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Effect of increased dietary sugar on dairy cow performance as influenced by diet nutrient components and level of milk production

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ABSTRACT

Interactions among diet nutrient parameters can influence dairy cattle response to added dietary sugar. With the objective to evaluate the effect of dietary sugar, 2 data sets with dietary information and production responses were compiled from published research that tested the effect of additional dietary sugar on dairy cattle performance. The first data set included 24 scientific papers (97 observations) with dietary forage NDF content ranging from 14.61 to 38.48% of diet DM. To evaluate the effect of dietary sugar in diets with a more narrow range in dietary forage NDF (17.37 to 29.51% of diet DM), the second data set omitted 3 of the scientific papers in the first data set, resulting in 85 observations. Mixed model linear regression analysis included treatment category [control, 1.5–3%, 3–5%, vs. 5–7% added dietary sugar (% of diet DM)], DIM category within treatment, control milk yield category within treatment, and several continuous nutrient variables. In cows producing >33 kg of milk/d, added dietary sugar had a greater response (2.14 kg of 3.5% FCM/d; $P < 0.0001$) than in cows producing <33 kg of milk (0.77 kg of 3.5% FCM/d). Additional dietary sugar did not affect milk fat or protein percentage ($P > 0.15$). Nutrient variables with a positive effect on 3.5% FCM yield included added starch and protein B_2 (insoluble in boiling neutral detergent but soluble in boiling acid detergent solution). Nonlinear statistical analysis predicted the optimal total dietary sugar to be 6.75% of diet DM. To optimize 3.5% FCM yield response when feeding additional dietary sugars, a low to moderate starch diet should be fed (22 to 27% of diet DM) in combination with a moderate to high soluble fiber content (6.0 to 8.5% of diet DM).

Key words: dairy cow, sugar, starch, milk yield

INTRODUCTION

Silage fermentation and feed ingredient processing reduce the concentration of sugar in the diets of many dairy cattle on commercial farms in the United States. Added dietary sugar has increased DMI and yield of milk fat (Broderick et al., 2008; Firkins et al., 2008; Penner and Oba, 2009). When Broderick and Radloff (2004) incrementally replaced high-moisture corn with molasses, there was a positive quadratic response in milk fat content, yield of fat, and FCM, with maximum responses occurring at 5.5 to 7.2% total dietary sugar (% of diet DM). However, other studies have seen no effect with sugar supplementation (Martel et al., 2011; Siverson et al., 2014). Dietary factors including levels of rumen effective fiber, starch, and unsaturated fatty acids may limit cow response. Also, a poor lactation initiation and long DIM may reduce cow response. Vargas-Rodriguez (2013) concluded that while sugar tended to promote DMI and milk fat content, energy-corrected milk yield did not consistently increase.

Fiber digestion, microbial protein synthesis, and VFA absorption from the rumen may increase with additional dietary sugars and positively affect dairy cow performance. Broderick et al. (2008) showed a positive quadratic effect of supplemental sugar on fiber digestion, with ADF and NDF digestion highest with the addition of 5% sucrose. Dietary sugar above 7% has reduced ammonia concentrations (McCormick et al., 2001; Broderick et al., 2008; Chibisa et al., 2015), indicating possible improvements in N utilization. Added dietary sugar has been shown to increase microbial protein synthesis (Khalili and Huhtanen, 1991; Chamberlain et al., 1993; Piwonka and Firkins, 1993), however, not consistently (Sannes et al., 2002; Broderick et al., 2008). Hall (2017) showed that when glucose was the substrate, microbial nitrogen yield was increased when peptides were supplied to rumen bacteria compared with urea only. This would imply that the composition of the RDP in a diet can influence microbial protein yield from sugar. Dietary sugar often increases the molar proportion of butyrate (DeFrain et al., 2004; Vallimont et al., 2004; Chibisa et al., 2015), potentially stimulating the rumen epithelial cells and increasing VFA absorption from the rumen (Oba et al., 2015).

The objectives of the current work were to predict dairy cow responses to added dietary sugar while accounting for the effects of other nutrients and cow factors including DIM and production level. A further objective was to determine nutrient parameters required to optimize re-

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sponses to added dietary sugar based on previously published results. In the published scientific papers included in the data set, supplemental dietary sugar was provided by either molasses or commercial liquid supplement, whey or dry sugar (sucrose or lactose).

MATERIALS AND METHODS

A literature review was conducted to identify research studies published between 1995 and 2014 with differing dietary sugar treatments and detailed diet definitions. The literature review was limited to papers published in English. The majority of the studies selected for the data set came from the *Journal of Dairy Science* and the *Animal Feed Science and Technology Journal*. A doctoral dissertation published in 2013 was included in the data set because it provided information on the effect of lactose on animal performance. To be included in the data set, a paper had to specify individual feed ingredients in the diet. This was necessary so that the sugar, starch, and soluble fiber content of the diets could be estimated. Prior to 1995 many of the published papers did not report the starch content of dietary treatments, and for this reason they were excluded from the literature review. Papers that only reported the nonfiber carbohydrate or nonstructural carbohydrate content of the dietary treatments could not be used in the analysis because these variables do not separate out starch, sugar, or soluble fiber. Dietary treatments containing more than 7% of diet DM as added dietary sugar (>11% total water-soluble carbohydrates) were not included because these very high levels of dietary sugar are not typically fed on commercial dairies. Two data sets were compiled that tested the effect of dietary sugar addition on DMI, milk yield, milk component content and yield, 3.5% FCM yield, and feed efficiency (kg of 3.5% FCM/kg of DMI). The first data set included 24 scientific papers (97 observations) with dietary forage NDF content ranging from 14.61 to 38.48% of diet DM. The

Table 1. Published research studies used to determine the effect of additional dietary sugar on dairy cattle performance with a description of the number of treatment means used, number of cows per treatment, mean DIM, and 3.5% FCM of cows consuming the experimental control diet

Experiment	No. of treatment means	No. of cows per treatment	Mean DIM	Control 3.5% FCM, kg
Baurhoo and Mustafa, 2014	3	12	129	38
Broderick et al., 2008	3	12	112	41
Broderick and Radloff, 2004 #1	3	12	167	41
Broderick and Radloff, 2004 #2	4	12	120	45
Cherney et al., 2003	4	20	98	38
Chibisa, 2013	4	8	165	41
De Frain et al., 2004	3	12	252	25
De Vries and Gill, 2012	2	12	109	43
Eastridge et al., 2011 #1	4	5	219	35
Eastridge et al., 2011 #2	4	12	109	41
Firkins et al., 2008 #1	4	10	81	36
Firkins et al., 2008 #2	5	10	81	34
Firkins et al., 2008 #3	4	12	112	38
Golombeski et al., 2006	4	12	173	30
Hall et al., 2010	4	18	114	40
Hindrichsen et al., 2006	3	6	223	18
Leiva et al., 2000[1]	2	11	120	32
Maiga et al., 1995	3	10	74	35
Martel et al., 2011 #1[1]	3	12	176	32
Martel et al., 2011 #2[1]	2	7	248	24
McCormick et al., 2001	4	8	100	38
Murphy, 1999[1]	2	20	88	23
Nombekela and Murphy, 1995	2	16	42	28
Oelker et al., 2009	5	7	202	36
Penner et al., 2009	4	8	205	24
Penner and Oba, 2009	2	25	14	37
Sannes et al., 2002	4	16	149	36
Siverson et al., 2014	4	40	238	31
Vargas-Rodriguez et al., 2014	2	48	157	35

[1]Experiment was omitted from second data set.