Lightening your frozen desserts with alternative sweeteners

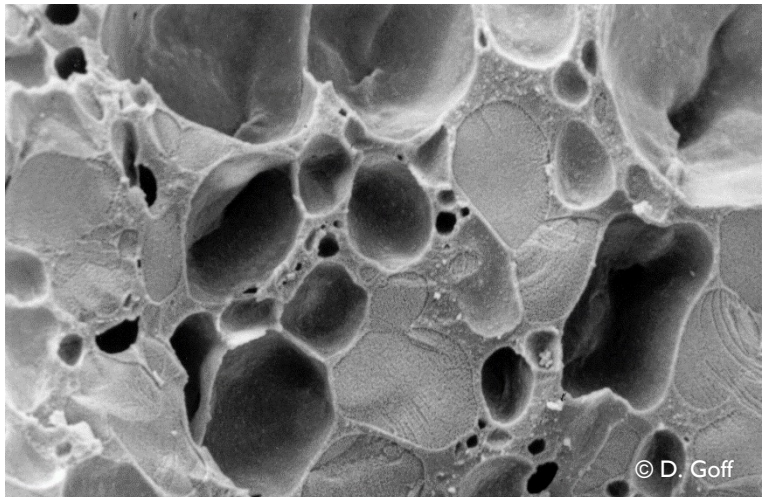
Zeynep Atamer & Sarah Masoni

Oregon State University | Dept. Food Science and Technology
atamerz@oregonstate.edu
https://foodsci.oregonstate.edu

Oregon State University

Overview of the presentation

1. Introduction
   - Frozen deserts (types and content) – ice cream
   - Functions of sugar in ice cream
2. Sweeteners
   - Classifications of sweeteners
   - Functions & structures
   - Freezing point depression
   - Examples of selected sweeteners
   - Sensory evaluation
3. Current research at OSU
   - BUILD Dairy projects
   - OSU Advantage Iterative Program
   - BEC Research Internship Projects
4. Workshops at FIC / OSU



1

INTRODUCTION

Types of ice cream

- Types of ice cream and their composition are presented.

Table: Typical ice cream formulas (Bylund, 2015)

Type of ice cream	Fat % wt	MSNF % wt	Sugar % wt	E/S % wt	Water % wt	Overrun % vol
Dessert ice	15	10	15	0.3	59.7	110
Ice cream	10	11	15	0.5	63.5	100
Milk ice	4	12	13	0.6	70.4	85
Sherbet	2	4	22	0.4	71.6	50
Water ice	0	0	22	0.2	77.8	0
Sorbet	0	0	22	0.5	77.5	30-50

Sugar is the main component of frozen desserts!

Fat: Milk fat or vegetable fat
MSNF: Milk solids-non-fat (protein, lactose, salts)
Sugar: Sucrose, glucose/dextrose or syrups
E/S: Emulsifiers / Stabilizers (e.g. ,monoglycerides, locust bean gum, guar gum or carrageenan)

Overrun: Amount of air in product

Other ingredients: Egg, fruit and chocolate pieces

What is sugar?

- Small molecular weight carbohydrate / sweet flavor / water soluble
- Many kinds of sweeteners are used. Examples:

Cane and beet sugars	Invert sugar	Brown sugar
Corn sweeteners	Fructose	Lactose
Maple sugar	Molasses	
Honey	Malt syrup	

Sucrose

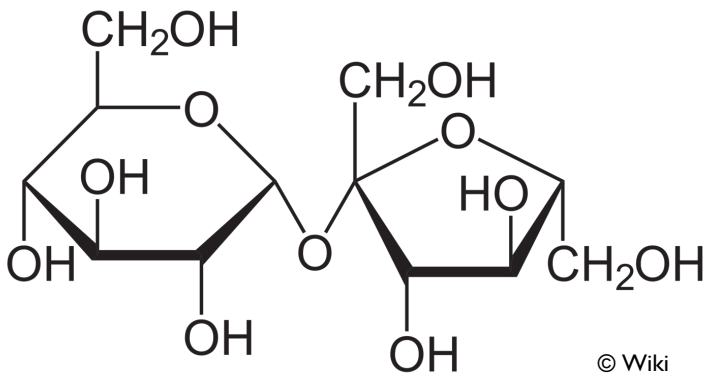


Fig.: Structure of sucrose

The traditional and still the most common choice of sweetener system in mixes is a combination of **sucrose** (10–12%) and corn sweeteners derived from hydrolysis of corn starch (corn syrup solids, CSS, usually 3–5%).

