



Dietary Carbohydrate Impact on Milk Components

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Introduction

Carbohydrates have long been recognized as the primary source of energy in dairy cattle diets, however, their effects beyond their energy values have not been well explored. There is basic recognition that fiber with its important role in maintaining rumen function can influence milk fat production: too little fiber vs. too much nonfiber carbohydrate (NFC) can lead to milk fat depression. Typically, this effect has been related to reduction in ruminal pH. The non-pH effects of the NFC on milk components, and effects associated with their interactions with other dietary components have not been as well explored. It is this topic that we will examine in this paper.

Nonfiber Carbohydrates (NFC)

Nonfiber carbohydrates include any of the carbohydrates not found in neutral detergent fiber (NDF). Whilst NDF is comprised of cellulose and hemicelluloses, NFC includes sugars (glucose, fructose, sucrose, lactose), starch, fructans, pectic substances, mixed linkage beta-glucans, galactans, and other carbohydrates. The NFC are a very diverse group of carbohydrates, both compositionally and nutritionally. The effects of NFC on milk composition has been best studied for starch, some sugars, and some soluble fiber sources (beet pulp, citrus pulp). However, two challenges we have in assessing the results of the research in this area: 1) Most studies evaluated feeds that differed in their carbohydrate complement, but relatively few evaluated the effects of the carbohydrates themselves, and 2) carbohydrates were supplemented without measurements

made of the composition of the entire diet. Now, the focus on evaluation of feeds may not be a major problem, because we feed the carbohydrates as components of feeds. Still, both evaluation of feeds and lack of information on total concentrations of carbohydrates in the diets leave the question open as to whether the effects reported were due to the carbohydrate or some other aspect of the feed or diet. The changes in milk composition related to carbohydrate feeding have been variable.

Starch vs. Sugars

There have been many questions from the field about supplementing sugars. The ruminal fermentation products of sucrose and lactose can include lactic acid (Strobel and Russell, 1986; Thivend and Ehouinsou, 1977) and these sugars have been reported to yield more butyrate than other NFC (Strobel and Russell, 1986; DeFrain et al., 2006). So, on the one hand, sugars can produce lactate, a stronger acid than other organic acids in the rumen that might be suspected to cause problems with ruminal pH, but they also produce butyrate, a lipogenic organic acid that can be used for the production of fat by the cow. Substituting sucrose for starch does sometimes appear to have potential to increase butterfat yield, but results are mixed. When sucrose was substituted for corn meal at 1.5% of ration dry matter, intake, milk yield, and fat-corrected milk yield did not change, but milk fat yield increased from 2.12 to 2.14 lb per day, and milk protein percentage decreased from 3.51% to 3.28% (Nombekela and Murphy, 1995). In another study, when sucrose was substituted for corn starch (0 to 7.5%

of diet dry matter, dietary NFC = 43%, NDF = 29.6%, crude protein = 16.8%; alfalfa silage, corn silage and high moisture shell corn as 40.0, 20.0, and 20.5% all on dry matter basis; Broderick et al., 2000), there were increases in dry matter intake, milk fat content and fat yield with increasing sucrose, and fat-corrected milk production tended to increase (Table 1). For feed efficiency, milk/dry matter intake and milk nitrogen /intake nitrogen (protein use efficiency) decreased linearly with increasing sucrose. The fat- and protein-corrected milk feed efficiency did not appear to change (no statistics applied). Ruminant pH did not differ among the treatments.

Sucrose feeding may affect milk components other than butterfat. Cherney et al. (2003) investigated the effects of substituting sucrose for ground corn at 3.6% or 1.9% of diet dry matter on high or low NFC on a grass silage-based diet (>19.6% CP; NDF at ~35 or 39 to 40%, NFC at ~36 or 30% for low and high NFC respectively; forage = fescue silage at 47 or 58% of diet DM). No carbohydrate related differences were found for milk yield, milkfat or protein, but lactose percentage was increased by 0.02 or 0.04% with sucrose feeding and milk urea nitrogen was increased by ~1.1 to 0.5 mg/dl with sucrose feeding (86 lb milk avg yield).

In another study that evaluated the effect of sucrose supplementation before calving on lactation performance, fat percentage tended to be higher (3.76 vs 3.54%) in the first 56 days of lactation in Holstein cows fed sucrose at 2.7% of diet dry matter prepartum, but fat and all other

milk composition values were similar between treatments (Ordway et al., 2002).

