The Value and Role of Sugar in Dairy Rations

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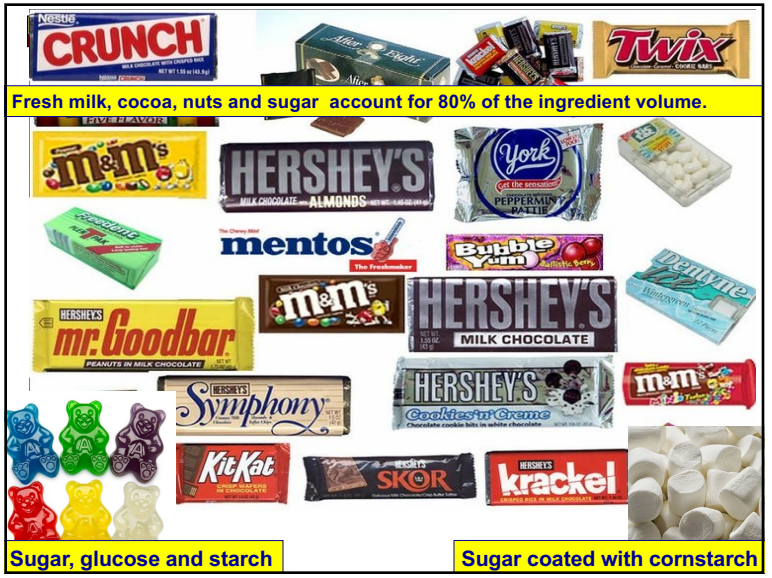

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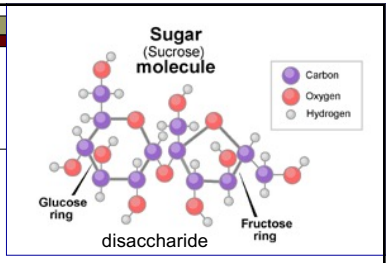
What is sugar?



- A sweet crystalline substance obtained from various plants, especially sugar cane and sugar beet, consisting essentially of sucrose, and used as a sweetener in food and drink.
- Sucrose is actually two simpler sugars stuck together: fructose and glucose

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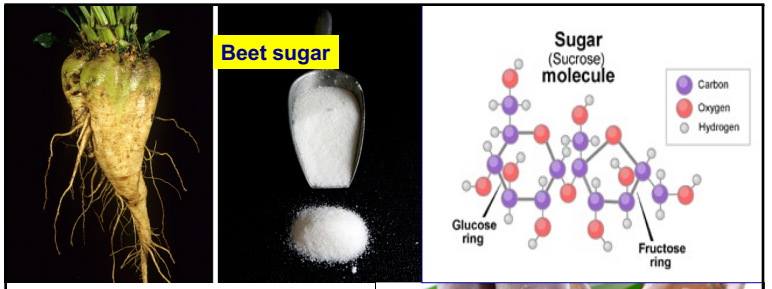

Sucrose is easily extracted from beets and sugar cane and both contain 50-60% sucrose.

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So what does this mean for the dairy cow?

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	Starch	Sugar	Sol Fiber
	----------%----------		
Corn	70	1	0
Wheat	64	2	3
Barley	58	2	3
Bakery waste	45	5-16	2
Cookie meal**	48	10	2
Hominy	49	4	2
Wheat midds	22	5	6
Corn distillers	3	3-15	8
Molasses	0	50-60	10-12
Beet pulp	1	5-10	21
Citrus pulp	2	15-30	34
Whey permeate	0	5-20	0

[1]Most of the data in this table were adapted from "Feeding Sugar to Ruminants," MB Hall
http://www.extension.org/pages/25322/feeding-sugar-to-ruminants

