MANAGING KEY ICE CREAM PROPERTIES USING THE FREEZING PROFILE CONCEPT

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OUTLINE

- Freezing profile overview.
- Review of relevant principles.
  - Freezing point.
  - Freezing point depression.
  - Crystallization rules.
  - Water mobility.
  - Freeze concentration
- Freezing profile
  - Overview.
  - Data calculation.
  - Indices.
  - Application examples.

FREEZING PROFILE OVERVIEW

Data showing the amount of water frozen in ice cream at various temperatures below its freezing point.

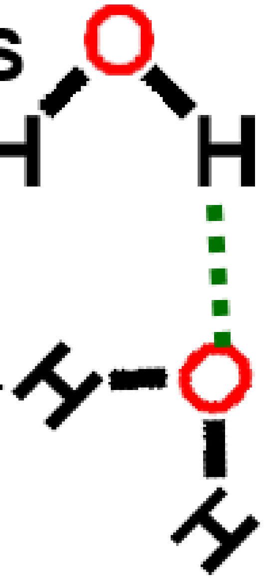
Particularly relevant to Ice cream – the only food product intended for consumption while frozen.

Provides insight into the influence of ice dynamics on key ice cream properties.

- Behavior at the freezer.
- Texture stability.
- Perception of richness/creaminess.
- Dippability.
- Shape retention on melting.

FREEZING PRINCIPLES

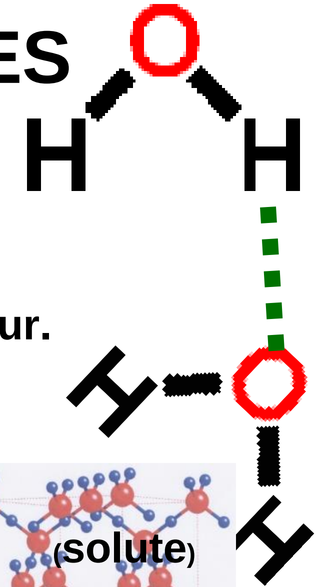
FREEZING - BASIC PRINCIPLES



Weak attraction between oxygen and hydrogen atoms in water molecules ("hydrogen bond").

At higher temperatures, movement of water molecules is too fast for bonding to occur.

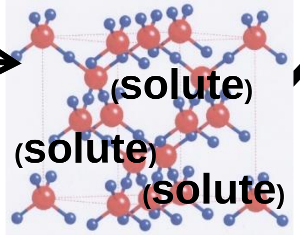
FREEZING - BASIC PRINCIPLES



Weak attraction between oxygen and hydrogen atoms in water molecules ("hydrogen bond").

At higher temperatures, movement of water molecules is too fast for bonding to occur.

Reduction in temperature slows movement enough to allow bonding and produce an alignment of molecules into a hard crystalline structure – an ice crystal.



Temperature at which that occurs is the freezing point.

Dissolved material (solute) interferes with this alignment. Makes it necessary to reach a lower temperature in order for crystallization to take place.

Effect of solutes known as *Freezing Point Depression .*

The degree of effect is directly related to number of molecules in solution, not the percent concentration.

The lower the molecular weight, the greater the freezing point depression, since more molecules are dissolved per unit weight.

FREEZING POINT DEPRESSION – EFFECT OF MOLECULAR WEIGHT

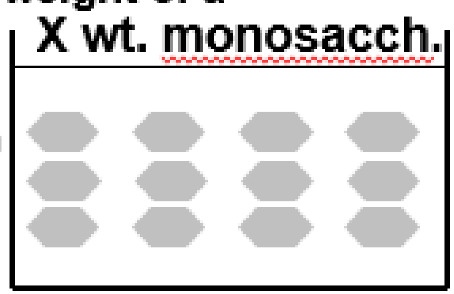
Monosaccharide molecule (for example, dextrose or fructose).

Schematic depiction – each corner represents a carbon atom with oxygen and hydrogen attached in variable configurations depending on the type.

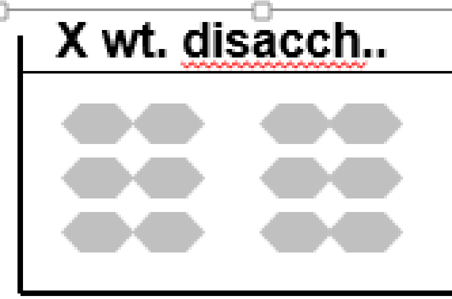
Disaccharide molecule (for example, sucrose).

Composed of two monosaccharide units, therefore, twice the molecular weight of a monosaccharide.

The number of molecules in a given weight of a monosaccharide (e.g., dextrose)



Will be twice what is in the same weight of a disaccharide (e.g., sucrose).



So, a monosaccharide will have twice the freezing point depression effect of a disaccharide

General rule – the lower the molecular weight of a solute, the greater its effect on freezing point depression, in direct proportion to molecular weight difference.

