

## WORKING WITH SUGARS (AND MOLASSES)

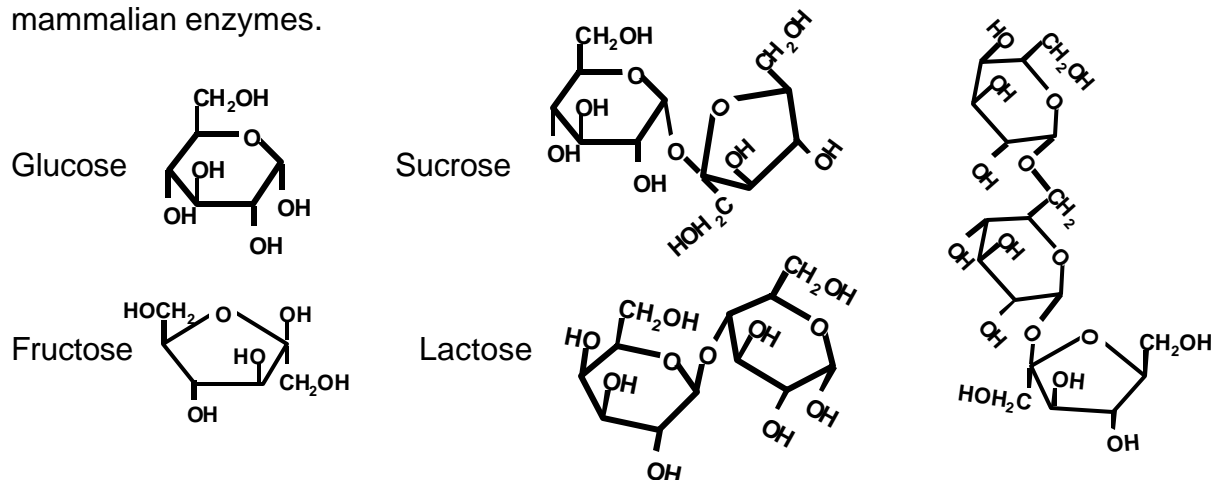
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### Introduction

There has been much interest in feeding sugars to dairy cattle in the last few years. One difficulty has been that there is little information on how sugars fit with other ration components (protein fractions, fiber, starch, pectins, etc.), precisely what nutrients they provide to cattle, and what total levels of sugars are in rations. Precise information is not available on sugar feeding levels, or how they can be used to enhance production. This paper will provide some background on feeding sugar, from purified sources or molasses, a high sugar byproduct feed. The story is far from complete.

### Sugars: Definitions

"Sugars" will be defined for the purposes of this paper as monosaccharides (simple sugars), disaccharides, and oligosaccharides. These carbohydrates are separated from polysaccharides (long chains of monosaccharides) by their solubility in 80% ethanol (Asp, 1993). Sugars are non-structural carbohydrate (NSC) as well as non-structural carbohydrate (NSC) because they are not included in NDF and are found in the cell contents. Glucose and fructose are the simple sugars most commonly found in plants (Figure 1). The most abundant disaccharide in plants is sucrose, which is a molecule of glucose bonded to fructose. Lactose (glucose + galactose) is found in milk. Maltose is a disaccharide with the same glucose to glucose alpha-linkage as starch. Oligosaccharides are the chains of monosaccharides that are two to approximately twenty units long. They include stachyose and raffinose found in soybeans (Smith and Circle, 1978). Plants do not generally have a large oligosaccharide content. Except for oligosaccharides, sugars are digestible by mammalian enzymes.



## Raffinose

Figure 1. Chemical structures of sugars.

The sugar content of feedstuffs can vary greatly (Table 1 at end of paper). Mature grains such as corn or oats may contain very little sugar because most has been converted to storage polysaccharides. Forages such as pasture or hay may have relatively greater amounts of sugars. The levels in hay are likely to depend at least in part on harvest management, and how much the plant respire away during the wilting process. Byproduct feeds such as molasses, bakery waste, citrus pulp, and almond hulls tend to have high contents of sugars. However, the variation in processing methods and source material can lead to great variation in sugar content. For example, citrus pulp samples analyzed in our laboratory varied from 12 to 40% sugars on a dry matter basis. With molasses, the information supplied on the total sugars as invert is a nutritionist's best guide for the sugar value to place on the feed. Fermented feeds including silages, distillers grains or brewers grains should have little remaining glucose, fructose, or sucrose, as they should have been largely consumed in the fermentation. A possible exception might be immature corn silage where available sugars exceed the amount needed to decrease pH for preservation. The surprisingly high sugar content (5-11% of dry matter) noted for some distillers grains and alfalfa haylage samples may reflect fragments of other carbohydrates that were hydrolyzed during the fermentation or with the acidic conditions of ensiling (Jones et al., 1992). It has been suggested that these sugars do not support the microbial performance of glucose, fructose, and sucrose (W. Hoover, personal communication).