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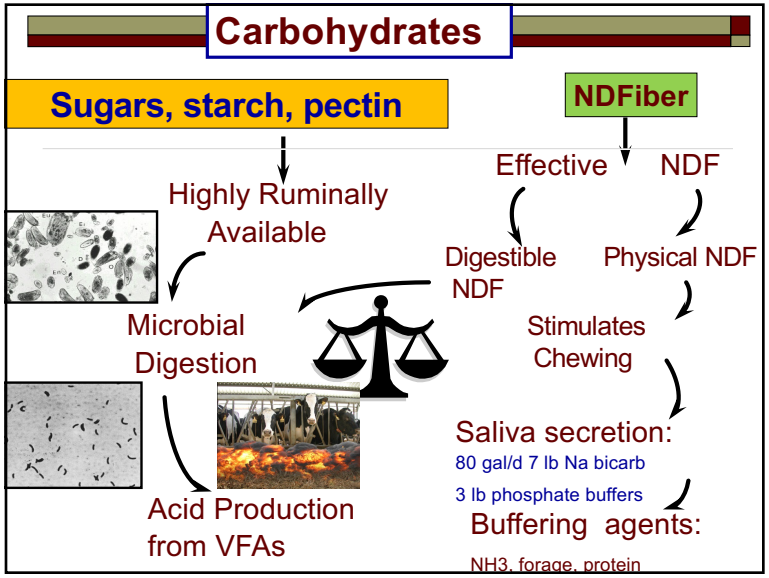
Carbohydrates



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Sugar concentration in forage

Forage source	Sugar % Range
Alfalfa fresh (pasture)	8 - 9
Alfalfa hay	2 - 12
Alfalfa silage	1 - 5
Corn silage	0.3 - 5

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Six-Carbon Sugars are Good for Making Beer and Growing Rumen Microbe's

✓Majority of sugars that remain in corn silage, haylage and small grain silage are 5- carbon sugars

✓Major sugars in cane molasses: sucrose, glucose (6-carbon sugars)

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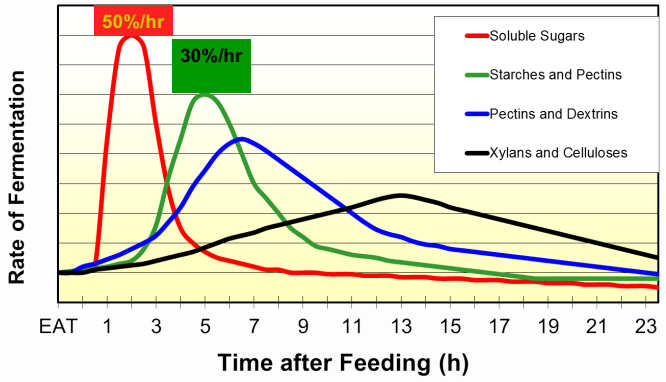
Ruminal carbohydrate profile



Adapted from Johnson, R.R., 1976

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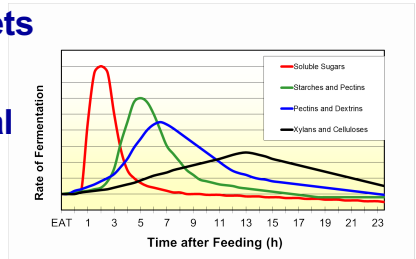
Goals for formulating rations for dairy cows

- Provide low-fill, highly fermentable diets
- Maintain normal ruminal pH
- Consistent fermentation over time



Mike Allen

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Major carbohydrates (CHO) and rumen fermentation end-products

	CHO	End-products
Alfalfa hay	Pectin; Starch	Acetate; Propionate/Lactate
Corn silage	Starch	Propionate/Lactate
Grass hay	Fructan, *Sugar*	Propionate/Lactate
Barley	Starch; b-glucans	Propionate/Lactate; Acetate
Corn	Starch	Propionate/Lactate
Wheat	Starch; b-glucans	Propionate/Lactate; Acetate
Beet pulp	Pectin; *Sugar*	Acetate; Propionate Butyrate Lactate
Citrus pulp	Pectin; *Sugar*	Acetate; Propionate Butyrate Lactate
Soyhulls	Pectin	Acetate

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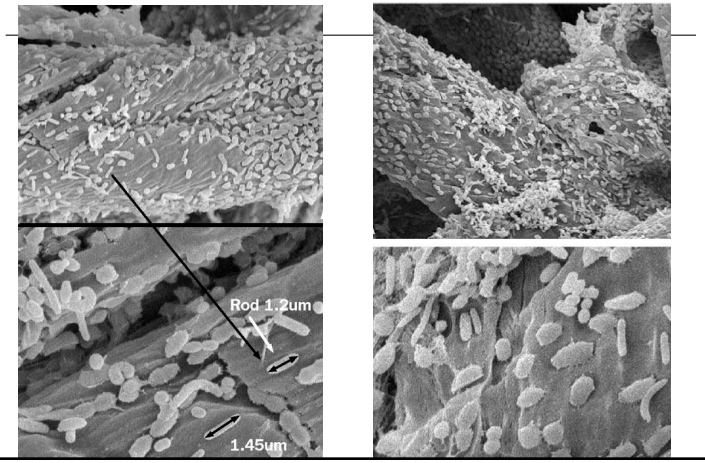
Rumen Bacteria



