

# Sugar aids lactating dairy cattle production

*Feeding supplemental sugar to dairy cattle has been shown to increase intake, milk yield and milk fat content and decrease rumen ammonia, potentially from increasing fiber digestion and production of rumen microbial protein and butyrate.*

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**A**GRICULTURE is very dependent on sugar. Plants grow by producing sugar, grain is produced by conversion of sugar to starch, silage is preserved by bacteria converting sugars to acids and the sugar in milk makes it one of nature's most perfect foods.

All types of carbohydrates (fiber, starch and sugar) fed to ruminants are degraded to simple sugar before being fermented to volatile fatty acids by rumen bacteria and used for energy. Cellulose (fiber) is converted to glucose, starch to glucose and sucrose (sugar) to glucose and fructose.

A typical lactation diet has less than 3% sugar because grains are low in sugar and silages have had the sugar fermented to organic acids to preserve the silage. Feeding supplemental sugar helps provide needed energy to the rumen bacteria at the right time in relation to starch and fiber digestion to increase the total ration's nutritive value. Sugar supplementation has been shown to increase feed intake, fiber digestibility and microbial protein production.

## Sugar content

Glucose and fructose are the most common simple sugars found in plants. The most abundant disaccharide in plants and molasses is sucrose, which is a molecule of glucose bonded to fructose. Lactose (glucose plus galactose) is found in whey (Hall, 2003).

The sugar content of feedstuffs varies greatly (Table 1). Mature grains like corn, barley or oats contain very little sugar because most of it has been converted to starch. Forages, such as pasture or hay, may have relatively greater amounts of sugar, but levels vary depending on maturity, harvest conditions and management. Byproduct

feeds, such as molasses, bakery waste, citrus pulp and almond hulls, tend to have high sugar contents.

With molasses, the total sugar as invert (TSI) is the best guide for its sugar value. Fermented feeds — including silages, distillers grains or brewers grains — should have little

remaining glucose, fructose or sucrose as fermentation largely consumes them. The high sugar content noted for some distillers grains and alfalfa haylage samples may reflect fragments of other carbohydrates that were hydrolyzed during fermentation or with the acidic conditions of ensiling (Hall, 2003).

Hoover et al. (2006) evaluated varying sugar levels as a portion of total non-structural carbohydrate (NSC; sugar plus starch). They found that sugar digestion was less than starch, but sugar digestion increased considerably by adding a supplemental sugar source. The sugar digestion for a 2.9% sugar diet (no supplemental sugar) was 45.0% compared to 79.1% for a 9.5% sugar

## 1. Typical sugar content of feedstuffs

Feed	Sugars, % DM
Alfalfa hays	3.0-6.0
Legume silages	1.7-5.0
Corn silages, mature	0.7-3.0
Corn grain	0.3-1.5
Barley grain	1.0-3.0
Hominy	1.0-6.0
Corn gluten feed	1.0-2.0
Brewers grains	3.0-6.0
Corn distillers grains	3.0-14.0
Molasses, cane	61
Whey, condensed	48
Bakery waste	8.0-12.0
Almond hulls	17-33
Citrus pulp	12.5-40.2

Adapted from Hall (2002) and Hoover and Miller-Webster (1998).

## 2. Effect of replacing high-moisture shelled corn with liquid molasses on dry matter intake and milk production

Liquid molasses, % DM	0	3	6	9
Total sugar, % DM	2.6	4.9	7.4	10.0
DMI, lb. per day	55.9	61.8	57.4	59.0
3.5% FCM, lb. per day	98.6	104.1	97.5	96.6

Adapted from Broderick and Radloff, 2004. FCM calculated based on Sklan et al. (1992).

## 3. Effects of starch and sugar with source of ammonia, peptides and amino acids on microbial protein synthesis

	Starch	Sugar
Microbial protein		
Control coefficient	-0.013	0.148
Treatment coefficient	0.062	0.495
Microbial-nitrogen per kilogram of digested carbohydrate		
Control coefficient	-2.777	0.802
Treatment coefficient	-0.797	9.786

Source: Adapted from Lean et al. (2005).

diet. Thus, the cause of the low sugar digestion across NSC levels appears to be related to the availability of the sugar in the feedstuffs (primarily the forages and soybean meal). It was estimated that 89-96% of the supplemental sugar was digested.

