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Meta-analysis of the effects of dietary sugar on intake and productivity of dairy cattle

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Abstract

A meta-analysis was performed to determine the possible effects of dietary sugar on feed intake and milk production in lactating dairy cattle. The database used in this analysis included 18 treatment comparisons frozm 10 studies reported from 1985 through 2011. Treatment comparisons were used only if: (1) either sucrose (9 comparisons) or molasses (9 comparisons) replaced corn grain without adding fat; and (2) sugar added by treatment ranged from 2 to 5% of dry matter. First, responses to sucrose and molasses were compared to assess whether these sugar sources could be considered together. Statistical analysis provided no evidence for different responses across sugar sources for dry matter intake (DMI), milk yield, energy-corrected milk (ECM) yield, milk fat content, or milk protein content. Different sugar sources were pooled for the remaining analyses; the combined data showed that adding sugar tended to increase DMI by 0.84 lb/day and milk fat content by 0.085%. No effects were detected for milk yield, ECM yield, or milk protein content. This analysis indicates that adding 2 to 5% dietary sugar may promote small increases in DMI and milk fat content but does not consistently increase ECM yield in lactating dairy cattle.; Dairy Day, 2012, Kansas State University, Manhattan, KS, 2012; Dairy Research, 2012 is known as Dairy Day, 2012

Keywords

Dairy Day, 2012; Kansas Agricultural Experiment Station contribution; no. 13-030-S; Report of progress (Kansas Agricultural Experiment Station and Cooperative Extension Service); 1075; Molasses; Sucrose; Lactation; Dry matter intake (DMI); Dairy cattle

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Meta-Analysis of the Effects of Dietary Sugar on Intake and Productivity of Dairy Cattle

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Summary
A meta-analysis was performed to determine the possible effects of dietary sugar on feed intake and milk production in lactating dairy cattle. The database used in this analysis included 18 treatment comparisons frozm 10 studies reported from 1985 through 2011. Treatment comparisons were used only if: (1) either sucrose (9 comparisons) or molasses (9 comparisons) replaced corn grain without adding fat; and (2) sugar added by treatment ranged from 2 to 5% of dry matter. First, responses to sucrose and molasses were compared to assess whether these sugar sources could be considered together. Statistical analysis provided no evidence for different responses across sugar sources for dry matter intake **(DMI)**, milk yield, energy-corrected milk **(ECM)** yield, milk fat content, or milk protein content. Different sugar sources were pooled for the remaining analyses; the combined data showed that adding sugar tended to increase DMI by 0.84 lb/day and milk fat content by 0.085%. No effects were detected for milk yield, ECM yield, or milk protein content. This analysis indicates that adding 2 to 5% dietary sugar may promote small increases in DMI and milk fat content but does not consistently increase ECM yield in lactating dairy cattle.

Key words: molasses, sucrose, lactation, dry matter intake (DMI)

Introduction
High demands for energy — especially to maintain profitable milk production levels in lactating dairy cows — are mostly covered by the dietary inclusion of highly fermentable carbohydrates. Starch has traditionally filled this role in most lactation diets, often comprising 25 to 30% of diet dry matter **(DM)**. The rapid fermentation of starch can decrease ruminal pH, which can negatively affect the growth of fiber-digesting bacteria and fiber degradation. As a result, excessive starch concentrations can suppress dry matter intake **(DMI)** and lead to milk fat depression.

To lessen the negative effects of high starch concentrations and reduce costs, feedstuffs with sugar as the main soluble carbohydrate (i.e., molasses, whey, and citrus pulp) have been included in diets for dairy cattle. Sugar, like starch, is rapidly fermented in the rumen, providing large amounts of rapidly available energy for microbial protein production. Surprisingly, recent evidence indicates that sugar does not acidify the rumen like dietary starch does. One reason may be that sugar inclusion supports the growth of bacteria that utilize lactic acid, providing a population of microbes that can limit this potent acid from accumulating. By increasing ruminal pH, dietary sugar may provide a better environment for fiber-digesting bacteria, resulting in greater fiber digestibility.

Although sugar sources have been used in diets for lactating dairy cattle for many years, the value of such ingredients is still controversial. One way to address such topics is by utilizing meta-analysis. This statistical methodology allows the results of many different studies to be considered together while accounting for different sample sizes. This approach was used to

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assess how dietary sugar affects DMI, milk production, and composition responses in lactating dairy cows.