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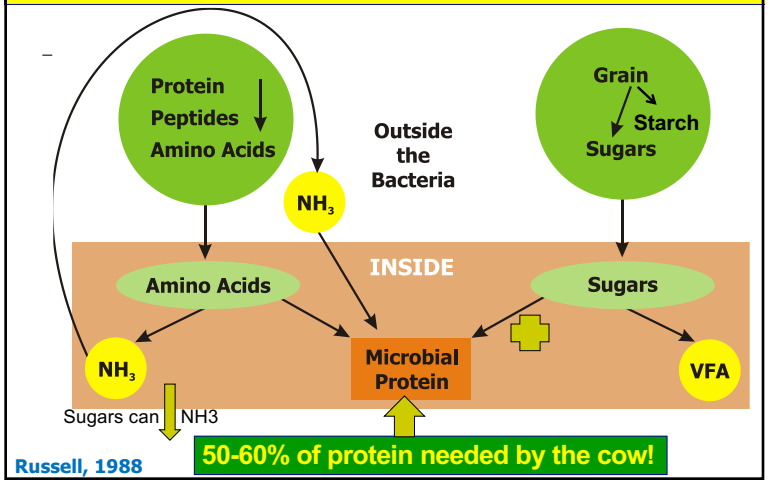
Use of protein and carbohydrate by rumen bacteria



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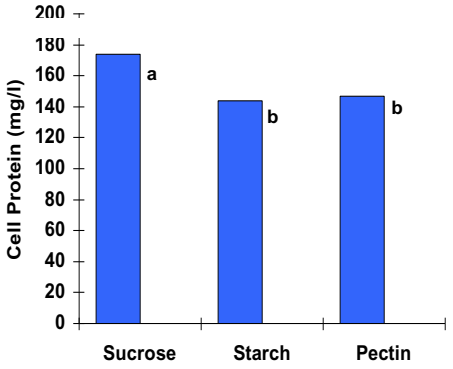
Microbial cell protein produced from fermentations by mixed rumen microbes



Different letters differ, $P < .05$. Stroebel and Russell, 1986

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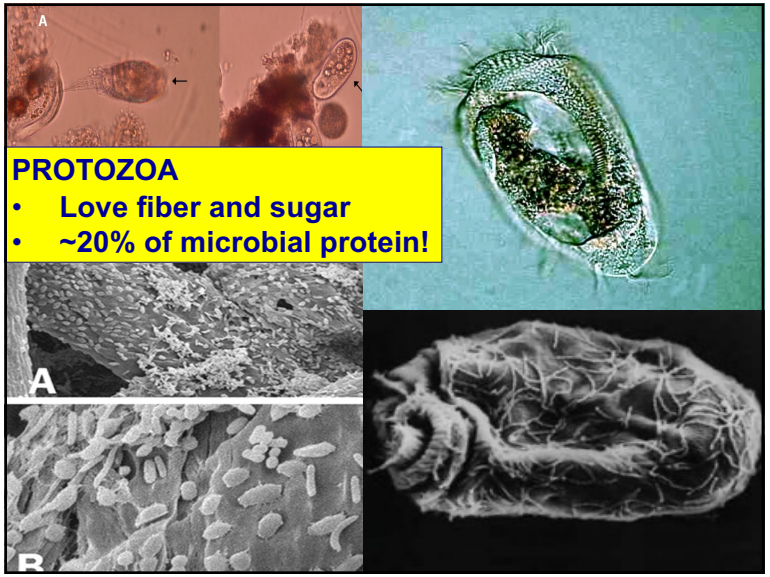