## Fermentation

Sugars ferment very rapidly in the rumen. Without linkages to other carbohydrates, and with high solubilities (glucose: 90.9 g/100ml, sucrose: 200 g/100 ml, fructose: "freely soluble", Merck Index, 1996) there is little to impede microbial access for their fermentation. Studies report relatively higher butyrate and similar to slightly lower propionate production (Strobel and Russell, 1986; Heldt, et al., 1999) and greater potential for lactate production with sugars than with starch (Cullen et al., 1986; Strobel and Russell, 1986; Heldt, et al., 1999). The tendency to produce more lactic acid was greater at lower pH (Strobel and Russell, 1986). Fermentation of sugars + malate with monensin increased the yield of propionate, but not at all sugar concentrations evaluated (Martin et al., 2000).

There may also be differences among sugar sources in their yield of organic acids. Ruminal fluid concentrations of organic acids was highest for steers supplemented (0.30% of BW) with sucrose (83.4 mM) as compared to those supplemented with glucose (74.9 mM) or fructose (76.1 mM) ( $P = 0.05$ ) when supplemented with 0.031% of bodyweight as rumen degradable protein. The monosaccharides yielded a greater molar proportion of acetate than did sucrose ( $P = 0.05$ ), but the sugars did not differ in propionate ( $P = 0.49$ ), butyrate ( $P = 0.12$ ), or lactate ( $P = 0.26$ ). The differences between sucrose, and glucose and fructose were not significant when rumen degradable protein supplementation was increased to 0.122% of bodyweight (Heldt et al., 1999).

A caution in interpreting in vitro studies with sugars: studies that include only the sugars of interest may provide a different result than if they are fermented with a fiber source. Kellogg and Owen (1969) found that pH declined more rapidly ( $P < 0.05$ ) and there was a greater lactate concentration at 2 hours of fermentation for sucrose fermented in vitro with 30% cellulose than with 70% cellulose. There was no significant sucrose level by cellulose level interaction. This difference in results with single vs. mixed substrates likely speaks to the importance of cross-feeding among bacteria and its effects on fermentation products.

Implications of the rate and type of organic acid production from sugars relate to their ability to meet specific animal requirements and affect ruminal pH. Butyrate is metabolized by the gut epithelium and is preferentially utilized as an energy source for colonic epithelial cells (Bergman, 1990). Butyrate is also more effective than propionate or acetate in eliciting development of rumen papillae (Van Soest, 1994). Accordingly, sugar feeding has the possibility of enhancing rumen papillae development as compared to other carbohydrate sources.

The effect of sugars on ruminal pH will largely be a function of rate of yield and type of organic acids within a given ration. Lactic acid is a stronger acid than the acetate, propionate or butyrate, but it is usually transient in the rumen, being fermented to other organic acids (Kellogg and Owen, 1969). In diets ranging from 0 to 30% molasses fed with concentrate and wheat straw, ruminal pH decreased to its lowest level (6.42 for 0% to 6.33 for 30% molasses) by 1 hour post-feeding. Ruminal pH and volatile fatty acid concentration of rumen contents showed an inverse relationship (Sahoo et al., 1999). In another study in which beef steers were fed low-quality tallgrass-prairie hay supplemented with 0.122% of body weight as supplemental rumen degradable protein and 0.30% of bodyweight as glucose, fructose or sucrose, ruminal pH reached its nadir at 3 hours post feeding (earliest sampling point). Cattle receiving starch reached their lowest ruminal pH at 9 hours post-feeding (Heldt et al., 1999). In this study, the average ruminal pH of the starch-fed animals was lower than those receiving one of the sugar treatments ( $P = 0.04$ ) and pH did not differ among sugar supplements. Given similar amounts of supplemental starch or sugars, why might their effects on pH differ?