### Milk yield, fat production

Broderick et al. (2000) and Broderick and Radloff (2004) looked at the effect three sources of supplemental sugar (sucrose, dried molasses and liquid molasses) on milk production when replacing high-moisture shelled corn (HMSC) in alfalfa silage/whole-corn plant silage (WCPS) diets.

Broderick et al. replaced 0, 2.5, 5.0 and 7.5% starch from HMSC with sucrose in a 60% forage diet (40% alfalfa silage, 20% WCPS). There were linear increases ( $P < 0.05$ ) in dry matter intake (DMI) and 3.5% fat-corrected milk (FCM) yield ( $P = 0.11$ ) and fat content ( $P = 0.01$ ) as sucrose increasingly replaced corn starch in the diet.

Broderick and Radloff reported on two trials. In the first trial, 0, 4, 8 and 12% dried molasses replaced the same amount of starch from HMSC in a 60% forage diet (40% alfalfa silage and 20% WCPS) supplying 2.4, 4.2, 5.6 and 7.2% total sugar (natural plus supplemental) in the diet. There was a significant ( $P = 0.05$ ) linear increase for DMI (55.6, 56.5, 57.9 and 57.2 lb. per day, respectively), and 3.5% FCM showed a quadratic ( $P = 0.07$ ) response (90.6, 92.8, 93.9 and 88.6 lb. per day, respectively).

In the second trial, 0, 3, 6 and 9% liquid molasses replaced starch from HMSC in a 50% forage diet (30% alfalfa silage and 20% WCPS) to supply total dietary sugar of 2.6, 4.9, 7.4 and 10.0%. DMI and 3.5% FCM showed a significant ( $P < 0.05$ ) quadratic response (Table 2).

According to the authors, "Most notable in this trial was the large number of quadratic responses ( $P < 0.01$ - $0.10$ ) to increasing dietary sugar. In addition to DMI and milk yield, quadratic effects were observed for milk protein, fat, solids-not-fat and urea nitrogen, apparent digestibility of NDF (neutral detergent fiber), ADF (acid detergent fiber), estimated urinary excretion of purine derivatives and ruminal ammonia concentration. Overall, these responses suggest that sugar supplementation improved performance over the control diet but that production actually declined after the maxima, indicating that sugar was being fed in excess."

Adding 2.4% supplemental sugar on a dry matter (DM) basis to the diet through liquid molasses to a basal diet containing 2.6% total sugar was the best for milk production and components. At 50 lb. of DMI per day, this would be

equivalent to 2.5 lb. of liquid molasses (48% TSI) on an as-fed basis and would supply 1.2 lb. of sugar per head per day.

Oldick et al. (1997) found that feeding 3.4% of diet DM as molasses increased milk production 2.9 lb. per day without increasing feed or energy intake.

Miller et al. (2005) showed that feeding liquid molasses significantly ( $P < 0.05$ ) increased pre-calving DMI of primiparous cows (25.5 versus 28.4 lb. per day) and multiparous cows (36.7 versus 40.7 lb. per day) and increased energy-corrected milk production (99.2 versus 108.9 lb. per day) of multiparous cows during the first 75 days of lactation. A ration providing a balance of both sugar and starch optimized production.

### Rumen acids, ammonia

The type and amount of organic acid production from sugars may have implications for their ability to elicit specific responses compared to other carbohydrates (Hall, 2003). Substitution of starch with sugar has shown increased butyric acid, no effect on propionate and slightly lesser amounts of acetate (Heldt et al., 1999; Hristov et al., 2003, 2005; Hoover et al., 2006). Butyrate is more effective than propionate or acetate in eliciting development of rumen papillae (Russell, 2002).