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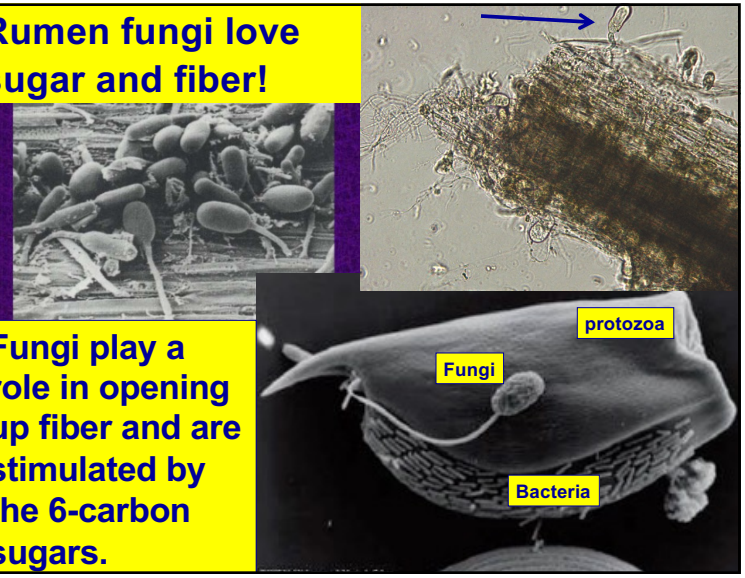
Rumen fungi love sugar and fiber!



Fungi play a role in opening up fiber and are stimulated by the 6-carbon sugars.

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Summary points

- Variety of sugar sources for dairy cows
  - Forage source?
- End products of fermentation impact microbial growth
- Bacteria, protozoa, and fungi in the rumen play an important role in fiber and sugar digestion
- Rumen microbes need six carbon sugars: sucrose, glucose

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Sugar in diets for dairy cows

- What factors may affect response:
  - How sugar is fermented by rumen microbes depends on diet ingredients
  - The types of sugars used
  - Fermentable carbohydrates
  - Rumen degradable protein
  - Fiber type and concentration

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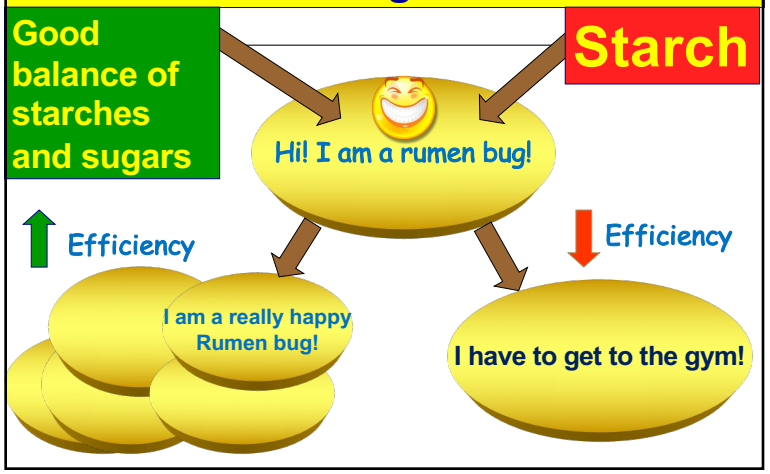
How carbohydrates affect response to sugars



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How rations are formulated may affect response to sugars

- Substitution of sugars for starch, may result in diets that have inadequate starch concentrations and a ration with too much fast carbohydrate available.
- Or sugar fermentation generates too much ATP than needed by microbes, efficiency is decreased, when diets already contain adequate levels of starch.

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Factors that affect response to sugars

- Sugar concentration and type
  - Sugars in feedstuffs may only be 45% available
  - Sugars from liquid blends were greater than 85% available.

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Common sources of supplemental sugar: %sugar DM

Table sugar	100%
Molasses	70%
Whey	70%
Candy	40%
Chocolate	35%
Almond hulls	30%
Citrus pulp	25%
Cookie	22%
Beet pulp	15%

- Due to variability need to analyze for sugar composition
- Cost and availability of sugars varies greatly by region.

De Ondarza, 2021

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Digestion rates of sugars (%/h)

Sucrose	1300%
Glucose	527%
Fructose	530%
Galactose	439%
Lactose	331%
Starch	10-20%

De Ondarza, 2021

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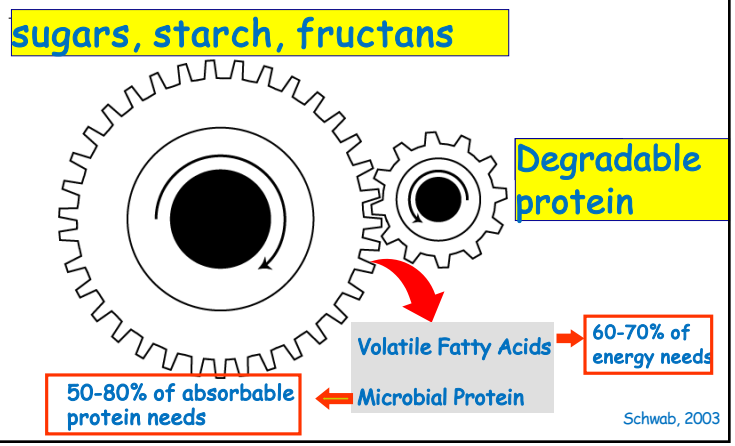
How degradable protein can impact response to sugars