Functions

- Imparts sweetness to the ice cream
- Improves flavor/texture
- Lowers freezing point

Daily added sugar intake

- Sugar intake must be slashed further. Target: **5%** of energy intake from free sugars (25g for women (five to six teaspoons) and 35g (seven to eight teaspoons) for men).
- **Problems:**
  - > 1.4 billion adults and >40 million children are overweight.
  - Worldwide, more people die of illnesses related to obesity (heart disease, type-2 diabetes, stroke, and even some cancers)

An opportunity for the low-calorie sweetener industry!

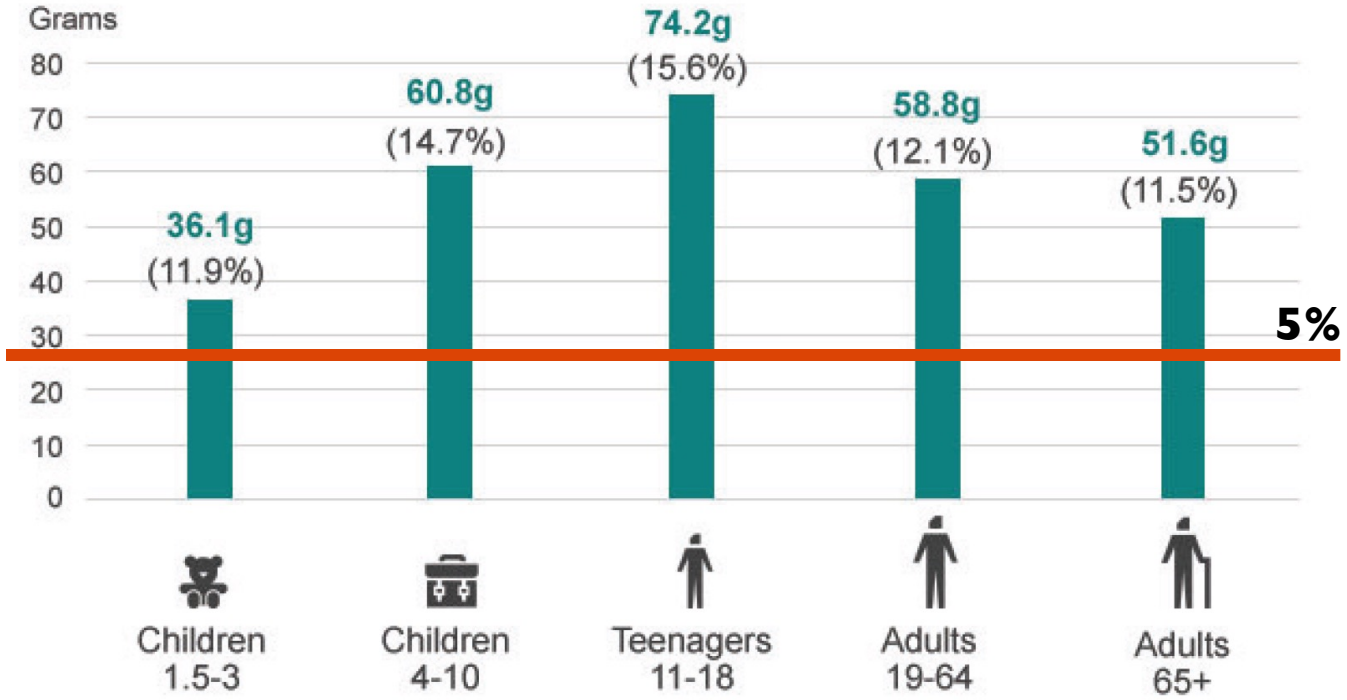


Fig. Percentage of daily food energy from added sugars shown in brackets (National Diet & Nutrition Survey, rolling programm 2008-12)

2

SWEETENERS

Classification of sweeteners

- Sweeteners are divided into two categories: those which have calories and provide nourishment (**nutritive**) and those that are calorie-free (**non-nutritive**).