CRYSTALLIZATION RULES

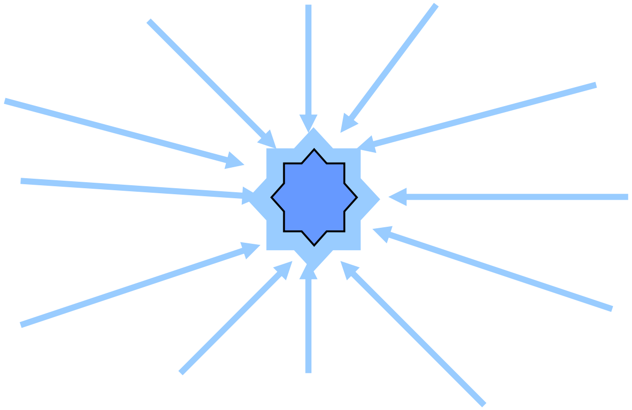
Nucleation

When ice forms, it will deposit on crystals already present (nuclei).

Nuclei generated only in freezer barrel.

Ice crystals grow during hardening.

No generation of nuclei, ice crystallizes on existing crystals.



CRYSTALLIZATION RULES

Ripening

Mother Nature prefers condition of minimal surface energy.

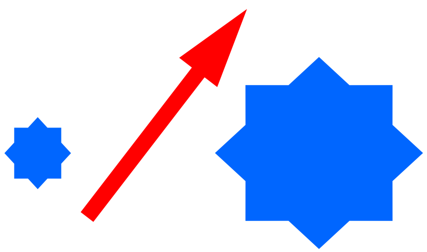
- Associated with minimal ratio of surface area to mass
  - Ratio decreases as particle size increases, so larger particles are favored.
  - When viscosity in the unfrozen portion is low (e.g., at higher temperatures) water will migrate from small ice crystals to larger crystals, making them bigger.

- Ripening can be minimized by avoiding high temperatures
  - Rapid hardening, low temperature during storage and distribution.

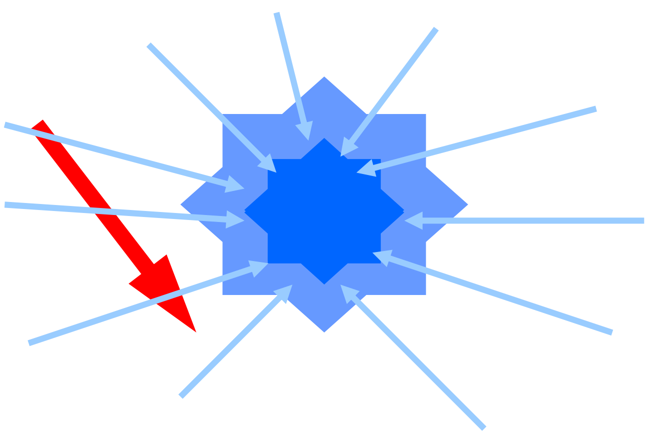
CRYSTALLIZATION RULES

Recrystallization

When temperature increases, water melts, ice crystal size reduced.



When temperature goes back down, water refreezes via nucleation, deposits on crystals already there and makes them bigger.



WATER MOBILITY

WATER MOBILITY IN FROZEN DESSERTS

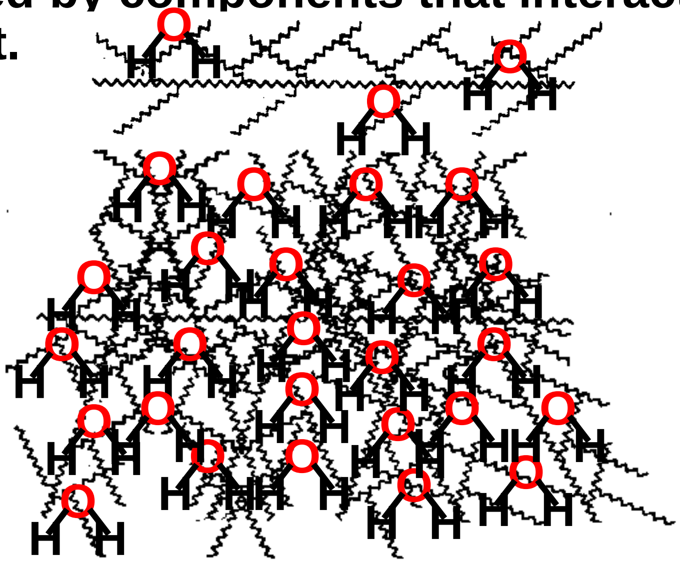
Overview

Ice crystal growth is directly related to mobility of water.

The more mobile, the easier water can move to ice crystal site and contribute to crystal growth.

<u>Minimizing water mobility is a key element of controlling ice crystal size after freezing.</u>

Accomplished by components that interact to restrict water movement.



WATER MOBILITY IN FROZEN DESSERTS
Overview

Water mobility control components.

Stabilizers - most effective. They immobilize large quantities of water in proportion to their own weight.

High molecular weight carbohydrate components of glucose solids.

Level decreases with increasing DE.

- 36 DE and 42 DE most common.
  - 36 DE has higher level of large molecules (good news/bad news)
    - Good news - superior water mobility control functionality
    - Bad news - higher viscosity, requires higher storage temperature.

Bulking agents, e.g. maltodextrin.

Proteins - complex structure immobilizes water.

WATER MOBILITY
IN FROZEN DESSERTS
Overview

Controlling water mobility is also an important factor in managing other key ice cream properties.

