TECH NOTES

New Thoughts on Sugar Fermentation and Metabolism in the Ruminant

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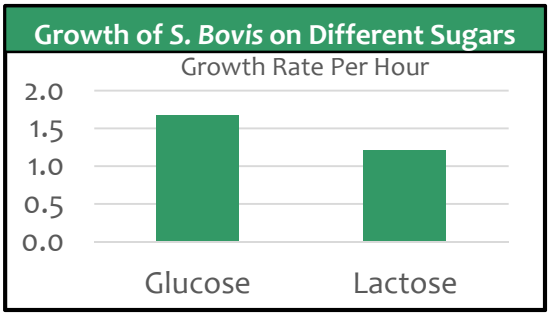
Sugar addition to rations has had a mixed history. We have had the paradigm of adding sugar to make the diets that we feed more palatable and to prevent sorting (liquid sugar products). It has only been in recent years that consideration has been given to the addition of sugar to the ration as a nutrient to benefit rumen function as well as the metabolism of the cow.

On a relatively recent basis, we have been measuring sugars in feedstuffs. The industry has utilized two different methodologies, the Smith procedure and the ethanol procedure. The Smith procedure involves the addition of a weak acid which breaks down the fructans to fructose. The ethanol extraction procedure extracts many different sugars, including some di-, tri- and polysaccharides, and has been considered the preferred measurement for nutrition programs. However, it does not extract fructans. Regardless of method used, we need to start thinking in terms of individual sugars.

The 5 and 6 carbon sugars are shown in the table at the right. The 5-carbon sugars are in the hemicellulose or NDF. These sugars have a lower ruminal and intestinal digestibility -- not only as a part of the NDF but also as free sugars. The most common plant sugar is a disaccharide, sucrose which is comprised of glucose and fructose.

5-Carbon Sugars	6-Carbon Sugars
Arabinose	Glucose
Xylose	Glucuronic acid
Ribose	Fructose
	Galactose
	Galacturonic acid
	Mannose



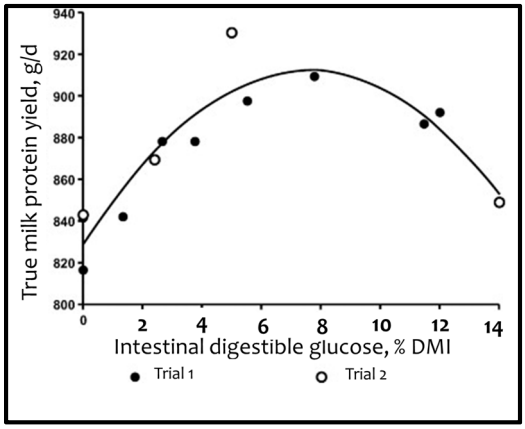
Research done at Cornell University (*Bond et al., 1998*) demonstrated that not all sugars are equal in stimulating microbial growth (See chart). Lactose (glucose + galactose) is not well utilized by bacteria. The research work done with the main sugars in molasses and plant materials has shown that sucrose (glucose + fructose), fructose and glucose are the very fermentable sugars that give responses in the rumen and in the cow.

There have been several studies over the years that have demonstrated the value of adding sugar to rations. Most of these studies have been with the addition of molasses or sucrose directly. Several of the studies replaced the starch with the sugars, keeping the NFC constant. The results were always positive not only in milk yield but also in components. In studies with fermenters, the work showed increases in fiber digestion. It has been suggested that the fungi, which play a role in opening up the fiber, are stimulated by the 6-carbon sugars. This is important because it fits well with the rapidly degraded protein (mostly the soluble fraction) to give an early stimulation to fiber digestibility. Additionally, if we can reduce the starch in the ration, we will have better control of rumen pH, an additional enhancement for fiber digestibility. This is increasingly important as we are now increasing the % forage in the ration due to the high cost of corn.

In the original nutrition models, it was assumed that all of the sugar was broken down in the rumen. This assumption is not correct. Only about 50 to 70% of the sugars are degraded in the rumen; the rest escapes. This is important because of the positive impact that the digestible sugars can play in the metabolism at the mammary gland. It is important to note that added sugars, in the form of sucrose or sucrose equivalents (glucose + fructose) is

about 84% degraded in the rumen. What brings this down to 50- 70% is the effect of fermentation and browning (heat) on the 6 carbon sugars. When forages are ensiled, the 6-carbon sugars are essential for the fermentation. The majority of the sugar left is 5-carbon sugars, which have lower ruminal digestibility.

The figure to the right is from some excellent work conducted in France at INRA (*Rulquin et al., 2004*). These results suggest that it is important not only to enhance rumen function, but also to have an optimum amount of digestible sugar that will enhance milk true protein yield. This means that we need to consider the feeding of additional sugars in ration.



Reports in the literature that do not show a positive response are typically those that define treatments by counting total sugars in the diet. Many rations that are fed in this country have silages as their forage base. This usually results in rations with a 3 to 4% total sugar as measured by the 80% ethanol procedure. Unfortunately, this procedure does not identify the individual sugars. A high percentage of these sugars are the 5-carbon sugars discussed earlier. These sugars are not very digestible in the rumen or in the small intestine. We now, in the updated CNCPS model, use a lower rate of ruminal digestion for the sugars in fermented feeds. It is recommended that we should provide about 3 to 5% additional sugar in the form of 6-carbon sugars. This will result in a total sugar in the ration of 5 to 8% of the DM. If we assume that 35% of this sugar will escape, then added to the base sugar level plus what we will derive from the escaped starch, we will approach the levels suggested by the work of Rulquin shown above. Research using molasses based liquids shows 84% utilization in the rumen.

We now need to formulate rations for a specific sugar level, replacing the starch, and maintaining a constant NFC while increasing the forages in the ration. This brings us to what can be used as sugar sources. Molasses is one of the most common ingredients to which we have access.

Sugar Content of Cane Molasses (Dry Matter Basis)
Assays in 2003 -- 70 shipments – 14 origins
(Source: Caldwell, 2006)

	Sucrose	Reducing Sugars	Total Sugars	Total Sugars as Invert (TSI)
Average	45.43	20.32	65.75	67.94
Range	34.88 – 54.19	13.81 – 28.59	55.39 – 73.78	57.56 – 76.49

Molasses can be used as a sole ingredient or can be used as a base into which other sugar sources can be blended. The usual "molasses" that is sold in the industry is a blend. These blends are formulated to enhance the value of the molasses. These blends take into account only the sugars identified by TSI. Again, it must be stated that no work has been done using total sugars.

Application

It is recommended that for lactating cows, we balance the ration to a 37 to 43% NFC, with preliminary guidelines above, on a fermentable basis. We now have the capability to formulate for the different fermentable CHO components, allowing us to better balance the rumen.

Group	Fermentable Total CHO, %DM	Fermentable Fiber, %DM	Fermentable Starch, %DM 7h	Fermentable Sugar, %DM	Fermentable Soluble Fiber, %DM
Close up	37	12	12.8 to 14.4	5	6
Early lactation	40	10	18.5 to 20.0	6	5
Peak cows	43	9	21.6 to 23.2	7	5
Mid lactation	40	10	18.7 to 20.3	6	4
Late lactation	38	11	17.5 to 19.0	5	4

Summary

The research is now beginning to move us ahead allowing us to balance for sugars in our rations with greater intelligence. It will not be long before we will be able to balance for individual 6 and 5 carbon sugars to enhance rumen function and intestinal digestibility and metabolism. This will be an exciting step forward.

References

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