Nutritive

Nutritive sweeteners (4 kcal/g)

- Sugar (sucrose)
- Lactose (milk sugar)
- Dextrose (glucose)
- Fructose (levulose)
- Corn syrup solids (glucose syrup solids)
- High fructose corn syrup

Nutritive sweeteners (0 - 2.5 kcal/g)

- Sugar alcohols (polyols)
  - Sorbitol
  - Mannitol
  - Xylitol
  - Isomalt
  - Lactitol
  - Maltitol
  - Erythritol
- Allulose
- Tagatose

Non-nutritive

Non-nutritive sweeteners (Zero calories)

- Saccharin
- Aspartame
- Acesulfame K (Ace-K)
- Neotame
- Sucralose
- Stevia leaf extract
- Monk fruit extract

Intensive sweeteners

Synthetic

Natural

Characteristics of sweeteners

Table: Selected characteristics of sweeteners (Goff, 2013)

Ingredient	Average molecular weight	Relative sweetness[a]	Total solids (%)	Relative freezing point depression[b]	Maximum total sugar supplied[c] (%)
Dextrose	180	74	92	1.90	40
Fructose	180	173	100	1.90	40
Sucrose	342	100	100	1.00	100
Lactose	342	16	100	1.00	d
Maltose	342	32	100	1.00	40
Honey	~270	75	74	1.46	45
Invert sugar	~270	95	77	1.12	30
High fructose corn syrup					
90%	180	125	77	1.88	50
55%	185	98	77	1.85	50
42%	190	86	71	1.80	50
High maltose corn syrup					
55 DE	411	55	81	0.83	40
Corn syrups					
64 DE	298	68	82	1.15	25–50
42 DE	428	48	80	0.80	25–50
36 DE	472	42	80	0.72	25–50
32 DE	565	40	80	0.61	25–50
20 DE	900	23	80	0.38	e
Maltodextrins					
15 DE	1,200	17	95	0.29	e
10 DE	1,800	11	95	0.19	e
5 DE	3,600	6	95	0.10	e

Nutritive sweeteners in standard sugar ice cream!

Ingredients and their functions

Freezing point depression

- The ice cream mix freezes at a temperature lower than water due to dissolved solutes. The freezing point depression obeys Raoult's Law.

$$\Delta T = \frac{R \cdot T^2}{r} \cdot \frac{m}{M}$$

ΔT: the decrease in freezing point
m: the mass of solute in water, kg/kg of water
M: the relative molecular mass of the solute, g/mol
R: the universal gas constant, 8.314 J/(mol K)
T: the freezing point of water on the absolute scale
r: the latent heat of fusion of water, 333.5 * 10^3 J/ kg

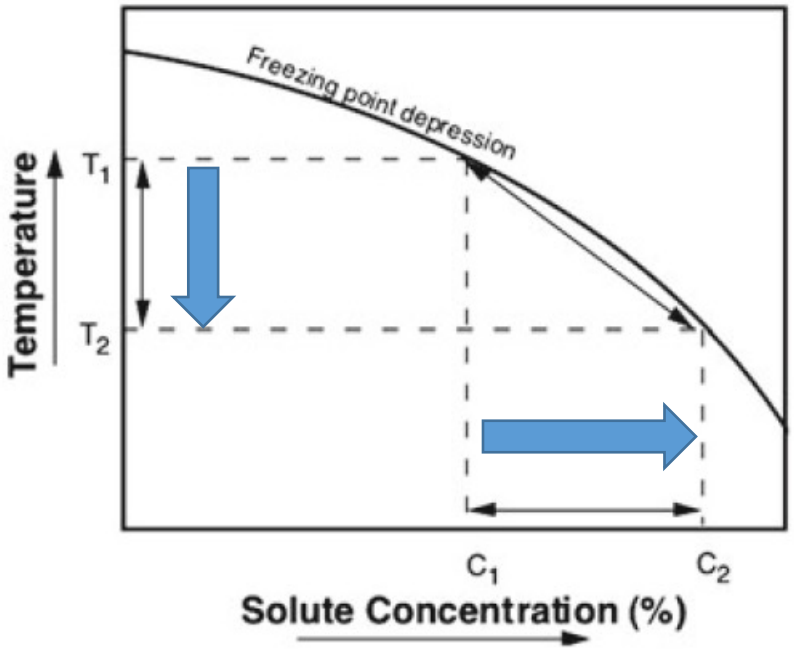


Fig. Slow freezing of ice cream along the freezing point depression curve (Goff, 2013)