Thus, sugar feeding has the possibility of enhancing rumen papillae development compared to other carbohydrate sources. Xu and Allen (1998) reported that replacing corn with lactose increased rumen papillae surface area, growth rate and length and width.

Since the rumen epithelium absorbs the majority of substrates that supply the daily energy requirements to the dairy cow, improvement in the growth and development of the rumen papillae could increase the absorptive capability of the rumen.

A reduction in ruminal ammonia concentration has been noted in nearly all studies in which sugars have been added to the diet (Hristov et al., 2005; Heldt et al., 1999; Poncet and Rayssiguier, 1980; McCormick et al., 2001; Broderick and Radloff, 2004). This suggests that fermentation rate was faster on the sugar-supplemented diets. Sannes et al. (2002) showed decreased total urinary nitrogen excretion and milk urea nitrogen with sucrose supplementation.

Ammonia emitted from livestock manure is mainly a product of urinary urea breakdown (Hristov et al., 2005). Thus, from an environmental point of view, diets providing sugar would potentially result in a lower rate of manure nitrogen volatilization. If ruminal ammonia concentration is elevated and adding sugar does not lower the ruminal ammonia concentration, fermentation

is uncoupled due to an increased fermentation rate and a lack of amino acid and peptide nitrogen (Emanuele, 2004).

### Fiber digestibility

Broderick and Radloff (2004), when replacing HMSC with dry molasses, reported significant ( $P < 0.01$ ) linear orthogonal contrast for dry matter digestibility (DMD = 57.7, 58.9, 60.0 and 61.9%, respectively), organic matter digestibility (OMD = 58.8, 60.1, 61.1 and 63.1%, respectively), neutral detergent fiber digestibility (NDFD = 37.5, 37.8, 38.6 and 41.1%, respectively) and acid detergent fiber digestibility (ADFD = 38.6, 39.4 and 42.1%, respectively) with increasing levels of supplemental sugar.

When replacing HMSC with liquid molasses, they found a significant ( $P < 0.01$ ) quadratic orthogonal contrast in NDFD (36.3, 36.3, 44.6 and 37.2%, respectively) and ADFD (42.2, 43.4, 49.6 and 43.0%, respectively) with increasing levels of supplemental sugar.

Vallimont et al. (2004) replaced starch with sucrose in diets containing 31-33% NSC, which resulted in NDFD quadratically increasing.

*In vivo* and *in vitro* studies suggest that sugars can increase the extent of ruminal fermentation of fiber if rumen degradable protein (RDP) supplementation is adequate; otherwise, they may depress it (Hall, 2003).

Heldt et al. (1999) found that increasing supplementation of RDP from 0.031 to 0.122% of bodyweight to steers consuming low-quality tallgrass/prairie hay supplemented with starch, glucose, fructose or sucrose increased fiber digestion.

McCormick et al. (2001) reported that milk yield declined when sucrose-supplemented diets contained expeller soybean meal compared to solvent soybean meal, suggesting different effects with more RDP.

In an *in vitro* study (Holsthausen and Hall, 2002) with mixed ruminal microbes, where available nitrogen was not limiting, supplementation with sucrose increased the rate of NDF digestion in a 24-hour period compared to NDF fermented alone.

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.

### Microbial protein

One of the greatest economic opportunities of proper sugar supplementation is to increase the

rumen microbial protein supply to the small intestines. In a number of trials, feeding sugar increased the supply of microbial protein compared to the control treatment (Hristov et al., 2005; Hoover and Webster, 1998; Hall, 2003; Broderick and Radloff, 2004). As stated earlier, a reduction in ruminal ammonia concentration has been noted in many studies in which sugars were supplemented.

This suggests a more efficient utilization of the rapidly available nitrogen components in the diet and an increase in microbial growth and metabolism. Sugar is digested at a rate of 300% per hour, while the digestion rate for starch varies from 6 to 60% per hour. Due to this difference in usage rate, replacing part of the starch in a ration can increase the fermentation rate, resulting in an increase in the amount of microbial protein produced.