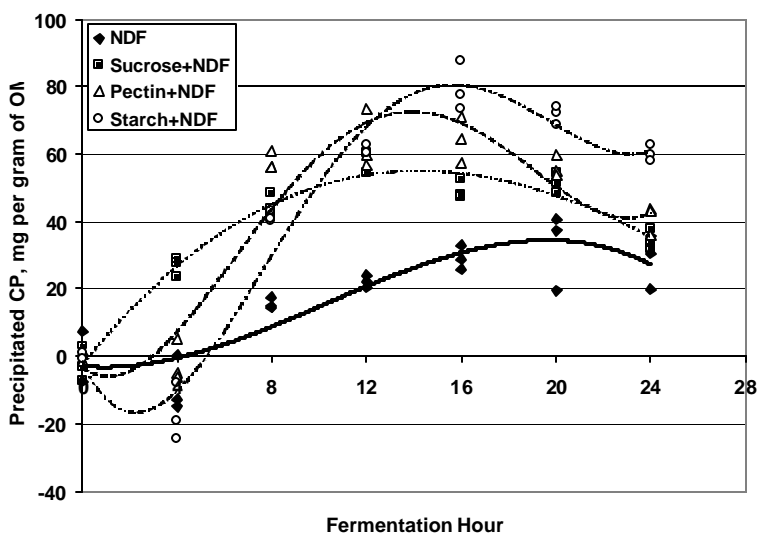
Among the ways that carbohydrates can avoid contributing to lower ruminal pH are 1) to enhance flow of fermentable materials from the rumen so they do not yield acids in the rumen, or 2) yield products other than organic acids. Increased intake noted with sugar feeding (Broderick et al., 2000) may be related to improved diet palatability or increased rates of solid or liquid passage from the rumen. The results have been few and mixed regarding effects of sugar on passage. When glucose syrup equivalent to 16.8% of diet organic matter was infused into the rumen, organic matter passage to the small intestine increased (Jersey cows; Rooke et al., 1987). However, the glucose treatment did not differ from the control for the passage of organic matter per gram of organic matter intake. In a study with heifers, dextrose (5.6% of diet DM; 74.5% forage) did not affect the fluid dilution rate, but did increase the rate of solid passage from the rumen. This rate was similar to that of a ration containing more concentrate (48.34% forage) (Piwonka et al., 1994). Sucrose fed at 14.2% of ration dry matter increased ruminal fluid dilution rate as it decreased rumen fluid volume (sheep; Sutoh et al., 1996). These experiments suggest that sugars may affect rates of

passage from the rumen, but only one study reflects sugar levels that might normally be seen in commercial rations.

Regarding yield of products other than organic acids: Sugars may differ in the types or temporal patterns of products they yield as compared to other NFC. In 1960, Gwen Thomas clearly showed that both bacteria and protozoa convert some portion of sugar and fructan substrates to “starch” (dextran). This storage of polysaccharide may be a mechanism to survive depletion of substrate in the environment. Her work showed peaks of dextran accumulation at 2 to 4 hours of fermentation. The amount of dextran then declined over the next 24 hours. If some portion of the sugars are stored as dextran, then they cannot have been converted to organic acids with their attendant depression of pH.

The yield of microbial protein does follow a different pattern over time for sucrose as compared to corn starch or citrus pectin when fermented with bermudagrass NDF in vitro (Hall and Herejk, 2001). Consistent with the notion of storage of dextran as a survival mechanism, the microbial protein yield from the sucrose treatment peaked rapidly and

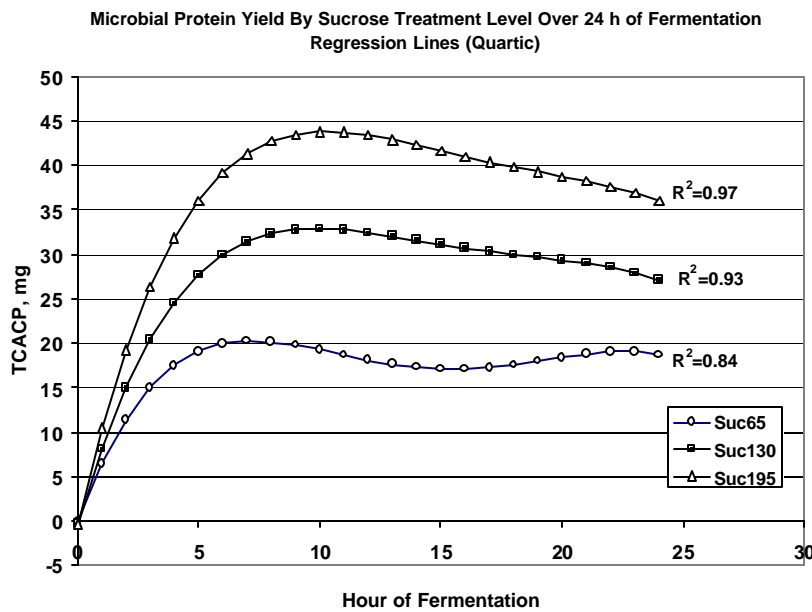
Figure 2. Precipitated crude protein yield curves from the fermentation of isolated bermudagrass NDF, and 60:40 blends of the NDF and sucrose, citrus pectin, or corn starch. Data from one fermentation. Precipitated CP should give a reasonable estimate of microbial CP. (modified from Hall and Herejk, 2001).