- **Stiffness at the freezer.**
- **Air bubble growth during early stages of hardening or any conditions of low freeze concentration. (Via disproportionation – similar to ripening of ice crystals.) Small air bubbles contribute to perception of richness and creaminess.**
- **Dippability.**
- **Shape retention on melting.**

FREEZE CONCENTRATION

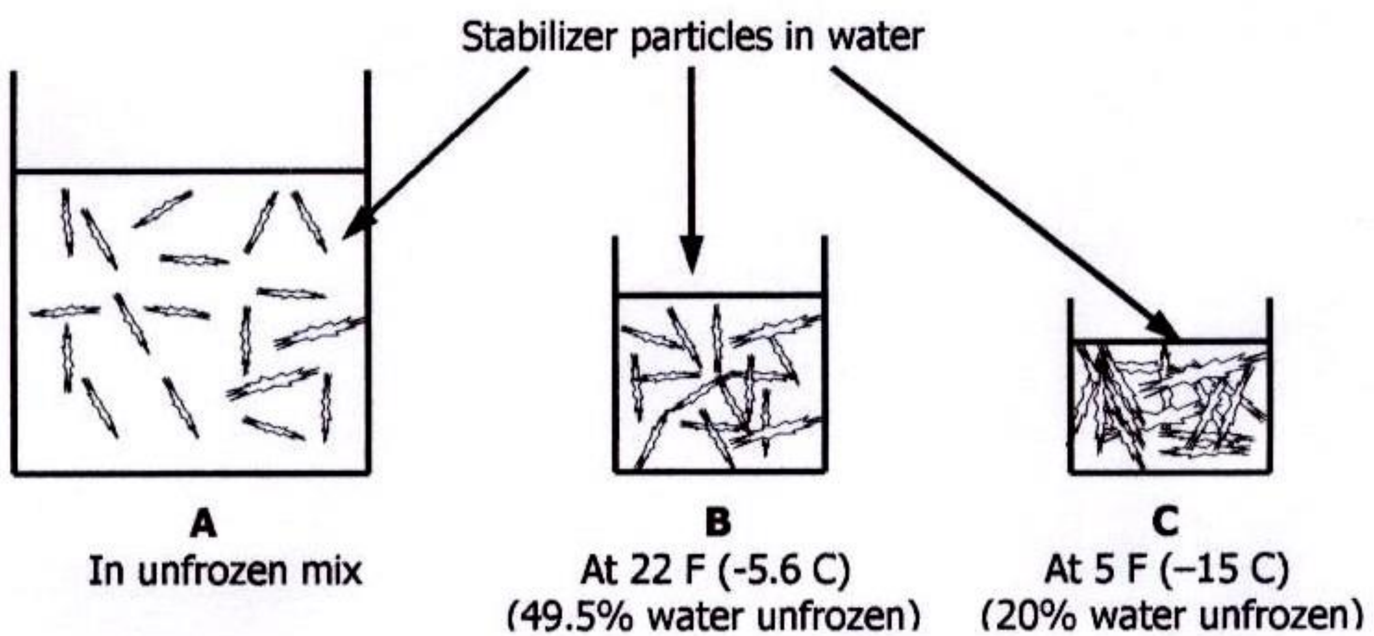
FREEEZE CONCENTRATION
Overview

Affects functionality of water mobility control agents.

- Basic principles.
  - Frozen water not a solvent.
    - When a portion of the water in an aqueous system freezes, the material which was dissolved in the water before freezing is concentrated in the unfrozen water.
    - Freezing concentrates mix components in unfrozen portion, magnifies effect of water mobility control influences.

INFLUENCE OF FREEZE CONCENTRATION ON CONTROL OF WATER MOBILITY

In unfrozen mix, water immobilizing agents (e.g., stabilizers) are widely dispersed, with low level of interaction. Freeze concentration brings them into closer contact. Interaction increases markedly, increasing viscosity and, in some cases, producing gel formation that adds to the degree of water immobilization.



From: ***Tharp &Young on Ice Cream : An Encyclopedic Guide to Ice Cream Science and Technology***

