for each cow by dividing mean milk N output (milk true protein/6.38) by mean N intake, assuming no net deposit or mobilization of N from body tissues. Body weights were measured on 3 consecutive days at the start and end of the 8-wk experimental phase to compute BW change.

All cows were injected with bST (500 mg of Posilac, Monsanto, St. Louis, MO) on the same day at 14-d intervals throughout the trial. Cows were housed in tie