early in the fermentation, and then was maintained (Figure 2). In contrast, yields of microbial protein from the starch and pectin treatments peaked and then declined, suggesting substrate limitation. The pH of the fermentations did not decline below 6.49, so acidic conditions likely did not affect yields.

An in vitro study with mixed ruminal microbes examined the effects of different levels of sucrose (65, 130, and 195 mg) fermented with bermudagrass NDF (130 mg) on microbial products (Hall and Weimer, unpublished). Fermentation tubes were removed from the incubator and destructively sampled every 4 hours during the fermentation. As in the previous study (Hall and Herejk, 2001), microbial protein was measured as trichloroacetic acid-precipitated crude protein (TCACP) corrected for fermentation blanks and TCACP in the substrate at 0 hour. Microbial protein increased rapidly, and then exhibited a gradual decline (Figure 3). The maximal yield of microbial

protein increased linearly with increasing sucrose, and the efficiency of production decreased linearly from 0.32 to 0.23 (microbial CP mg / sucrose mg). The decrease in efficiency of microbial product yield is not much discussed regarding NFC. Dextran yield peaked at 4 hours of fermentation and gradually declined (Table 2). This peak was achieved before peak microbial protein yield, but corresponded to a decrease to 0 mg of free fructose in the fermentation medium. Reports of inefficiency of crude protein utilization in diets containing molasses compared to those containing corn (Bell et al., 1953) may be related to sucrose-utilizing microbes storing dextran to use for maintenance rather than growth.



Graph 3. Microbial crude protein yield (TCACP) at three levels of sucrose fermented in vitro with mixed ruminal microbes (Hall and Weimer, unpublished).

Table 2. Least squares means of dextran yield at fermentation hour 4 and its proportion of sucrose initially added to the vial.

Sucrose mg <sup>1</sup>	Dextran, mg	SE <sup>2</sup>	For Hour 4, Dextran/Initial Sucrose In Vial
65	9.3	1.59	0.14
130	11.8	1.59	0.09
195	15.0	1.59	0.08

<sup>1</sup> Milligrams of sucrose added per fermentation vial.

<sup>2</sup> Standard error

Volatile fatty acids increased rapidly to 4 hours, and increased linearly, but more slowly thereafter (Figure 4). Lactic acid peaked at 4 hours and then declined to base levels (Table 3). Peak lactic acid production increased quadratically with increasing

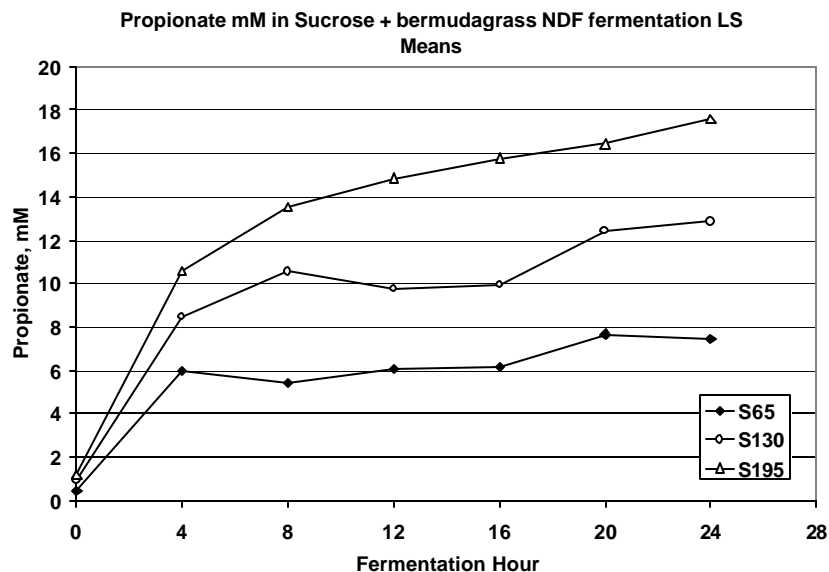


Figure 4. Change in propionate over time with different levels of sucrose fermented in vitro (Hall and Weimer, unpublished).