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SUGAR FOR COWS

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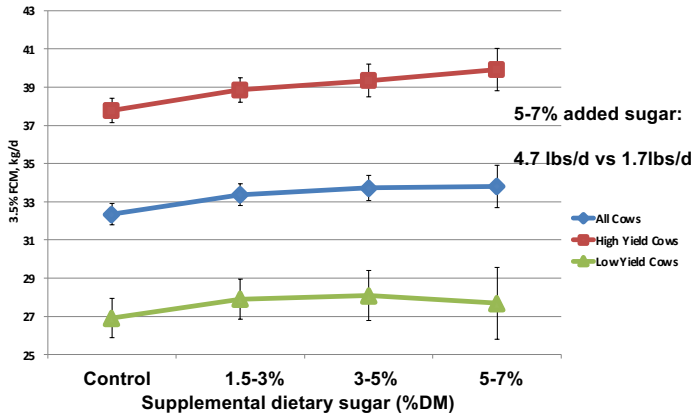
Effect of supplemental dietary sugar on 3.5% milk yield (kg/d) by production level (All Cows vs. > 73 lb=High Yield Cows vs. < 73 lb=Low Yield Cows).



Milk true protein: .05-1.0 kg/d; all cows vs > 33 kg/d

Ondarza et al. 2016

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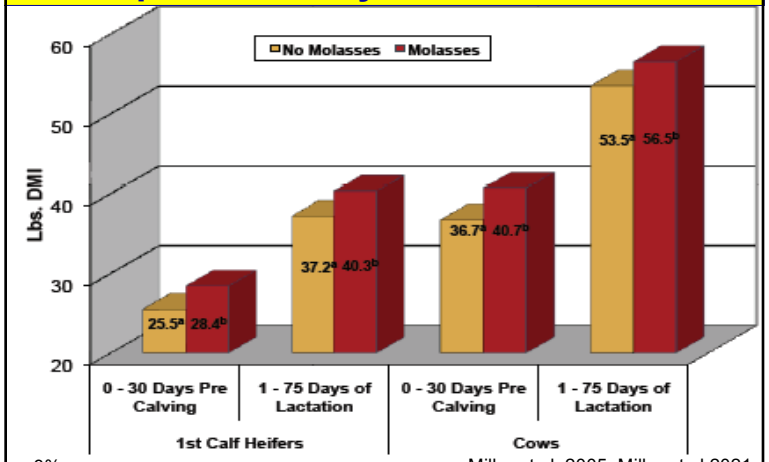
Effect of feeding molasses during the dry period on dry matter intake



~3%,

Miller et al, 2005; Miller et al 2021

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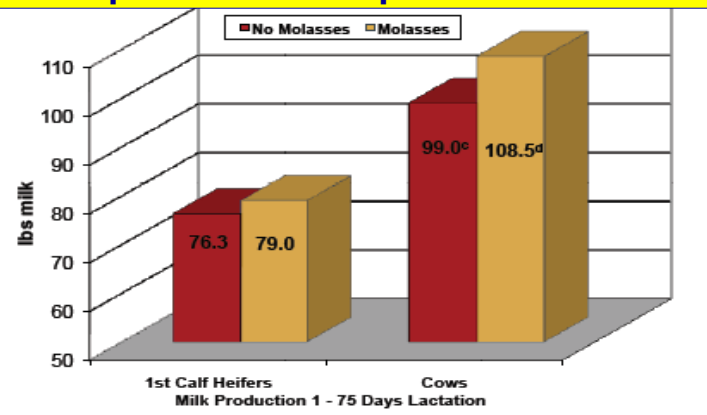
Effect of feeding molasses during the dry period on milk production



Miller et al, 2005; Miller et al 2021

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Changes in milk yield and composition with changes in sucrose and starch supplementation