The data in Table 3 (Lean et al., 2005) show that starch itself has a negative effect on microbial protein production (coefficient -0.013) and on microbial protein-nitrogen produced per kilogram of digested carbohydrate (coefficient -2.77), whereas sugar stimulates microbial crude protein (MCP) production (coefficient 0.148) and efficiency of microbial protein production (coefficient 0.80).

When a source of ammonia, amino acids and peptides was added with the starch, MCP increased by a factor of seven (coefficient 0.062) and efficiency improved (coefficient -0.79) over starch alone. The combination of sugar with the source of ammonia, amino acids and peptides increased MCP by a factor of three (coefficients 0.148 versus 0.495) over sugar alone, and this was eight times greater than the combination with starch. The sugar combination increased efficiency tenfold over the starch combination (coefficient 9.7).

When molasses is added to a dairy diet replacing starch, it will speed up the microbial growth rate, which increases the microbial requirement for ammonia, amino acids and peptides. Thus, diets adequate in RDP prior to molasses addition may not be adequate with molasses (Emanuele, 2004).

## Summary

Feeding supplemental sugar has been shown to increase DMI, FCM yield and milk fat content and decrease rumen ammonia. This potentially results from increasing fiber digestion, rumen microbial protein production and

butyrate production. Increasing rumen ammonia utilization decreases nitrogen loss to the environment.

Sugars are not just fast starch; they differ from other carbohydrates in their effects on animal performance. Rations containing the proper level and balance of sugar and starch give optimum production. When supplementing sugar, adequate effective fiber is essential for good rumen function, and RDP must be available to meet microbial needs. Nitrogen and carbohydrate nutrition can be monitored using milk urea or plasma urea nitrogen.

Lactating dairy cattle can and do sort total mixed rations (Shaver, 2002; Clark, 2004; Enderes et al., 2005). An additional benefit of using liquid molasses or a molasses-based liquid supplement as the source of sugar is their effect on sorting reduction (Shaver, 2002; Clark, 2004).

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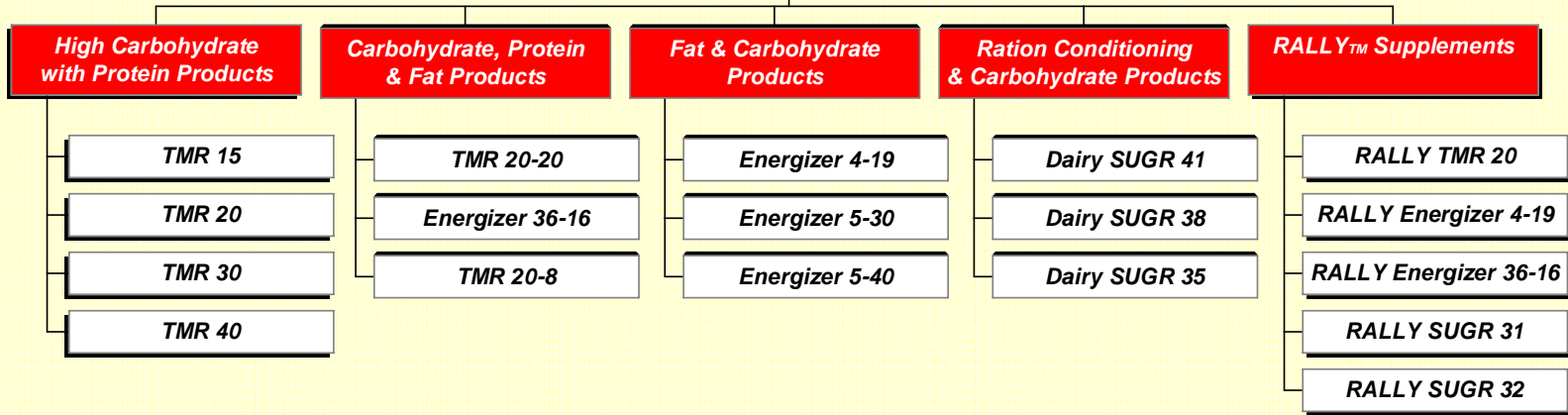
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