sucrose ( $P < 0.01$ ). Acetate, propionate, and butyrate yields increased linearly with increasing sucrose at 24 hours ( $P < 0.01$ ). The molar proportions of acetate increased linearly ( $P < 0.01$ ), propionate increased quadratically ( $P < 0.01$ ), and butyrate increased linearly ( $P < 0.01$ ) with increasing sucrose. The molar proportion data is in agreement with the work of Kellogg and Owen (1969) which showed an increase in butyrate and decrease in acetate with increasing sucrose in an in vitro fermentation with cellulose. In that study, propionate was not affected by sucrose level.

It appears that yields of microbial products (dextran, microbial protein, types of organic acids) usable by the animal to meet nutrient requirements may change with changing level of sucrose.

Table 3. Least squares means  $\pm$  standard error of organic acid production at the hour of their peak yields (millimolar in 32 milliliters).

Sucrose mg <sup>1</sup>	Total				
	Organic Acids 24 hour	Acetate 24 hour	Propionate 24 hour	Butyrate 24 hour	Lactate 4 hour
65	25.8 $\pm$ 1.9	15.9 $\pm$ 1.2	7.4 $\pm$ 0.6	2.4 $\pm$ 0.2	0.12 $\pm$ 0.83
130	39.6 $\pm$ 1.9	22.7 $\pm$ 1.2	12.8 $\pm$ 0.6	4.0 $\pm$ 0.2	1.75 $\pm$ 0.83
195	53.8 $\pm$ 1.9	29.9 $\pm$ 1.2	17.6 $\pm$ 0.6	6.0 $\pm$ 0.2	4.82 $\pm$ 0.83

<sup>1</sup> Milligrams of sucrose added per fermentation vial.

Sucrose and molasses fed at high levels have been shown to decrease ruminal fiber digestion. On grass silage/barley/rapeseed meal diets (5.3 kg/dry matter intake per day) fed to cattle, supplementation of 1.0 kg/day of sucrose (~15.9% of diet dry matter) decreased ruminal NDF digestion, but inclusion of sodium bicarbonate reversed that depression (Khalili and Huhtanen, 1991). In that study, lag time for NDF digestion increased on sucrose treatments. A companion study showed that the sucrose supplementation also decreased the rate of ruminal NDF digestion (Huhtanen and Khalili, 1991). In feeding trials with ammoniated tropical grasses supplemented with urea or cottonseed meal, and molasses at 25% of ration dry matter (Brown 1990), or offered freechoice and consumed at 35 (with cottonseed meal) to 37% of intake dry matter (Brown 1993), NDF digestibility was decreased by 5 percentage units and 3.5 to 5.2 percentage units, respectively. However, total diet organic matter digestibility was increased by 5.7 to 7.5 percentage units with molasses inclusion.

Yet another study suggests that the depression in NDF digestibility is not simply a function of feeding sugars. In the feeding study in which steers consuming low quality tallgrass-prairie hay were supplemented with rumen degradable protein at 0.122% of bodyweight and starch, glucose, fructose, or sucrose at 0.30% of bodyweight (~13.8 to 14.5% of diet organic matter), starch supplementation decreased ruminal NDF digestibility more than sugar ( $P = 0.05$ ). Disaccharides decreased NDF digestibility more than monosaccharides ( $P = 0.03$ ), but glucose and fructose did not differ in their effects (Heldt et al., 1999).

The depression in NDF digestibility related to molasses feeding has been related to level of molasses fed and to level of protein feeding. Essentially, the greater the amount of molasses fed, the greater the depression in fiber digestibility (Hughes-Jones and Peralta, 1981). This has high probability of being a function of supplementing increasing quantities of NFC, with their potential effect on ruminal pH. Increasing the amount of protein in molasses-supplemented rations can significantly improve the digestibility of fiber (Martin et al., 1981). The relationship between fiber digestibility and protein supplementation on molasses diets may be related to a competition for ammonia nitrogen between fiber and NFC fermenting bacteria (Jones et al., 1998). Adequate nitrogen must be supplemented to the rumen to avoid starving fiber digesters, especially if rapidly growing NFC bacteria are scavenging available nitrogen. Gas production data from in vitro fermentations of sucrose, isolated NDF and combinations of the two suggest that when nitrogen is not limiting, and pH change is not precipitous, sucrose may have little effect on NDF fermentability (Hall and Weimer, unpublished).