	Added Sugar				
Variable	0.0%	2.5%	5.0%	7.5%	Linear
DMI, lb/d	54	56	57	57	0.01
FCM, lb/d	89	93	97	95	0.11
Fat, %	3.8	3.8	4.1	4.2	0.01
Protein, %	3.2	3.2	3.3	3.3	0.23

Broderick et al., 2007

Butyrate mol/100mol	12.2	13.8	13.7	14.2	0.01

Vallimont et al., 2004

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Sucrose vs lactose in dairy cow diets (5.5% ration DM)

All rations 27% starch
Total sugar 9%

	Control	Sucrose	Lactose
DMI, lb/d	57.9	60.5	60.5
Milk, kg/d	82.5	83.8	82.9
fat%	3.65	3.54*	3.63
protein,%	3.46	3.51	3.50
Butyrate, mol/100 mol	13.3	14.4	15.9*

Gao and Oba, 2016

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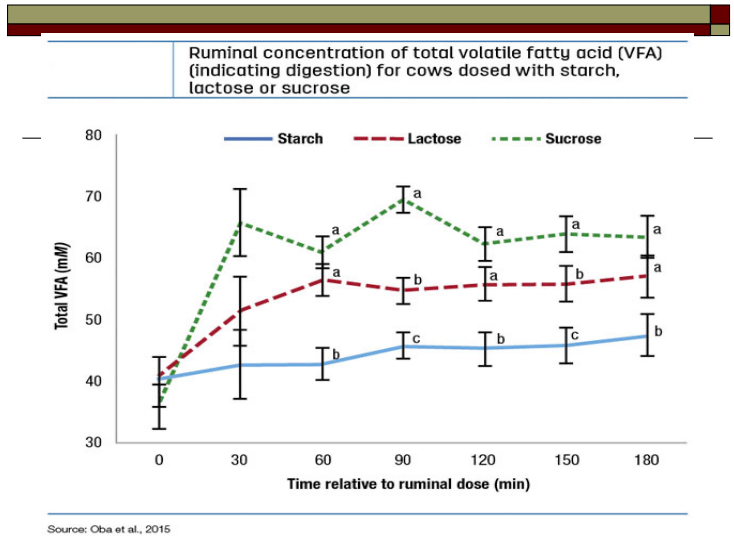

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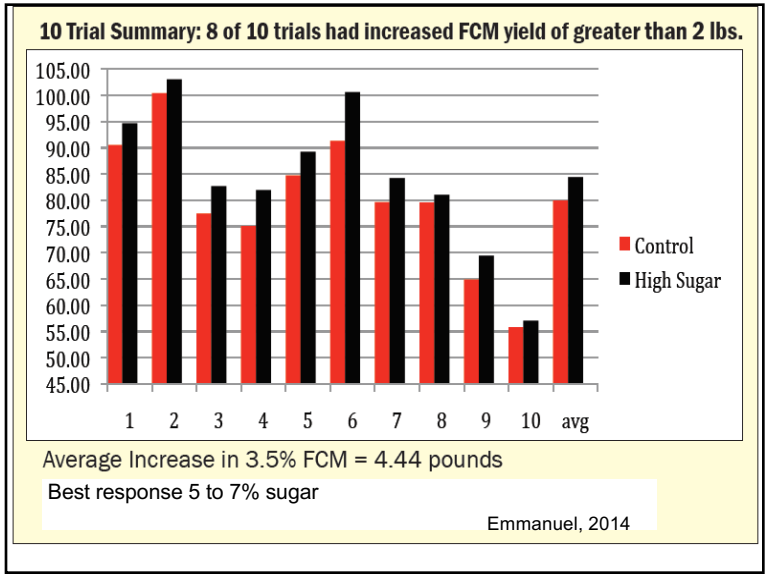

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Replacing starch with sugar

- 10 University studies (2004-2009)
- 0.16 lb increase in fat (0.04 to 0.22)
- 0.11 lb increase in protein (0 to 0.26)

Emanuele, 2011

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Sugar / Liquid Supplements

- **DMI, FCM**
  (4% & 8% dried molasses; Broderick et al., 2004)
- **DMI, FCM**
  (3% liquid molasses; Broderick et al., 2004)
- **DMI, ECM**
  (37% NFC; 2.7 lb/d TMR 20; Firkins et al., 2008)
- **DMI, FCM**
  (2.5 % & 5% sucrose; Broderick et al., 2008)
- **DMI, FCM and Ruminal pH**
  (4.7% added sucrose; Penner and Oba; 2009)