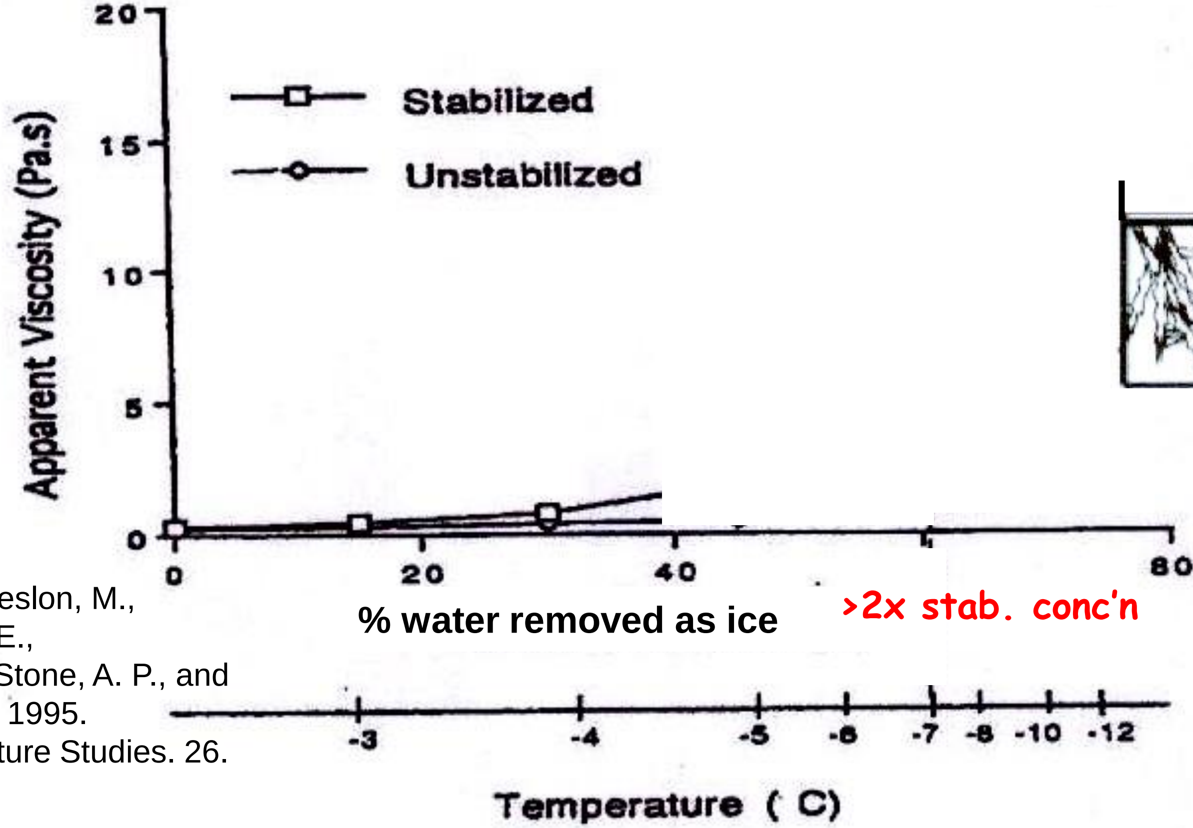
Effect of freeze concentration on composition of ice cream's unfrozen portion

Tharp & Young On Ice Cream

	COMPOSITION (%)			
		UNFROZEN PORTION IN ICE CREAM		
	MIX 0 % Frozen	@ -5.6 C 51% FROZEN	@ -17.8 C 82% FROZEN	@-28.8 C 86.7 % FROZEN
Fat	10.00	14.62	20.29	21.56
MSNF	10.00	14.62	20.29	21.56
Sucrose	12.00	17.54	24.34	25.88
36 DE CSS	6.00	8.80	12.17	12.94
Stabilizer	0.15	0.22	0.30	0.32
Total Solids	38.15	55.77	77.39	82.26
STABILIZER IN WATER				
Level (%)	0.24	0.49	1.33	1.79
Conc'n	---	2.0X	5.5X	7.5X

INFLUENCE OF FREEZE CONCENTRATION ON CONTROL OF WATER MOBILITY

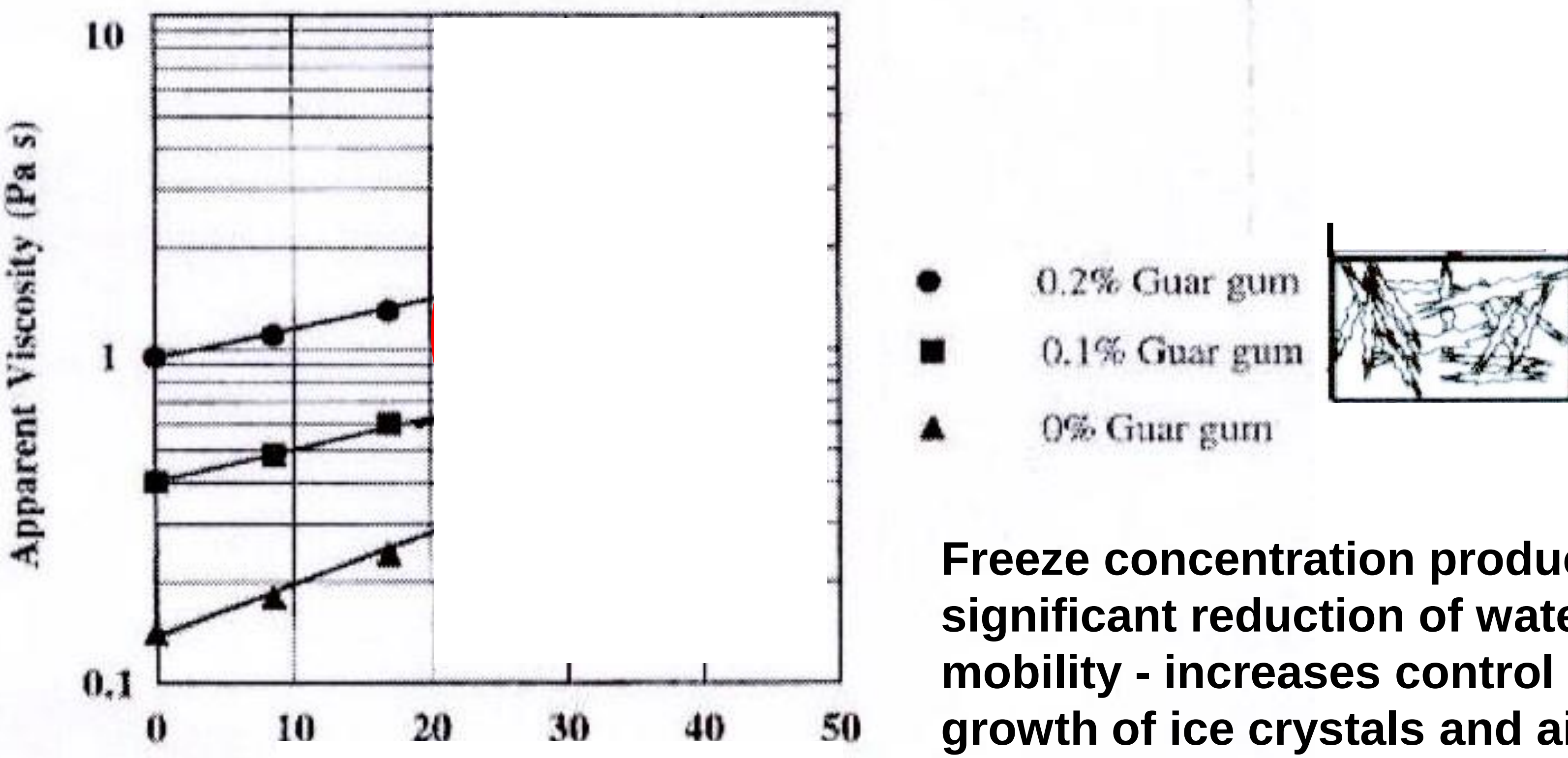
- Illustrate using stabilizer (same principles apply to other ingredients with water mobility control functionality)