### **Animal Studies**

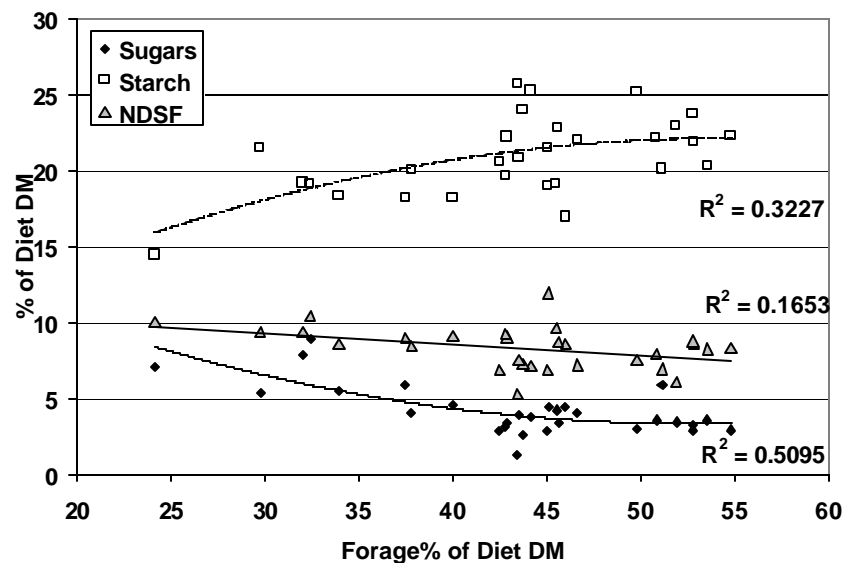
There have been relatively few animal performance studies using purified sugars. Two studies in which sucrose was substituted for starch in lactating dairy cow rations suggest that sucrose increases butterfat yield, but other results are mixed. In diets where sucrose was substituted for corn starch (0 to 7.5% of diet dry matter, diet NFC ~ 43% of DM; Broderick et al., 2000), there were increases in dry matter intake, milk fat content and fat yield. Fat-corrected milk production tended to increase (Table 4). In terms of feed efficiency, milk / dry matter intake decreased from 1.60 to 1.52, and the

conversion of ration nitrogen to milk protein N declined linearly with increasing substitution of sucrose for starch (from ~0.31 to ~0.29; G. Broderick, personal communication). When sucrose was substituted for corn meal at 1.5% of ration dry

Table 4. Changes in milk yield and composition with changes in sucrose and starch supplementation. (Broderick et al., 2000). FCM = fat-corrected milk.

Sucrose%	Starch %	DM Intake, lb	Milk, lb	Milk Fat, lb	Milk Protein, lb	FCM, lb
0	7.5	54.0	85.8	3.24	2.73	89.3
2.5	5.0	56.4	89.1	3.37	2.82	93.0
5.0	2.5	57.3	88.2	3.64	2.84	96.8
7.5	0	57.3	86.9	3.57	2.82	95.2

Figure 5. Estimated sugars, starch, and NDSF (soluble fiber) relative to the forage in the diets all as % of diet dry matter. (Hall, unpublished).



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 % decreased from 3.51% to 3.28% (Nombekela and Murphy, 1995).

There has been much testimonial in the field about the benefits or lack thereof of sugars added to dairy cattle rations. The greatest difficulty has been that nutritionists have not known what levels of sugars they are starting with, so they would be hard pressed to develop recommendations. Several commercial laboratories are now offering sugar analyses for feedstuffs, which will help to resolve this situation. Anecdotally, it appears that added sugars may have some benefit when the base ration has a low sugar content. Recommendations to provide approximately 5% of the ration as sugars have been suggested. It seems a fairly reasonable value when compared to the levels of sugars estimated to be in rations supporting good production and health (Figure 5). Our difficulty is that we still do not know how sugars will interact as other carbohydrate and protein components of the ration are altered.



Based upon in vitro data and upon animal studies, I would suggest considering the following when evaluating inclusion of sugars in dairy cattle rations:

- ◆ Make sure effective fiber levels are adequate to maintain good rumen function.
- ◆ Make sure that enough rumen degradable protein is available to meet microbial needs. Bear in mind that more or less may be needed, since sucrose utilizers have a lower microbial yield than starch utilizers. Because of this potentially lower microbial yield from sugars, consider adding additional rumen undegradable protein when feeding more sugars.
- ◆ Be able to evaluate animal performance resulting from the ration changes.