Experimental Procedures

The information used for this meta-analysis included treatments from studies reported from 1985 through 2011. Numerous databases (including CAB abstracts, Web of Science, Agricola, Agris, CRIS, PubMed, Science Direct, S-PAC, and Google Scholar) were searched for applicable studies. Treatments were included in the analysis only if the added sugar ranged between 2% and 5% of DM. Only studies that directly tested responses to molasses or sucrose replacing corn grain in lactating cows were evaluated. If the sugar source contained any additional source of fat or urea that was not matched in the control diet, the treatment was excluded from the meta-analysis to avoid possible confounding effects.

A total of 10 published studies were found with at least one treatment comparison that met the criteria. An additional two unpublished studies from Kansas State University were included in the database, providing 18 total treatment comparisons. Both published and unpublished data were included to reduce publication bias.

Cochran's Q statistic was used to test for differential responses to sucrose vs. molasses. The meta-analysis was conducted using a random effects model. In addition to determining the effects of dietary sugar on production outcomes, experimental diets were characterized to test for dietary conditions that may influence the response to sugar. The following dietary concentrations were determined for each treatment: crude fat, neutral detergent fiber **(NDF)**, forage NDF **(fNDF)**, starch, crude protein, rumen-undegradable protein, and rumen-degradable protein. The amount of sugar added by treatment was also included in this list of predictive variables. Effects of dietary conditions were tested using multiple regression analysis.

Results and Discussion

Because the analysis for differential responses between molasses and sucrose detected no difference in DMI, milk yield, energy-corrected milk **(ECM)** yield, milk fat content, or milk protein content, molasses and sucrose treatments were combined for all subsequent analyses.

Results of the meta-analysis are presented in Table 1. According to the combined results of the 18 treatment comparisons included in this study, supplemental sugar tended to increase DMI by 0.84 lb/day, with a 95% likelihood that the true mean response lies between a decrease of 0.08 lb/day and an increase of 1.77 lb/day. Despite the finding that DMI tends to increase with sugar supplementation, there was no evidence that dietary sugar increased milk production, protein content, or ECM production. The meta-analysis did identify a tendency for supplemental sugar to increase milk fat content by 0.085 percentage units. This finding is consistent with recent reports suggesting that sugar can help mitigate milk fat depression.

The initial analysis grouped all 18 comparisons without respect to the amount of sugar added by treatment or the basal composition of the diet used in each study. Subsequently, multiple regression techniques were used determine if responses to supplemental sugar depended on any of these predictive variables. None of the factors tested were significant predictors of milk yield, ECM yield, or milk protein content responses to dietary sugar. For DMI, two variables significantly affected the response to supplemental sugar: the fNDF content of the basal diet and the amount of sugar added to the diet. Additionally, these two factors interacted: the response to the amount of sugar added depended on the fNDF content of the diet. This complex relationship is represented in part by Figure 1, which indicates that in a diet with low fNDF content (i.e., a low-forage diet), adding progressively more sugar (from 2% up to 5% of diet dry matter) decreases the DMI response. Conversely, adding progressively more sugar to a diet with high fNDF content increases the DMI response.

The idea that adding more sugar may increase DMI more in higher-forage diets is consistent with some of the current thinking about sugar effects in the rumen. In rations with high fNDF content, including sugar may provide more available energy to the fiber-digesting bacteria because they do not compete effectively with starch-digesting bacteria for access to energy from starch. Increasing populations of fiber-digesting bacteria should allow them to colonize the fiber substrate faster, increasing the rate of fiber degradation and freeing up space in the rumen for additional feed intake.

In summary, a combined assessment of sugar responses across 18 treatment comparisons failed to demonstrate clear production effects when sugar was added at 2 to 5% of diet DM. Interactions between fNDF content of diets and the amount of sugar added by treatments suggest that variable responses to dietary sugar may result from the wide range of diets involved in these treatments. Further research directly testing the differential effects of sugar supplementation in high-fNDF vs. low-fNDF diets may help clarify the importance of considering which diets benefit the most from additional sugar sources.