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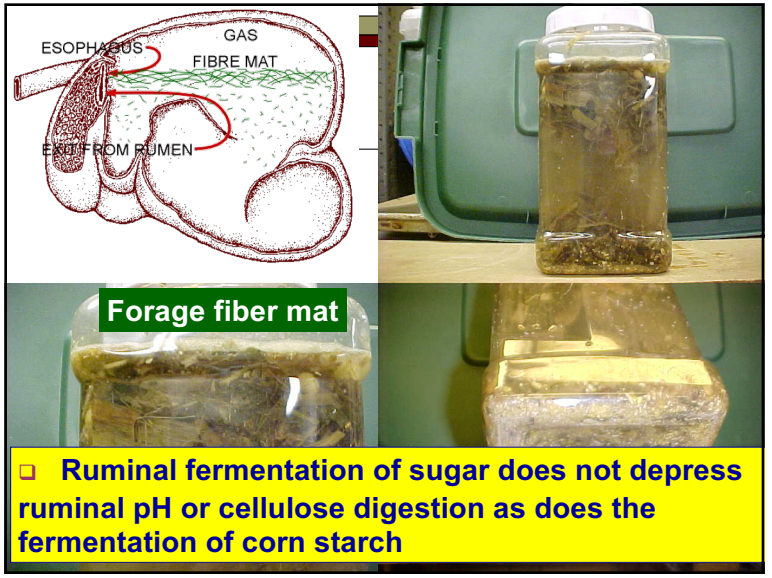

- Ruminal fermentation of sugar does not depress ruminal pH or cellulose digestion as does the fermentation of corn starch

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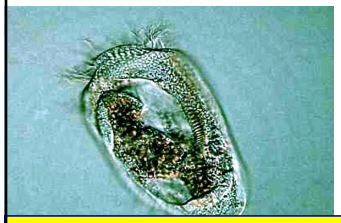
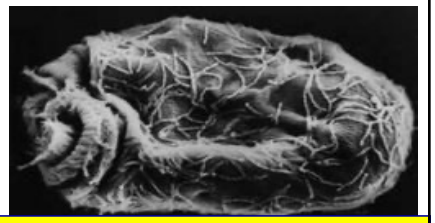
Sugar vs starch and rumen pH?

- The accumulation of carbon into microbial reserve carbohydrates could help explain why ruminal pH is not reduced when sugar replaces starch. Slows fermentation to control acidity.

Hall, 2017





- protozoal glycogen accumulation represented 51% of the total glycogen recovered.

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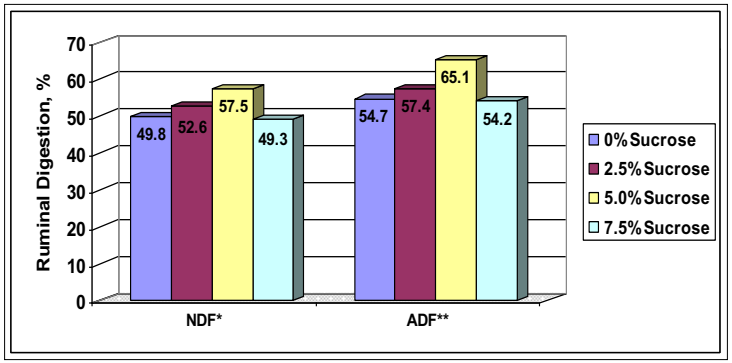
Ruminal fiber digestion



*Quadratic Effect *P* = 0.04
**Quadratic Effect *P* = 0.13

Broderick et al. 2008.

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Effects of sucrose replacing cracked corn

	No Sucrose	4.7% Sucrose	P value
DMI, lb/d	37.8	40.3	0.04
Milk, lb/d	72.6	75.7	0.19
Protein, lb/d	2.31	2.40	0.23
Fat, lb/d*	2.97	3.17	0.10
Milk 18:1*trans*, % fat	**3.14**	**2.72**	**0.04**

n = 25 each starting on d 1 post-calving for 4 weeks.

