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# Milk production responses to a change in dietary starch concentration vary by production level in dairy cattle

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## ABSTRACT

The effects of dietary starch concentration on yield of milk and milk components were evaluated in a crossover design experiment. Holstein cows (n = 32; 115 ± 22 d in milk) with a wide range in milk yield (28 to 62 kg/d) were assigned randomly within level of milk yield to a treatment sequence. Treatments were diets containing 30% dry ground corn (CG) or 30% soyhulls (SH) on a DM basis. Diets containing corn silage and alfalfa silage were formulated to contain 16% crude protein, 24% forage neutral detergent fiber, and either 27 or 44% neutral detergent fiber and 30 or 12% starch for CG and SH, respectively. Cows were fed a diet intermediate to the treatments during a preliminary 14-d period. Treatment periods were 28 d with measurements taken throughout the period for energy calculations and the final 5 d used for data and sample collection for production variables. Compared with SH, CG increased dry matter intake, and yields of milk, milk protein, milk fat, and energy-corrected milk, as well as milk protein concentration. Treatment did not affect milk fat concentration. Yield of de novo synthesized and preformed milk fatty acids increased with CG. Treatment interacted with level of preliminary milk production for several response variables (yields of milk, milk protein, milk fat, energy-corrected milk, and 3.5% fat-corrected milk). Compared with SH, the CG treatment increased energy-corrected milk in higher-producing cows with a lesser response to CG as milk yield decreased. The CG treatment increased milk:feed compared with the SH treatment, but not body weight or body condition score. In conclusion, higher-producing cows benefited from the high-starch diet, and lower-producing cows were able to maintain production when most of the starch was replaced with nonforage fiber.
**Key words:** diet starch concentration, feed efficiency, variation in treatment response, energy partitioning

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## INTRODUCTION

Corn grain is typically substituted for forage in dairy cattle diets to increase the energy density of the ration providing glucose precursors for milk production and substrates for microbial protein production. Competition for corn is increasing because of increasing use for human food and biofuels (Edgerton, 2009). Identifying alternative feedstuffs that provide energy and maintain milk component yields will decrease dependence on high-starch ingredients such as corn. Nonforage fiber sources (**NFFS**) have been researched as alternatives to starch for lactating dairy cattle (e.g., Firkins and Eastridge, 1992; Ipharraguerre et al., 2002; Voelker and Allen, 2003; Mahjoubi et al., 2009). For example, soyhulls have been effectively used in diets because of their high energy density, low filling effect, and highly digestible NDF. Soyhulls, however, are not as rapidly digestible in the rumen as starch sources, so they could improve rumen pH (Firkins, 1997) but yield fewer glucose precursors compared with corn.

Previous studies have compared the effects of NFFS and starch on milk production. Ipharraguerre et al. (2002) determined the effect of replacing dry ground corn with soyhulls at concentrations from 0 to 40% diet DM in low-producing dairy cattle (30 kg/d), and Voelker and Allen (2003) determined the effect of replacing high-moisture corn with beet pulp at concentrations up to 24% diet DM. In both experiments, substitution of NFFS for corn did not affect milk yield and, in one case, increased milk fat yield (Ipharraguerre et al., 2002). Both studies, however, observed a reduction in DMI at the highest levels of NFFS inclusion, likely because physical fill was beginning to limit feed intake (Allen, 2000).

Cows varying in milk production have previously been reported to respond differently to diets differing in the ratio of forage to concentrate (Voelker at al., 2002) and the ruminal fermentability of starch (Bradford and Allen, 2004). A low-forage diet increased DMI linearly as preliminary milk yield increased compared with a high-forage diet. However, 3.5% FCM increased quadratically as preliminary milk yield increased, but the response was positive only for cows over ~45 kg/d of milk (Voelker at al., 2002). Compared with dry corn, high-moisture corn decreased 3.5% FCM and fat yields for low-producing cows but increased 3.5% FCM and fat yields for high-producing cows (Bradford and Allen, 2004). Although treatment responses to changes in ratio of forage to concentrate and ruminal starch fermentability differed with level of milk production, we are uncertain if the same is true for changes in the concentration of starch in the diet with the same concentration of forage NDF across levels of milk production. This information is important to aid the optimum allocation of feeds by production level of dairy cows.