Goff, H. D., Freslon, M., Sahagian, M. E., Hauber, T.D., Stone, A. P., and Stanley, D. W. 1995. Journal of Texture Studies. 26. 517-536.

Effect of freeze concentration on viscosity in the unfrozen portion of stabilized and unstabilized ice cream.

INFLUENCE OF FREEZE CONCENTRATION ON CONTROL OF WATER MOBILITY



Freeze concentration produces significant reduction of water mobility - increases control over growth of ice crystals and air bubbles.

Effect of variable guar gum level on the viscosity of the unfrozen portion of ice cream

Bolliger, S., Wildmoser, H., Goff, H. D. and Tharp, B. W. 2000. *International Dairy Journal* 10. 791 - 797.

FREEZING PROFILE

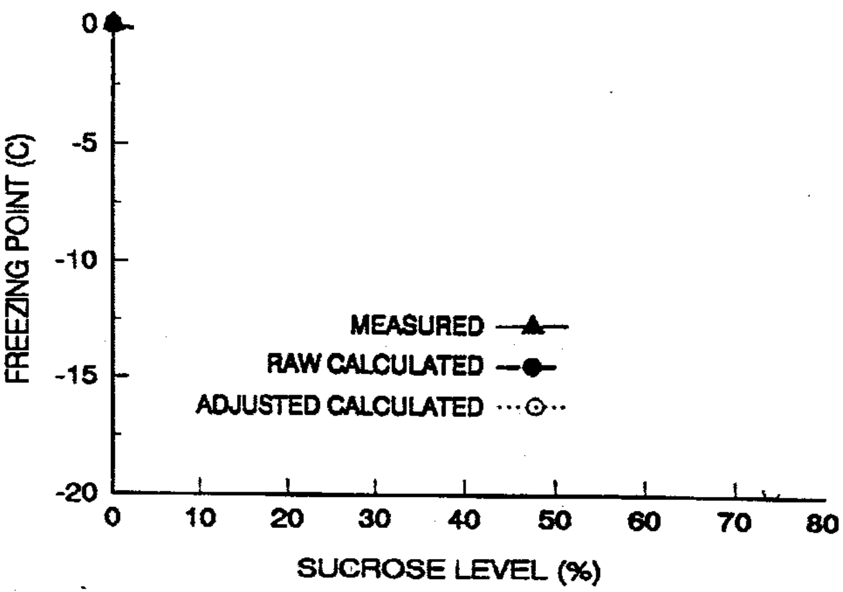
FREEZING PROFILE
Calculation of Data

Calculated data re ice cream freezing point, effect of temperature on amount of water frozen below freezing point.

Application of Mother Nature's rules re influence of molecular weight on freezing point depression + research re milk salts effect

Modified by factors to achieve conformity between measured and calculated data. Calculated values compare closely with measured data

Comparison of the measured and calculated freezing points of sucrose solutions



FREEZING PROFILE INDICES

Tharp & Young On Ice Cream

Water frozen at selected temperatures.