Sweetness intensity

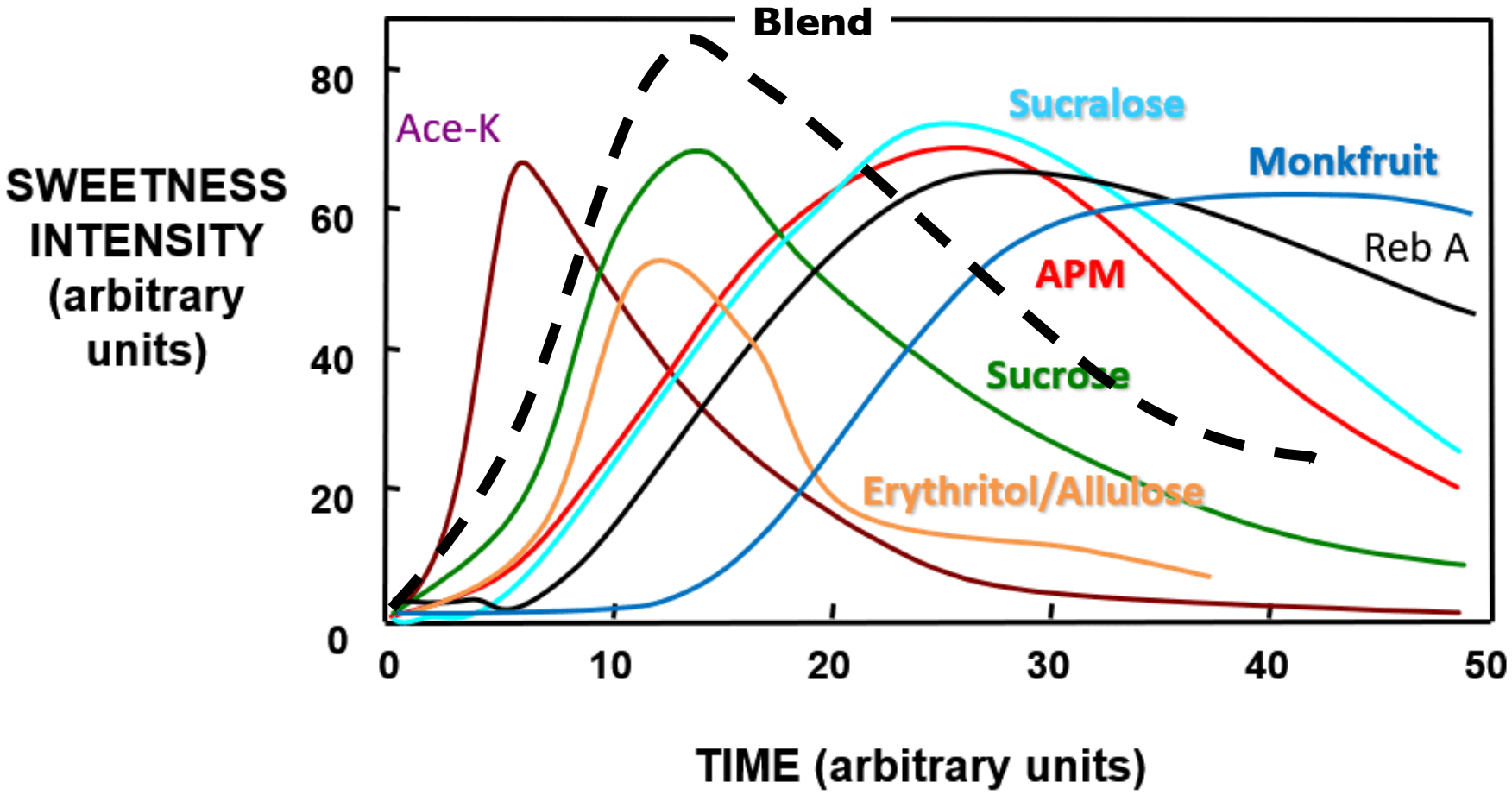


Fig. Sweetness intensity of various sweeteners as a function of time. Ace-K: acesulfame potassium, APM: aspartame, Reb A: Rebaudioside A (form of stevia) (Walsh et al., 2014)