Many thanks to the Florida Milk Check-Off and Liquid Feed Committee of the American Feed Industry Association for supporting our research.

Articles from “Molasses in Animal Nutrition” (NFIA, 1983) are on the web site, [www.ifas.ufl.edu/~ona/onahp.html](http://www.ifas.ufl.edu/~ona/onahp.html), of the Range Cattle Research and Education Center, University of Florida, Ona. Go to Publications, and page down to “Molasses Feeding.” This site is an excellent example of using the web to deliver research and extension information about forages and nutrition.

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Table 1. Feed composition values for analyses performed at the University of Florida through September 2001. Values are presented as a percentage of sample dry matter.<sup>1</sup>

Feed	Ash	CP	NDF	NDFCP	Organic Acids	Sugars	Starch	Soluble Fiber
<b>Alfalfa Hay<sup>3</sup></b>					6	8	3	14
<b>Alfalfa hay, CV</b>						12.1	1.7	
<b>Alfalfa hay, CV</b>						8.2	4.5	
<b>Alfalfa hay, FL 4/99</b>	9.8	21.0	37.8	4.4		5.8	1.9	16.8
<b>Alfalfa hay 1999</b>	10.1	20.6	37.0	3.1		5.7	1.2	17.7
<b>Alfalfa hay, CA 8/99</b>	7.2	21.6	43.3	5.0		6.8	1.6	19.1
<b>Alfalfa hay, CA 8/99</b>	8.7	24.8	38.7	9.1		5.7	1.8	20.8
<b>Alfalfa hay, CA 8/99</b>	12.9	25.6	32.0	7.9		5.1	3.4	19.8
<b>Alfalfa hay, CA 9/99</b>	13.0	20.4	37.0	5.9		5.9	1.6	22.1
<b>Alfalfa hay, CA 9/99</b>	11.9	29.4	34.2	6.0		6.0	2.0	16.0
<b>Dehy. alfalfa pellets</b>							4.0	17.6
<b>Alfalfa silage, WH</b>	9.5	19.1	45.5	2.1	10.4	1.8	0.7	12.1
<b>Alfalfa silage, WH</b>	11.3	18.1	38.1	2.0	14.2	1.1	1.4	13.3
<b>Alfalfa silage, CV</b>						7.7	1.1	
<b>Alfalfa silage, CV</b>						7.3	4.9	
<i>Alfalfa silage average</i>					12	2	1	12.5
<b>Alfalfa stem, mature</b>	7.8	12.4	58.0	2.3	4.6	7.2	0.3	10.8
<b>Alfalfa stem, immature</b>	14.0	18.5	32.9	1.3			0.4	16.9
<b>Alfalfa leaf mature</b>	10.5	31.5	22.2	3.1			1.0	18.4
<b>Alfalfa leaf, immature</b>	9.2	29.3	18.6	1.6	9.1	10.2	3.4	19.4
<b>Almond hulls, WH</b>	5.0	7.1	26.0	1.2	8.2	32.8	1.4	16.9
<b>Almond hulls, CA 8/99</b>	5.1	5.5	32.0	4.07		34.3	3.2	15.6
<b>Almond hulls, CA 9/99</b>	5.0	5.4	35.0	5.6		31.8	3.2	12.2
<b>Almond skins, CA 8/01</b>	6.0	12.2	33.0	2.4		14.3	0	10.7
<b>Bakery waste, CA 8/99</b>	8.7	14.4	23.3	6.6		10.8	17.9	9.6
<b>Broccoli</b>	8.8	30.4	14.3	0.5	5.0	17.7	0.7	18.9
<b>Canola meal, CA 8/99</b>	8.2	40.8	27.2	9.8		9.9	2.1	13.2
<b>Canola meal, CA 8/99</b>	8.4	41.9	28.7	7.1		10.2	2.0	9.7
<b>Canola meal, NM 4/01</b>	4.4		24.0	5.6		2.8	1.3	10.6
<b>Citrus pulp, FL 4/99</b>	8.5	8.7	24.1	4.2		13.4	1.4	37.5
<b>Citrus pulp, FL 4/99</b>	8.5	8.2	24.4	4.2		18.4	1.6	34.5
<i>Citrus pulp, average<sup>2</sup></i>	6.7	7.2	22.1	2.9	9	26.5	1	32.9
<b>Citrus pulp, ranges<sup>1</sup></b>	4.4- 8.7	4.1- 9.4	17.8- 29.4	1.6 - 4.5		12.5- 40.2		25.2- 43.7
<b>Corn distillers, ethanol</b>						14.5	6.6	
<b>Corn distillers, whiskey</b>						6.2	4.2	
<b>Corn distillers, FL 4/99</b>	4.3	31.3	58.2	15.2		11.0	2.0	8.9
<b>Corn distillers, FL 5/99</b>	4.8	28.3	54.4	14.8		5.4	3.1	7.8
<b>Corn distillers, 1999</b>	4.3	30.3	46.3	12.7		3.2	0.5	11.6
<b>Corn distillers, CA 8/99</b>	6.43	31.6	50.9	15.7		7.5	1.1	9.9