- **Only general interest as absolute numbers - most effective in comparing compositions.**

  - **Freezer Index - water frozen at a selected freezer exit temperature.**
    - **Index of initial ice crystal size.**
      - **The more water frozen in the freezer, the smaller the ice crystals.**
    - **Consistency at freezer, pre-packaging behavior**
  - **Firmness Index - water frozen at a selected temperature in distribution/serving range.**
    - **Firmness at dipping and consumption.**
    - **Shape stability.**

FREEZING PROFILE INDICES

<u>Texture Stability Index </u>(TSI)

- Water that melts and refreezes during a specified temperature fluctuation, e.g. between -10 C and -20 C.
  - Mathematical difference between water frozen at the two temperatures of interest.
  - Direct reflection of effect of heat shock (recrystallization) on ice crystal growth – the more water involved in heat shock, the greater and faster will be ice crystal growth and the shorter will be the textural shelf life.

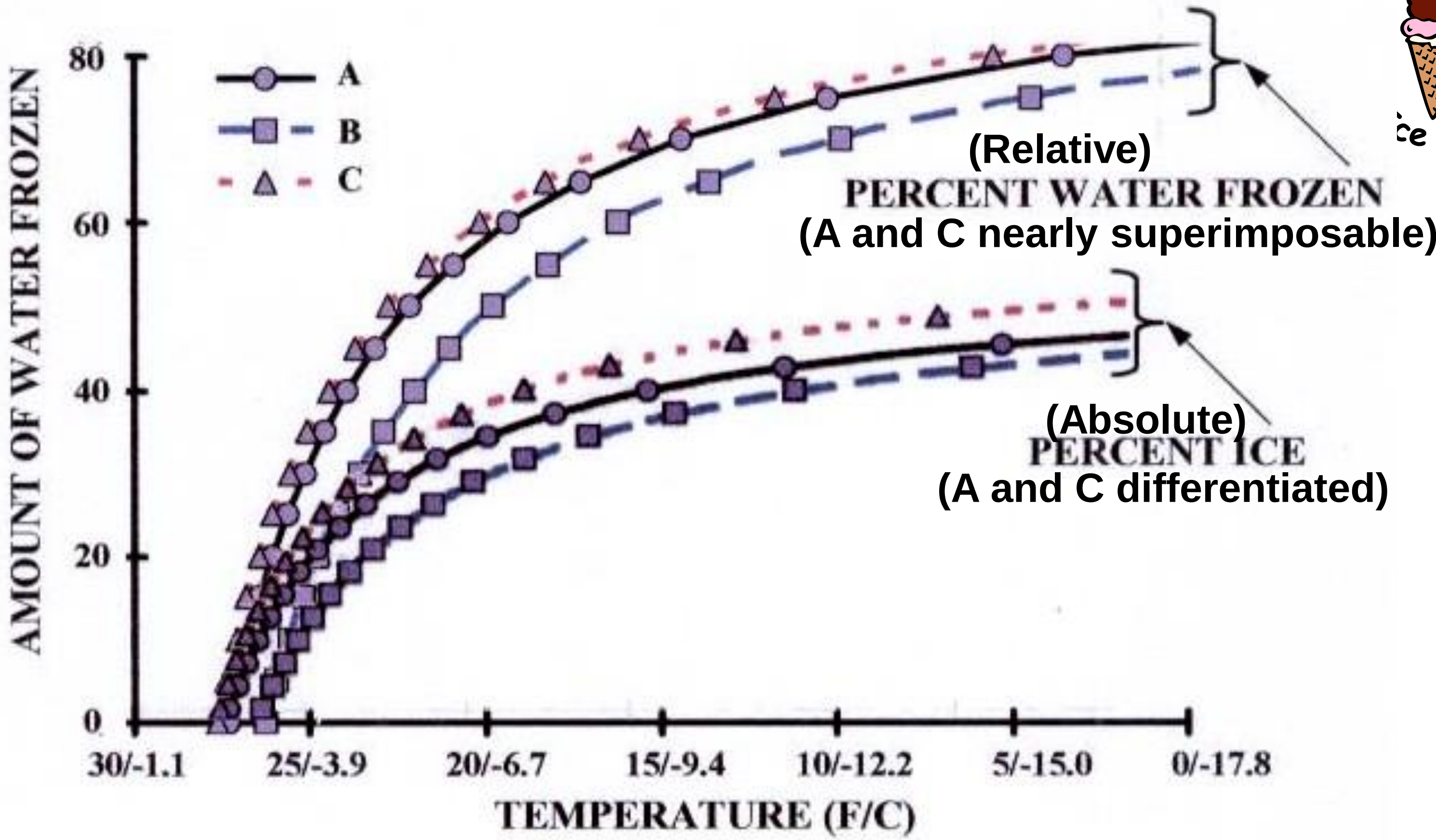
FREEZING PROFILE
Achieving Overview

View data as graph

Broad insight into impact of compositional change.

Two views of data.

- **Relative**
  - **% water frozen.**
    - **Useful when comparisons involve similar water levels.**
- **Absolute.**
  - **% ice in product.**
  - **Useful when comparisons involve different water levels.**



Relative vs. absolute displays of ice cream freezing profile data.