Table 1. Production responses to replacing corn grain with 2 to 5% dietary sugar as determined by meta-analysis

Item	Change	95% confidence interval	*P*-value
Dry matter intake, lb/day	+0.84	-0.08, +1.77	0.08
Milk yield, lb/day	+0.24	-1.15, +1.64	0.73
Energy-corrected milk, lb/day	+0.62	-0.64, +1.87	0.33
Fat, %	+0.085	-0.005, +0.175	0.06
Protein, %	+0.009	-0.041, +0.058	0.72

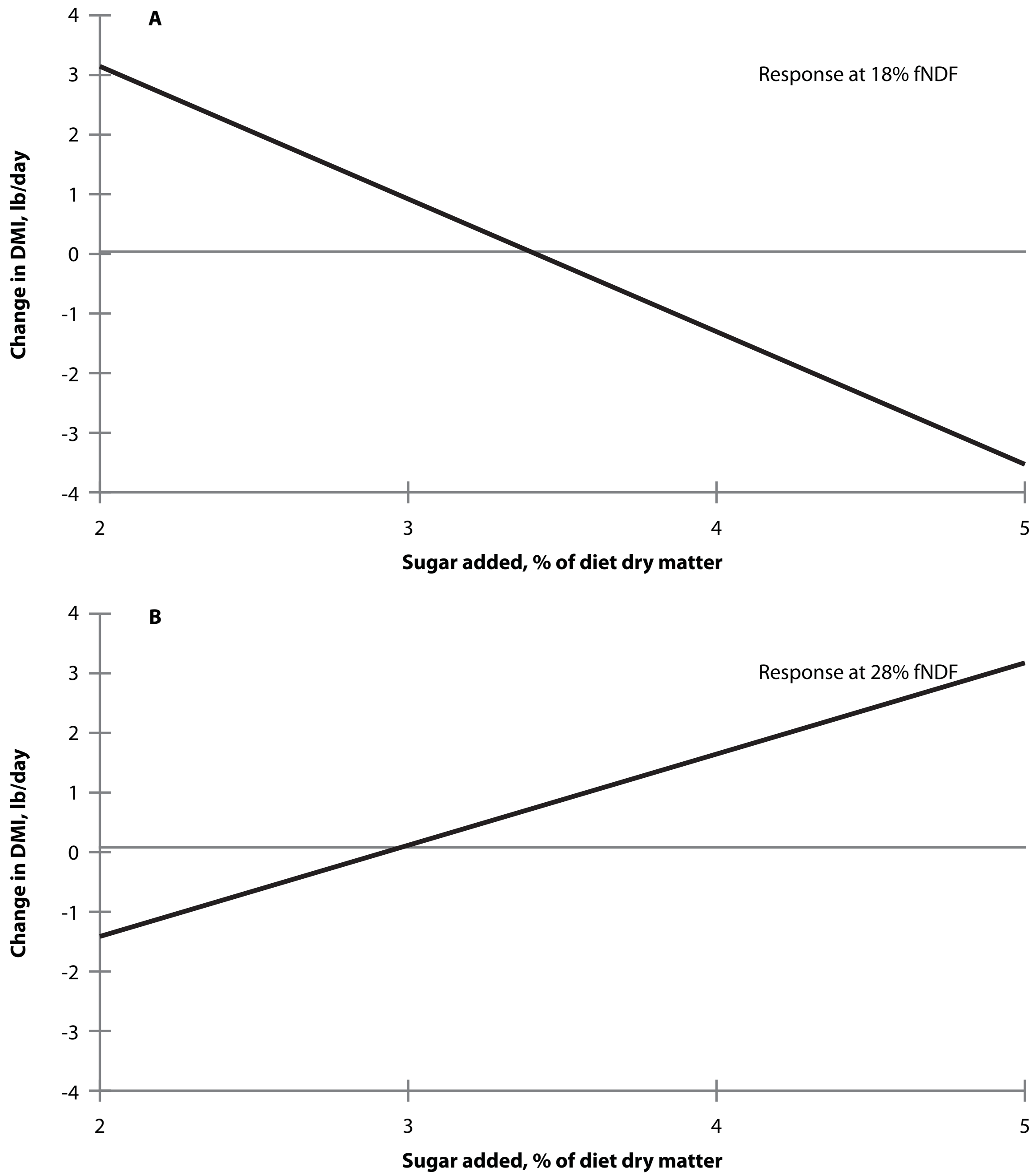

Figure 1. Interaction of added sugar and forage neutral detergent fiber (fNDF) influences dry matter intake (DMI) responses to sugar supplementation.

The interaction of factors is represented by plotting responses to the amount of added sugar at the lowest (18%) and highest (28%) fNDF levels used in diets in the database of studies.