Some examples of frozen dairy deserts

Sorbet	Light ice cream	Frozen dairy dessert no sugar added	Ranch ice cream
Water, **Erythritol**, Chicory Root Fiber, **Polydextrose**, Strawberry Puree, **Allulose**, Strawberry Juice Concentrate, Strawberries, Rice Flour, Citric Acid, Natural Flavor, Xanthan Gum, Guar Gum, **Monk Fruit Extract,** Beet Juice From Concentrate (color).	Ultrafiltered Skim Milk (Not an Ingredient in Regular Ice Cream), Skim Milk, Soluble Corn Fiber, **Erythritol**, Sugar, Cream, Vegetable Glycerine, **Corn Syrup**, …, Mono and Diglycerides, Xanthan Gum, **Stevia Leaf Extract (Reb M)**, Vitamin A Palmitate.	Milk, **Maltitol Syrup**, Maltodextrin (Corn), Cream, Whey, Less Than 2% Of: Mono And Diglycerides, Vegetable Gums (Carob Bean, Guar, Tara), Natural Flavor, Acesulfame Potassium, Sucralose, Vitamin A Palmitate, Annatto (For Color).	Ingredients: Cream, milk, **cane sugar**, and egg yolks with buttermilk powder, onion powder, garlic powder, spices, sea salt, lactic acid, and natural flavors.

Sucrose

Sensory evaluation

Comparison of the samples

- Sweetness
- Bitterness
- Aftertaste
- Total flavor

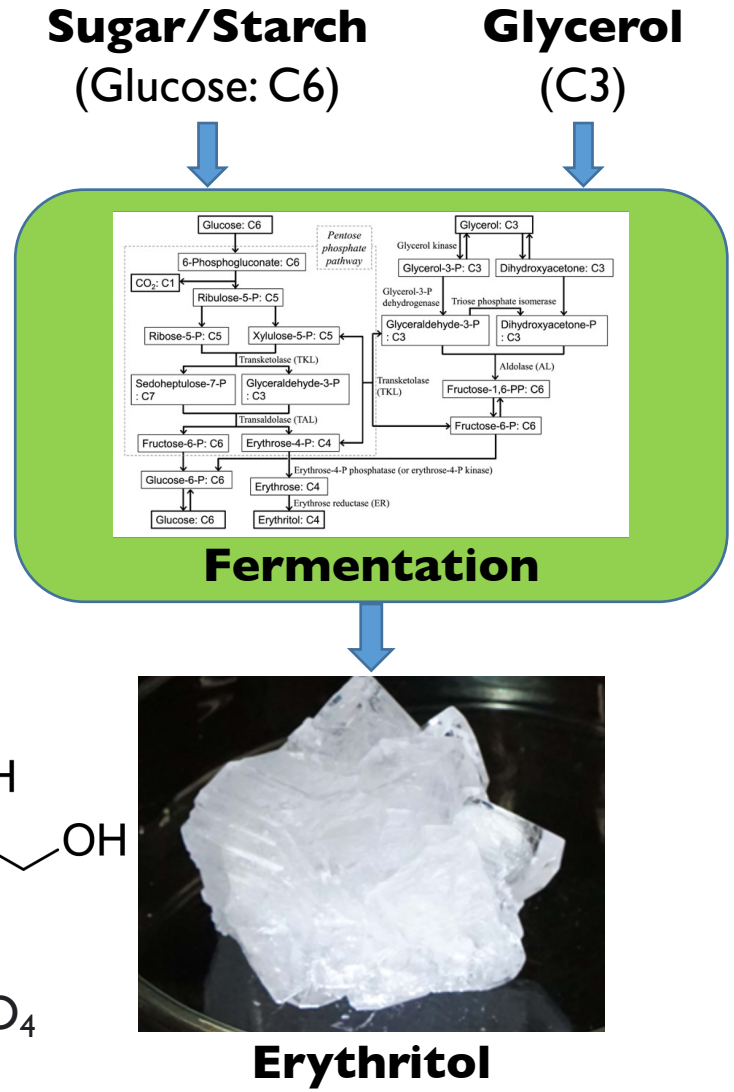
Blend:

- Erythritol (>55%)
- Allulose (< 55%)
- Stevia extract (< 3%)
- Monk fruit extract (< 2%)