Penner and Oba, 2009

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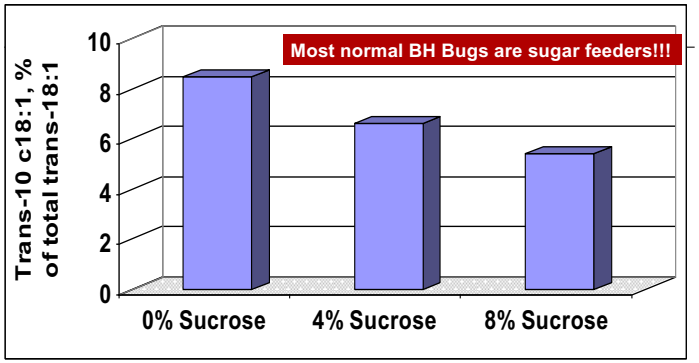
Sucrose helps keep rumen biohydrogenation on the normal pathway



t10 18:1 has Milk Fat Depression implications.

Source: Ribiero et al. 2005
Razzaghi et al 2016

Butyrivibrio fibrosolvens ↑ Megasphaera elsidenii ↓

Sun et al., 2015

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Adding sugar to the diet:

- **Increases molar proportions of butyrate**
  - **Increases in milk fat and/or yield**
  - **Stimulates the rumen epithelial cells, increasing VFA absorption from the rumen**
- **Can improve rumen pH**
  - **Less organic matter converted to fermentation acids**
  - **Butyrate generates only on H+; acetate and propionate generate 2 H+**

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What have we learned so far?

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Summary points

- ✓ A balance of sugars and starches are needed for efficient microbial growth
- ✓ Rumen degradable protein is needed for efficient use of sugars
- ✓ Sugar in the diet stimulates intake prepartum and enhances milk yield and components postpartum
- ✓ Sugar enhances fiber digestion and can benefit pathways in the rumen that alleviate milk fat depression

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So when should we consider feeding sugar sources to cows?

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When to consider sugar feeding to cows

- ➢ Relatively mature hay and/or silage
- ➢ Silage that went through extended fermentation – if it was put up either too wet or too dry.

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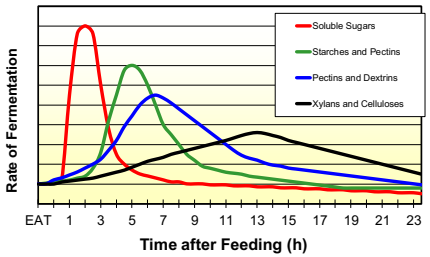
When to consider sugar feeding to cows

- ➢ High soluble protein in hay and silage



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When to consider sugar feeding to cows

- When considering delivering other nutrients in the liquid feed:
  - *Minerals*
  - *Yeast*
  - *Nitrogenous sources*
  - *Fats*

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When to consider sugar feeding to cows

- Low feed intake/ketosis
  - Prepartum
  - Early lactation
- Butterfat concerns
- Coarser CS
- Need to reduce shrink
- Sorting issues

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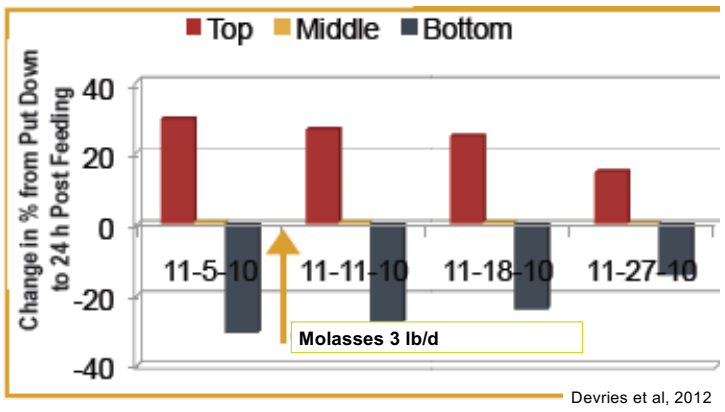
Reduce sorting



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When to consider sugar feeding to cows

- If stocking density high and bunk space limited
  - Poor management factors
  - More sugar less starch
- Increase beneficial effects to the environment
  - enhanced nitrogen efficiency by reducing nitrogen loss in urine and feces

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So when should we consider feeding sugar sources to cows?

In all rations!
5-7% of ration DM:
2 to 3 lb of sugar/d

Soluble fiber: 6-8%DM
RDP: 10-11% DM
Starch: 22-27% DM

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Take home messages

- Work with your nutritionist to assure that there is adequate sugar in the diet for your cows
- Sugar can be used to replace corn up to 7% of the ration DM
- Sugar has been shown to enhance fiber digestibility, improve DMI, milk yield and components

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