Based on these previous findings, our objectives were 2-fold: first, to determine the effects of starch concentration in diets with the same concentration of forage NDF on DMI, nutrient digestibility, yields of milk and milk components, and feed efficiency, and second, to evaluate whether responses to dietary treatments differ for cows varying in milk yield. We hypothesized that low-producing cows are able to maintain milk yield on a low-starch diet, whereas higher-producing cows require higher-starch diets to achieve maximum milk production.

**Table 1.** Ingredients and nutrient composition of experimental diets[1]

| | Treatment | |
|---|---|---|
| Item | CG | SH |
| Ingredient (% of DM) | | |
| Corn silage | 22.5 | 22.5 |
| Alfalfa silage | 22.5 | 22.5 |
| Wheat straw | 5.0 | 5.0 |
| Ground corn | 30.0 | 3.6 |
| Soyhulls | — | 30.0 |
| Soybean meal | 17.0 | 13.7 |
| Vitamin and mineral mix[2] | 2.0 | 2.0 |
| Limestone | 0.50 | — |
| Sodium bicarbonate | 0.50 | 0.50 |
| Dicalcium phosphate | — | 0.25 |
| Nutrient composition (% of DM) | | |
| DM[3] | 53.9 | 53.6 |
| NDF | 27.2 | 43.9 |
| Forage NDF | 23.6 | 23.9 |
| Starch | 30.1 | 12.2 |
| CP | 16.5 | 15.9 |
| FA | 2.26 | 1.69 |

[1]Average composition of experimental diets fed to 32 cows in a crossover design with 28-d periods. Values based on nutrient composition of individual ingredients sampled the last 5 d of each period. Treatments contained 30% dried ground corn (CG) or 30% soyhulls (SH) on a DM basis.

[2]Vitamin and mineral mix contained 34.1% dry ground shell corn, 25.6% white salt, 21.8% calcium carbonate, 9.1% Biofos (The Mosaic Co., Plymouth, MN), 3.9% magnesium oxide, 2% soybean oil, and <1% of each of the following: manganese sulfate, zinc sulfate, ferrous sulfate, copper sulfate, iodine, cobalt carbonate, vitamin E, vitamin A, vitamin D, and selenium.

[3]Expressed as percent of as fed.

## MATERIALS AND METHODS

### *Design and Treatments*

Experimental procedures were approved by the Institutional Animal Care and Use Committee at Michigan State University. Thirty-two midlactation (115 ± 22 DIM, mean ± SD; range 77 to 148 DIM) Holstein cows (7 primiparous, 25 multiparous) with a wide range in milk yield (28 to 62 kg/d) from the Michigan State University Dairy Field Laboratory were randomly assigned to treatment sequence in a crossover design experiment with 28-d periods preceded by a 14-d preliminary period. Measurements were taken throughout periods for energy calculations and the final 5 d of each period used for data and sample collection for production and digestibility variables.

Treatments consisted of diets containing either ground corn grain (**CG**) or soyhulls (**SH**) at 30% diet DM. The diet fed during the preliminary period was intermediate between the 2 diets. Diets were based on corn silage and alfalfa silage as the major forage components. The ingredient and nutrient composition of the diets fed as TMR are described in Table 1. Minerals and vitamins were formulated according to NRC (2001) recommendations. The DM concentration of forages was determined twice weekly, and diets were adjusted when necessary. All cows were housed in the same tie-stall throughout the entire experiment and milked twice daily (0430 and 1530 h). Access to feed was blocked from 1000 to 1200 h to allow for collecting orts and offering feed. Cows were fed 115% of expected intake at 1200 h daily. Water was available ad libitum in each stall, and stalls were bedded with sawdust and cleaned twice daily.

### *Data and Sample Collection for Production and Digestibility Variables*

Milk yield was recorded for each milking during the last 3 d of the preliminary period when cows were offered the common diet. For production and digestibility responses, samples and data were collected during the last 5 d of each treatment period. Samples of all diet ingredients (0.5 kg) and orts from each cow (12.5%) were collected daily (d 24 to 28) and composited by period for analysis. Milk yield was recorded, and 2 milk samples were collected at each milking (d 24 to 28). One aliquot was collected in a sealed tube with preservative (bronopol tablet; D&F Control Systems, San Ramon, CA) and stored at 4°C for milk component analysis. The second aliquot was stored without preservative at −20°C until analysis for FA composition. Fecal (~400 g) grab samples were collected every 15 h for the last 5