Erythritol – Sugar alcohols

- Polyols (Erythritol)
- Naturally occurs in some fruits and fermented foods
- 70% of relative sweetness of sucrose
- More soluble than sugar
- Deliver less energy (~0.2 kcal/g)
  - 95% less than sugar
- Main use: low-sugar or sugar-free formulations
- Non-cariogenic
- Classified as GRAS* by the FDA
- Adsorbed rapidly into the blood
- Very beneficial in the diets of insulin-dependent diabetics

*GRAS: generally recognized as safe



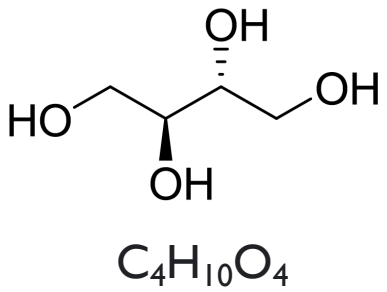
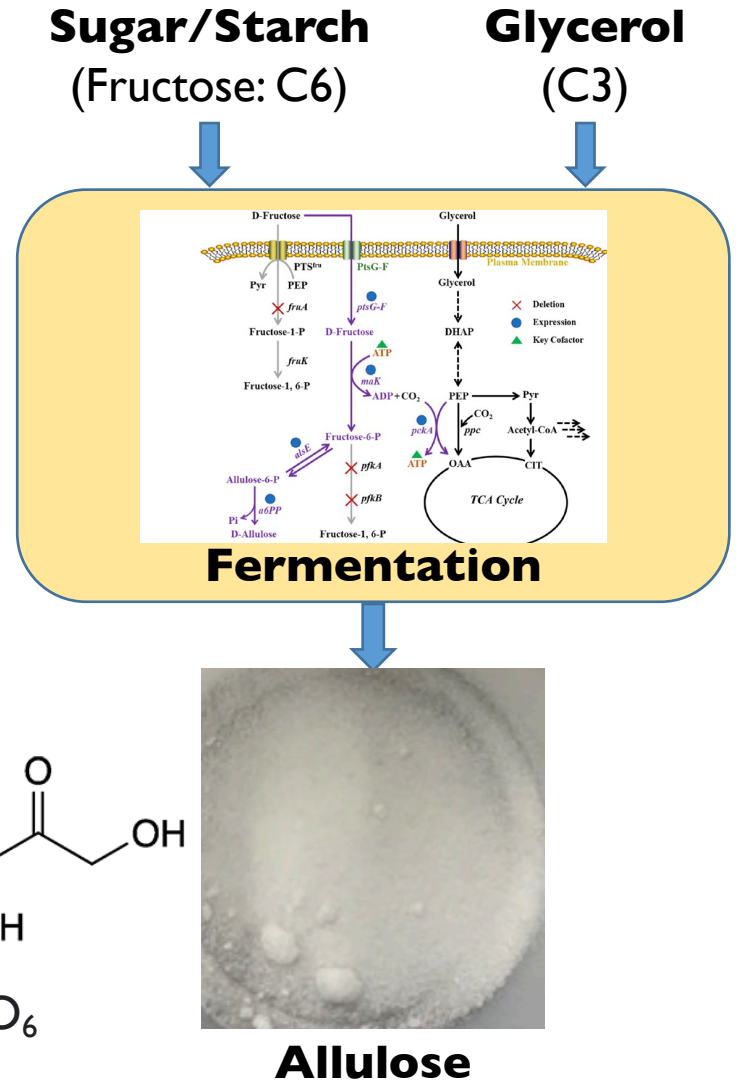


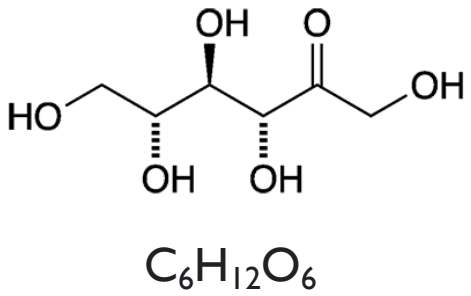
Fig. Metabolic pathway of erythritol biosynthesis (Nakagawa et al., 2020)

Allulose – rare sugars

- Rare sugars, monosaccharide sugar fructose (Fruits like figs contain allulose, as do raisins, maple syrup, and wheat)
- 70% of relative sweetness of sucrose
- Deliver less energy (0.4 kcal/g)
- Main use: low-sugar formulations
- Non-cariogenic
- Classified as GRAS* by the FDA
- More soluble than sugar
- Adsorbed rapidly into the blood
- Very beneficial in the diets of insulin-dependent diabetics