Then there is research where no changes in milk composition or yield were noted with sugar supplementation. Studies that have investigated the supplementation of lactating cows with a brown sugar food product fed with fresh ryegrass (5% and ~50% of diet dry matter, respectively; McCormick et al., 2001), or lactose fed to cows in early lactation (1 to 21 days in milk) (27.9, 14.5 and 8.3% of dry matter as corn silage, alfalfa haylage and alfalfa hay; lactose at 0 or 15.7% substituted for ground corn, all on a dry matter basis) have found no effects of sugar supplementation on milk yield or on milk composition and component yield. The NFC content of the ryegrass ranged from 3.9 to 27.7% (McCormick et al., 2001). That NFC would likely be predominantly sugars, fructans and organic acids, so supplemental sugar would be in addition to what might already be a substantial pre-existing amount of sugar in the diet. Anecdotally, responses of lactating cows to addition of sugars to the diet seems to vary by growing season (L. E. Chase, personal communication), suggesting that changing plant composition (and sugar content?) and basal diet composition, must be considered when considering sugar supplementation and evaluating effects of sugars.

Then there is evidence to show that sugars may decrease milk component yield. An investigation into the effect of no sucrose inclusion or adding sucrose (3.0 to 3.4% of diet dry matter) at a low (~17% of diet dry matter) or higher (18.5 – 19.6%

Table 1. Changes in milk yield and composition with changes in sucrose and starch supplementation. (Broderick et al., 2000).

Sucrose% of diet DM Starch% of diet DM	0 7.5	2.5 5.0	5.0 2.5	7.5 0
DM Intake, lb*	54.0	56.4	57.3	57.3
Milk, lb†	85.8	89.1	88.2	86.9
Fat, lb*	3.24	3.37	3.64	3.57
Protein, lb	2.73	2.82	2.84	2.82
Rumen pH	6.19	6.16	6.19	6.21
Milk/DMI*	1.60	1.58	1.54	1.52
FPCM/DMI	1.64x	1.63x	1.66x	1.64x
MN/IN*	0.312	0.291	0.291	0.295
*P < 0.05, † P < 0.10, linear response to increasing sucrose. DM = dry matter, DMI = dry matter intake, FPCM = 3.5% fat- and protein-corrected milk; MN = milk nitrogen, IN = intake nitrogen, x = calculated from data tables.				

of diet dry matter) levels of dietary crude protein from urea or soybean meal was carried out by Sannes et al. (2002). The diets included corn silage, alfalfa hay and whole cottonseed (33.0, 25.4, and 3.6% of dry matter; 34% dietary NDF). Diet changes made to include sucrose removed dry ground corn. Yields of milk, milk fat, milk protein and lactose all decreased with inclusion of sucrose, though percentages of milk components did not change (Table 2). The cows were on the study from 107 through 191 days in milk, and so represent a response in mid-lactation.

So, where does this information leave us? Compared to starch, can sugars have an effect on milk composition? Maybe. It becomes obvious that we need to get a better understanding of what factors affect how added sugar in a diet affects production and milk composition. These factors

may include other nutrient concentrations in the diet, their sources, differences among forages (?) and effects of stage of lactation. We will also need to measure the basal amount of sugars in the diet to understand what we are adding to.

Starch vs. Soluble Fiber

Citrus and beet pulps contain substantial concentrations of pectic substances that tend to yield much acetate when they are fermented by rumen microbes (Strobel and Russell, 1986). Acetate is a “lipogenic”, or “usable for fat” organic acid, but that does not necessarily translate to an increase in fat production by the cow when these pulps are fed in place of a starchy concentrate. Table 3 shows the results of studies in which lactating cows were fed diets that contained a

Table 2. Changes in milk yield and composition with changes in sucrose and protein supplementation. (Sannes et al., 2002).

Item	Low Protein no Sucrose	Low Protein Sucrose	High Protein, Sucrose, Urea	High Protein, Sucrose, SBM
DM Intake, lb/day	56.7	56.3	59.1	57.9
Milk, lb/day*	75.7	73.2	74.2	74.3
Fat, %	3.88	3.83	3.88	3.87
Protein, %	3.14	3.12	3.10	3.13
Lactose, %	4.77	4.76	4.74	4.76
Fat, lb/day*	2.93	2.80	2.87	2.89
Protein, lb/day*	2.36	2.27	2.29	2.31
Lactose, lb/day*	3.62	3.48	3.51	3.53

* $P < 0.05$, effect of sucrose.
DM = dry matter, SBM = soybean meal

Table 3. Lactation studies comparing starch and sugar + soluble fiber sources.

	Mansfield et al., 1994		Solomon et al., 2000		Leiva et al., 2000	
	Corn	Beet Pulp	Corn	Citrus	Hominy	Citrus
DM Intake, lb	47.4*	44.8*	46.1*	44.8*	47.2	46.1
Milk, lb	71.0	70.3	78.3	76.3	72.3	69.0
Fat %	3.64*	3.82*	3.33	3.38	3.43	3.54
Fat lb	2.60	2.67	2.60	2.56	2.47	2.45
Protein %	3.01*	2.90*	3.00*	2.93*	2.83*	2.71*
Protein, lb	2.14*	2.03*	2.31†	2.23†	2.05†	1.87†
Milk N/Intake N	0.24x	0.25x	0.31x	0.29x	0.24†	0.22†
3.5FPCM/DMI	1.51x	1.59x	1.63x	1.64x	1.48x	1.45x