Feed	Ash	CP	NDF	NDFCP	Organic Acids	Sugars	Starch	Soluble Fiber
Corn gluten feed						5.9	16.4	
Corn grain, WH	1.5	9.0	12.6	0.7	0.7	0	64	8.1
Corn grain, CV						5.2	60.8	
Corn meal, FL 4/99	1.6	8.9	20.5	3.6		0	66.2	6.4
Corn meal, FL 5/99	3.3	9.0	15.7	3.8		4.5	55.9	10.6
Corn meal, 1999	1.1	9.5	11.8	2.9		2.3	65.8	8.6
Corn, rolled, CA 8/99	1.5	9.7	15.2	6.9		2.2	60.1	12.1
Corn, rolled, CA 8/99	1.5	9.1	16.1	5.3		0.9	62.6	8.6
Corn silage, WH	4.9	7.5	50.9	0.9	10.6	0.9	18.9	4.3
Corn silage, WH	3.8	7.0	41.8	0.6	7.9	0.3	30.4	5.8
Corn silage, CV						3.4	14.4	
Corn silage, CV						4.7	29.9	
Corn silage, FL 4/99	4.8	10.2	51.1	4.4		0.5	19.4	7.0
Corn silage, FL 5/99	3.8	10.4	51.1	3.4		4.6	23.6	3.2
Corn silage, CA, 8/99	12.8	11.4	55.2	4.3		0.8	7.2	10.8
Corn silage, CA 8/99	6.3	7.5	47.7	6.5		1.3	21.2	15.7
Corn silage, OH	12.1		47.1	1.6		3.3	18.1	11.1
Corn silage, OH	4.0		48.8	1.3		0.9	19.5	7.7
Cottonseed, whole							1	8.5
Ctsd whole, FL 4/99	4.2	24.2	48.3	5.3		6.2	1.6	6.8
Ctsd whole, FL 5/99	4.1	23.3	47.6	5.6		5.9	0.8	10.8
Cottonseed hulls							< 1	4
Green peas (frozen)	3.2	25.9	18.2	0.4	1.7	25.0	20.6	2.4
Molasses, cane						55+		
Oat hay, CA 8/99	10.6	8.7	68.0	3.8		3.2	2.8	9.4
Potatoes						4.8	57.5	
Soybean meal (48%)	6.5	52.7	10.9	1.4	4.2	10.9	1.0	14.0
SBM (48%) FL 4/99	7.3	56.9	14.4	8.6		11.9	2.4	18.8
SBM (48%) FL 5/99	7.0	56.3	16.0	8.5		11.6	2.1	14.0
SBM (48%) 1999		56.7	9.7	3.2		10.2	0.5	16.9
Wet soy product, CA, 99	4.1	32.0	25.6	1.6		0.8	0.6	31.4
Soybean hulls	4.2	9.8	69.0	4.0	< 1	< 1	1	17.4
Sugar beet pulp, ID 3/94	8.9	8.0	44.6	5.1	0.4	12.8	0	30.0
Sugar beet pulp, CA 8/99	9.1	9.6	51.1	7.3		14.2	1.7	17.4
Sugar beet pulp, CA 8/99	7.4	9.8	39.8	5.7		24.7	2.3	20.1
Timothy hay	5.0	8.2	67.3	1.8	4.4	9.1	0.4	6.4
Ground wheat	1.7	10.9	12.1	1.1	0	1.8	64.6	8.8
Wheat middlings	5.5	19.0	42.3	3.4	4.6	5.4	21	3.4
Wheat silage, CA 9/99	12.4	12.8	50.8	6.1		2.5	2.7	16.8

<sup>1</sup> Capitalized abbreviations denote lab source, smaller font capitalized abbreviations indicate state and date of origin.

<sup>2</sup> Results from analyses of 79 dried citrus pulp samples.

<sup>3</sup> Alfalfa hay: soluble fiber content decreases with increasing maturity and with leaf loss.