*GRAS: generally recognized as safe





$C_6H_{12}O_6$

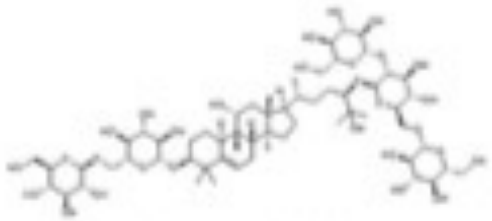
Fig. Metabolic pathway of allulose biosynthesis (Guo et al., 2022)

Monk fruit extract, stevia leaf extract

Zero calorie sweeteners

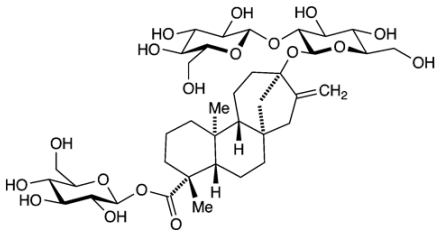
Monk fruit extract	Stevia leaf extract
Fruit of *Siraitia grosvenorii*, grown in China	Found in the leaves of Stevia rebaudiana
No intense bitter aftertaste	Approx. 10-12 known compounds
Delayed onset of sweetness compared to sugar	Slight delayed onset of sweetness compared to sugar
Sweet component: Mogroside (1% of the fresh fruit)	Sweet component: Stevioside
Classified as GRAS by the FDA	Classified as GRAS by the FDA
150-250 times sweeter than sugar	200-300 times sweeter than sugar

Monk fruit



$C_{60}H_{102}O_{29}$

Stevia



$C_{44}H_{70}O_{23}$

3

CURRENT RESEARCH AT FST/OSU

Project I: Whey lactose conversion to rare sugars

Objectives

- Perform tri-enzymatic treatment of lactose
- Determine the quantity of lactose, galactose, glucose, fructose, and tagatose
- Utilize the sugar syrups in yogurt and perform sensory analysis on yogurt products

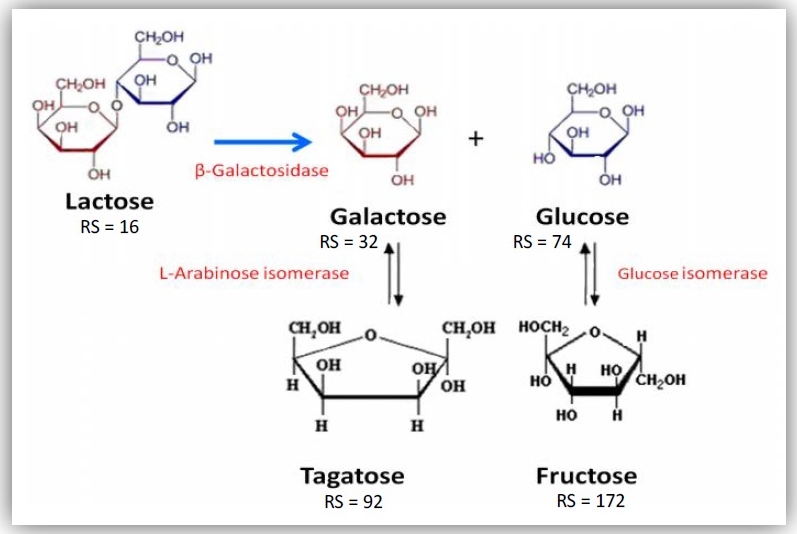


Fig. Enzymatic conversion of lactose

Fig. Application of obtained sugars for fruit yoghurt productions

Application

- Technology for downstream processing to enrich lactose
- Production of a sugar syrup with enhanced sweetness
- Dairy and other food products

Kate Sorenson

MSc. Student: Kate Sorenson
Coop. Partner: Brigham Young University, Nutrition, Dietetics, & Food Science, Provo, Utah
Funded by: BUILD Dairy

Project II: Reduction of sweetness in ice cream

Objectives

- Utilize different low-calorie sugars in ice cream production
- Evaluate the performance of these sugars as sweeteners in ice cream

Fig. Applications of various sweeteners as powder form for manufacture of ice cream