* $P < 0.05$, † $P < 0.15$. Values within same study differ.
DM = dry matter, N = nitrogen, x = calculated from data in paper.
Milk N/Intake N = milk nitrogen divided by intake nitrogen, a measure of feed efficiency.
3.5FPCM/DMI = 3.5% fat- and protein-corrected milk divided by dry matter intake; a measure of feed efficiency.

greater proportion of soluble fiber and sugars (from citrus pulp or beet pulp), or more starch (from corn products). Cows fed citrus or beet pulp diets had lower intakes (on two studies), decreased milk protein percentage and yield (on three studies), and increased butterfat percentage (on two studies). The feeding of pulps did not increase the yield of butterfat on any of the studies, and milk yield was numerically lower on these diets. On another study, though milk component percentages did not differ, decreases in yields of milk, milk fat, milk protein, lactose and solids not-fat have were reported when dried citrus pulp was compared with high moisture ear corn and cracked shell corn fed in a 50:10 alfalfa silage:grass silage-based diet (crude protein = 18.6 to 22.7%, NDF = 26 to 29%, NFC = 38 to 44%, dry matter basis) (Broderick et al., 2002). It seems that addition of the pulps that provide soluble fiber and sugars tends to decrease yield of milk components, though percentages may or may not be affected.

So, is it always a mistake to feed sugar + soluble fiber sources if you are interested in milk components and production? That seems to depend what the soluble fiber source is replacing in the diet and the proportion of the diet it accounts for. A study by Sutton et al. (1987) examined the effects of feeding grass hay with supplement accounting for 60 or 80% of the diet (air dry basis). The supplements contained citrus pulp, beet pulp and low starch feedstuffs (soluble fiber supplement) or barley, wheat, cassava and high starch feedstuffs (starch supplement). Cows on the 80% starch supplement diet gave the most

milk, but had a drastically reduced milk fat percentage and yield (Table 4). The percentages of milk protein tended to be greater for cows fed the soluble fiber supplemented diets, but protein yield followed milk production giving the 80% starch supplement diet the greatest yield. Lactose concentration was lower with starch compared to soluble fiber supplementation, but, again, lactose yield was greatest for the highest level of starch supplementation owing to the high level of production. The authors noted that “off-feed” problems that could be related to ruminal acidosis were encountered on the high starch diet in the early stages of the study.

It would appear that increasing starch feeding can give increased yields of milk components as compared to feeds that provide more soluble fiber and sugar, such as pulps. However, the potential of the diet to maintain good animal health needs to be considered, as well. In my experience, the amount of starch that is acceptable to feed to maintain production and health is determined by the ability of the amount and quality of forage and fiber in the diet to maintain good rumen function, as well as feeding management. In cases where starch content of the diet needed to be reduced to improve production and decrease diet related problems such as ruminal acidosis, replacing starchy feeds with the appropriate quality and amount of forage or feeds higher in soluble fiber and sugar appeared to work well. This area needs to be further researched so that we can define guidelines for feeding based on sound research information, rather than working from anecdotal experience.

Table 4. Changes in milk yield and composition with changes in carbohydrate supplementation during weeks 3 through 14 of lactation. (Sutton et al., 1987).

Item	60% supplementation		80% supplementation	
	Soluble Fiber	Starch	Soluble Fiber	Starch
DM Intake, lb/day	39.2	39.2	37.9	37.1
Milk, lb/day	58.6	57.8	58.4	65.7
Fat, %	4.35	4.19	3.69	2.69
Protein, %	2.79	2.78	2.92	2.79
Lactose, %	4.68	4.53	4.68	4.42
Fat, lb/day	2.51	2.43	2.12	1.72
Protein, lb/day	1.59	1.61	1.68	1.87
Lactose, lb/day	2.71	2.62	2.76	2.91
DM = dry matter Soluble Fiber: supplement contained citrus pulp, beet pulp and low starch feedstuffs; Starch: supplement containing barley, wheat, cassava and high starch feedstuffs. Supplements were provided as 60 or 80% of the diet (air dry basis).				

Summary

It appears that there is potential to change milk composition by altering the proportions of sugars, starch and soluble fiber in the diet. Sugars show some potential for increasing butterfat, but show a neutral or negative effect on milk protein. Starch has potential to increase component yield, but excessive feeding has potential to lead to health disorders. Feeds containing soluble fiber and sugars do not appear to enhance yield of milk components of

themselves, but may help as an amendment to high starch diets to maintain animal health and productivity.

The impact of any dietary carbohydrate will likely be a function of what it is replacing in the diet, the basal amounts of that carbohydrate in the diet before supplementation, and interactions with other dietary components and management. But, based on our current research information, the changes to make to get the desired response in milk composition are not crystal clear.

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Notes