A. Full fat ice cream sweetened with sucrose and glucose solids. 38% total solids, freezing point -2.62 C .

B. Modification of A in which half of the sucrose has been replaced by high fructose corn sweetener. 38% total solids, freezing point -3.12 C,

C. Low fat ice cream sweetened with sucrose and corn syrup solids. 33.3% total solids, freezing point -2.52 C

COMPOSITIONAL COST REDUCTION

COMPOSITION			
	REFERENCE	MOD'N A	MOD'N B
% Fat	10.00	10.00	10.00
% MSNF	10.00	8.00	8.00
% Whey solids	0.00	2.00	2.00
% Sucrose	14.00	11.00	12.50
% Glucose solids (36 DE)	2.00	2.00	2.00
% Dextrose	0.00	4.00	2.00
% Stabilizer/emulsifier	0.30	0.30	0.30
% Total Solids	36.30	37.30	36.80
% Theoretical sweetness	~16	~16	~16
FREEZING PROFILE DATA			
Freezing point (C) (diff.)	-2.40(ref)	-2.98 (-0.58)	-2.71(-0.31)
Indices (% water frozen)			
Freezer Index @ -5.50 C(diff.)	53.80(ref.)	43.20(-20%)	48.09(-10.6%)
Texture Stability Index(diff.) -18 C to -12 C	6.62(ref.)	8.13 (+23%)	7.44(-12.3%)

Cost saving using dextrose to replace sucrose, whey solids to replace conventional MSNF.

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HIGH INTENSITY SWEETENER (HIS) IN CONVENTIONAL ICE CREAM – Cost saving/product improvement

COST PER UNIT SWEETNESS (CUS)

CUS = Cost of sweetener ÷ sweetness equivalence

CUS US$ – sucrose vs. high intensity sweetener (HIS) blend.			
	COST/LB DRY BASIS	SWEETNESS EQUIVALENCE	CUS (US$)
Sucrose	$0.55	1	$0.55
HIS Blend	$18.50	200	$0.0925 ~85% less
Prices, US $, Summer 2011 HIS Blend = 50/25/25 sucralose/aspartame/acesulfame-K (based on relative sweetness)			

Possible to achieve cost savings by replacing portion of conventional sweetener system with HIS blend. Such a composition modification can also provide benefits related to freezing profile characteristics.

HIS IN CONVENTIONAL ICE CREAM

COMPOSITION			
	REFERENCE	MODIFICATION A	MODIFICATION B
% Fat	10.00	10.00	10.00
% MSNF	7.50	7.50	7.50
% Whey solids	2.50	2.50	2.50
% Sucrose	12.00	6.00	9.00
% Glucose solids (36 DE)	6.00	6.00	6.00
% Maltodextrin (10 DE)	0.00	6.00	3.00
% HIS blend*	0.00	0.030	0.015
% Stabilizer/emulsifier	0.30	0.30	0.30
% Total Solids	38.30	38.330	38.315
% Theoretical sweetness	~16	~16	~16
FREEZING PROFILE DATA			
Freezing point ©(diff.)	-2.65(ref.)	-2.13 (+0.52)	-2.39 (+0.26)
Indices (% Water frozen)			
Freezer Index @ -5.56 C(diff.)	49.6(ref.)	59.2 (+19%)	54.5(+10%)
Texture Stability Index(diff.) -26.1 C to -17.8 C	4.9(ref.)	3.9 (-20%)	4.4(-10%)
Texture Stability Index(diff.) -17.8 C to -9.4 C	12.9(ref.)	10.5 (-19%)	11.7(-9%)
Sweetener cost reduction	Ref.	40%	21%
*HIS Blend = 50/25/25 sucralose/aspartame/acesulfame-K			

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HIS EFFECTS - CONVENTIONAL ICE CREAM

Cost reduction

Improved textural shelf life

More water frozen in freezer, where conditions favor development of small ice crystals

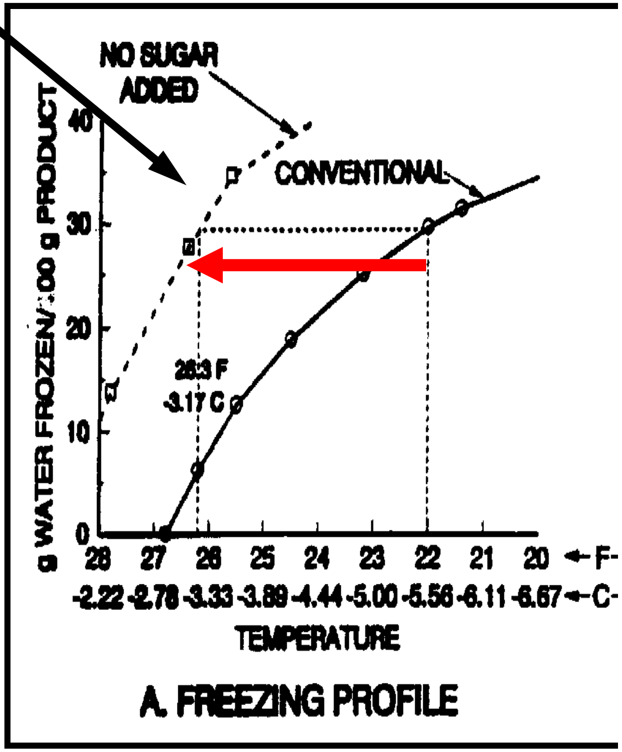
Less water involved in heat shock cycles.