Fig. Batch freezer (Carpigiani, Bologna, Italy, LB 200 G up to 4.7 L)

Application

- Production of variety of ice cream samples in reduced sweetness
- Other frozen products

Two FST undergraduate students
Funded by: OSU Advantage Iterative Program

BEC Research Internship Projects at FIC

- Branch Experiment Station Research Internship Projects
- 5 OSU undergraduate students
- May – Sept. 2023






4

WORKSHOPS AT FST/OSU

Oregon State University
Food Innovation Center

Cheese Course

October 2022

Objectives

- Understand the basic steps in cheese making
- Learn about milk composition and quality, ingredients and key process factors.
- Gain practical skills in production, sensory and quality evaluation
- Create network

Marc Bates

Cheese Course

Topics:

- Milk production
- Cheese production
  - Hard cheese
  - Ricotta
- Membrane processing of whey

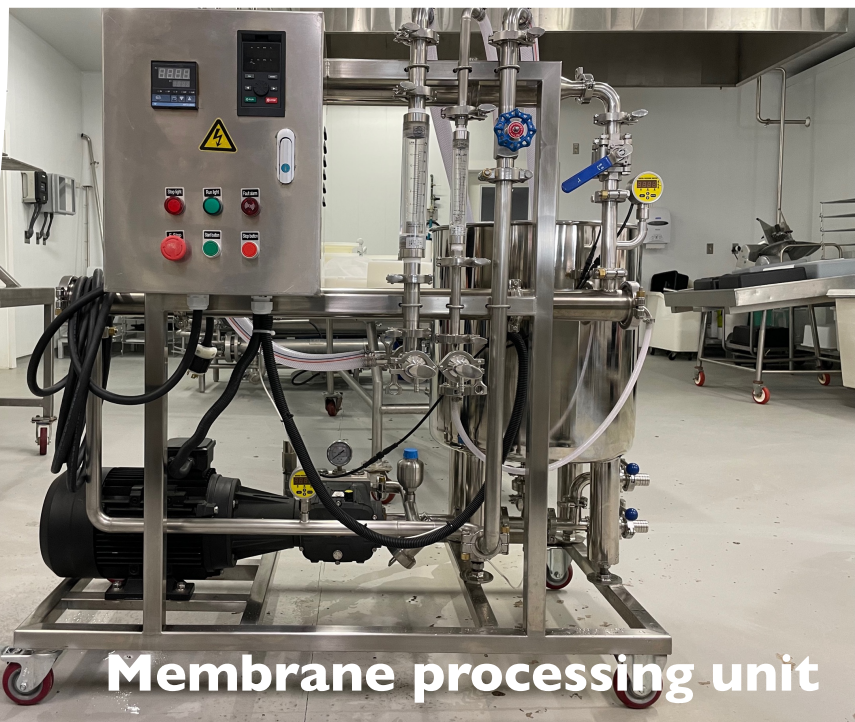
Oregon State University
Food Innovation Center

11.-12. October 2023


Seminar room


Cheese production unit


Milking unit


Membrane processing unit

Oregon State University
Food Innovation Center

Ice cream course

8.-9. November 2023

Objectives

- Understand the production of ice cream and its technology
- Learn about the ice cream structure and texture and ice cream defects
- Gain practical experience in sensory and quality evaluation
- Create network

Sarah Masoni

Prof. D. Goff

Citations

1. Bylund, G. (2015). Dairy Processing Handbook: Dairy technology (2nd ed.). Lund, Sweden: Tetra Pak.
2. Goff, H.D. and Hartel, R.W. (2013). Ice Cream. Boston, MA: Springer US.
3. Guo Q. et al., (2022). Metabolically Engineered Escherichia coli for Conversion of D-Fructose to D-Allulose via Phosphorylation-Dephosphorylation. Frontiers in Bioengineering and Biotechnology, doi: 10.3389/fbioe.2022.947469
4. Nakagawa Y. et al., (2020). Erythritol: Another C4 Platform Chemical in Biomass Refinery. ACS Omega 2020, 5, 2520−2530
5. National Diet and Nutrition Survey (NDNS)(https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012)
6. Walsh J. et al. (2014). Playing hide and seek with poorly tasting paediatric medicines: Do not forget the excipients. Advanced Drug Delivery Reviews, 73, 14–33


Thank you for your attention!