FREEZING PROFILE
AS A DEVELOPMENT TOOL

NO SUGAR ADDED ICE CREAM

<u>Freezing profile</u>

Shows effect of candidate composition on amount of water frozen.



NO SUGAR ADDED ICE CREAM

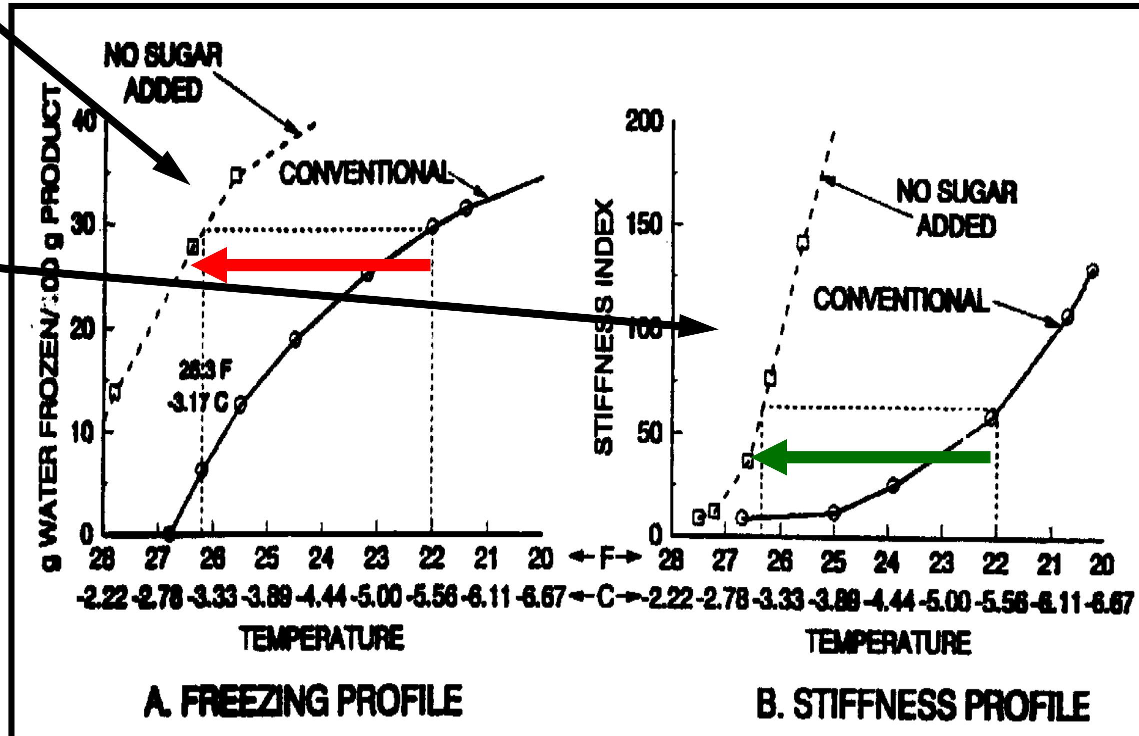
Freezing profile

Shows effect of candidate composition on amount of water frozen.

Stiffness profile

Shows effect of candidate composition on stiffness in draw temperature range .

Note similarity between temperature offsets

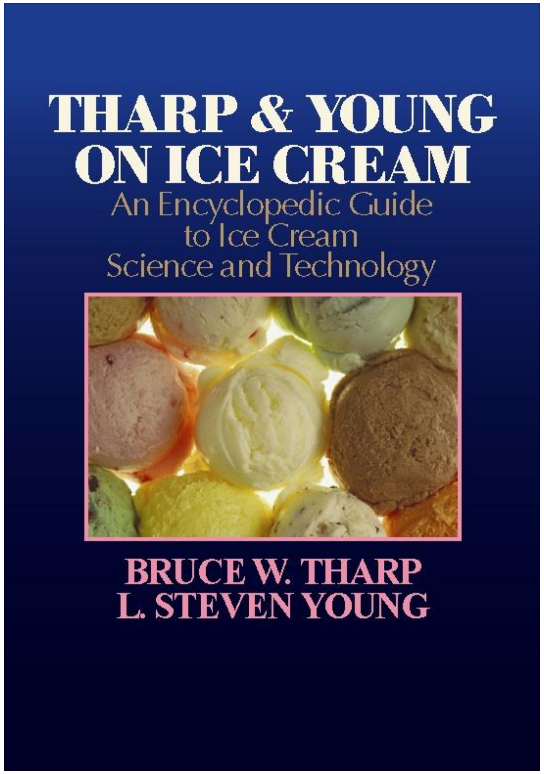


Freezing profile can be a useful tool in product development as a screening tool to evaluate effects of candidate composition as input into the selection of compositions for pilot trials.

GENERATION OF FREEZING PROFILE DATA

- Included in “Tech Wizard®” software.
  - http://www.owlsoft.com/frozdessert.html

FOR MORE, SEE:



Includes methodology for calculation of freezing profile data.

THARP & YOUNG ON ICE CREAM: TECHNICAL SHORT COURSE
November 30 – December 2, 2016 Las Vegas, NV, USA

For information on course and book, see www.onicecream.com

Tharp & Young On Ice Cream

Thank you