Best Quality Practices for Small-scale Manufacturing and Scooping Operations

Prof. H. Douglas Goff, Ph.D.
University of Guelph, Canada
Welcome to the NEW Dairy Education Series at the University of Guelph!
“Robin Weir’s relentless research and boundless passion have inspired me for years”

HESTON BLUMENTHAL

ICE CREAMS, SORBETS & GELATI
THE DEFINITIVE GUIDE

CAROLINE & ROBIN WEIR

Grub Street, London
2010
Outline

- Ice cream recipe development for batch-freezer operations
  - Should I make my own mix?
- Optimal storage conditions for maximal shelf-life in scooping operations
- Open discussion
# Ice Cream Mix Composition

- **Milk Fat**  
  (5% - 10%) - 16%

- **Milk solids-not-fat**  
  9% - 12%

- **Sweeteners**
  - **Sucrose**  
    10% - 14%
  - **Glucose solids**  
    4% - 5%

- **Stabilizers**  
  0% - 0.4%

- **Emulsifiers**  
  0% - 0.25%

- **Water**  
  55% - 70%
Ice Cream Mix Composition

- **Milk Fat** (5% - 10%) – 16%
  - Generally cream is used
  - Less need for homogenization with high-fat mixes
  - Less overrun/yield with high-fat mixes
  - With mid- to lower-fat mixes, if you don’t homogenize the mix, homogenized cream (up to 20% fat) can be used
Ice Cream Mix Composition

- **Milk solids-not-fat** 9% - 12%
  - Generally from condensed skim or skim powder in a premium formula
  - Some also from milk and cream, which must be accounted for in recipe
Ice Cream Mix Composition

- **Sweeteners**
  - Sucrose 10% - 14%
  - Glucose solids 4% - 5%

- Glucose solids from hydrolyzed starch, adds body/texture/viscosity; not as sweet as sucrose
Ice Cream Mix Composition

- **Stabilizers** 0% - 0.4%
- **Emulsifiers** 0% - 0.25%
- **Water** 55% - 70%

- Traditional ingredients were gelatin, egg yolks
- A stabilizer/emulsifier blend can be purchased to meet the needs of your formula/distribution
- Water from cream and milk, or added.
Batch freezers

- 3-40 L
- Air or water cooled condensors
- 10-20 minutes/batch to achieve -5°C draw temperature and 50-70% overrun

Advantages
- Small quantity
- Less expensive
- More flexibility

Disadvantages
- Limited quantity
- Incorporation of ripples and particulates can be difficult
- Hand packing
Taylor Freezers

Model 220
20L barrel

Model C118
12L barrel
Automated operation

Model 104
3L barrel
Table-top
Flavouring

• Goal: Sufficient high-quality ingredients for good flavour and balance

• Market share: it may be easy to make it, but is anyone going to buy it?

• Flavoured mix.

• Particulates: Batch freezer addition vs. hand mixing.
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Pasteurization

- **Batch**: $\geq 69^\circ C \ (156^\circ F)$ / $\geq 30$ min.

- Kills pathogens if raw milk, cream or eggs are used; guarantee of food safety

- Reduces total bacterial numbers

- Hydrates proteins & stabilizers, if dried ingredients are used
Batch Pasteurizer

- Small operations could be 100-300 L
Steam Kettle
• 20-50 L

Double boiler
• Over a gas hot plate
• 8-20 L
Homogenization

- The purposes of homogenization
  - Reduces the size of fat globules so they won’t separate out in milk or cream
  - In mix, makes possible the use of butter, frozen cream, etc.
  - In ice cream, helps to establish fat structure, which provides a smoother texture, allows for a higher overrun, and slows down the melt (structural collapse) rate.
Do you need to homogenize mix?

- Maybe not, if you are using fresh cream, have a high fat and total solids content in the mix, are using batch freezing, and don’t have any meltdown or texture issues.

- Homogenized cream?
Outline

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Food Freezing: conversion of water to ice

- Initial ice crystal size distribution is controlled by freezing and hardening equipment
  - Small crystals: smooth texture

- Freeze-concentration of the sugars - controls ice content/hardness
  - More sugar: softer ice cream

- Ice Recrystallization and Heat shock
  - Controlled by adding stabilizers and minimizing temperature fluctuations
Ice crystals in freshly hardened ice cream
Ice crystal size cumulative distribution in fresh ice cream

Percent of ice crystals less than size on the x-axis

Ice Crystal Size (µm)

45 µm sensory threshold
Food Freezing: conversion of water to ice

- Initial ice crystal size distribution is controlled by freezing and hardening equipment
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- Freeze-concentration of the sugars - controls ice content/hardness
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Freeze-concentration of the sugars establishes the ice : unfrozen water ratio at any given temperature.

More and more ice crystals form, so unfrozen water, which acts as the solvent, is continually

Temperature is lowered

Unfrozen phase: with decreasing temperature, we get increasing concentration of solutes in progressively less and less water, and the freezing point of that solution continually goes down because the concentration is going up.
The Freezing Curve

Temperature

Percentage of Water Frozen

Temperature

Percentage of Water Frozen
The Freezing Curve

Temperature

-24
-20
-16
-12
-8
-4
0°C

Product A (lower concentration of sugars)

Product B (higher concentration of sugars)

Percentage of Water Frozen

20 40 60 80
The unfrozen phase: expands and shrinks with temperature (equilibrium with the ice);
Hardening

- Goal: -25°C core temperature in 4 hours or less
- Need specialized equipment
MASTER ICE

Freezer specifically for the workshop, with static-RS or ventilated refrigeration-RV, for storage (static refrigeration version) and for hardening and storage (ventilated refrigeration version) of ice cream and frozen dessert products.
Rate of Heat Transfer =

Heat Transfer co-efficient x area
x temperature difference

\[ Q = U \ A \ \Delta T \]
Factors affecting hardening

- Temperature of hardening freezer - the colder the temperature, the faster the hardening, the smoother the product. Maintain high $\Delta T$. 

![Diagram showing temperature decrease over time with a cooling medium (cold air)]
Factors affecting hardening

- Temperature of hardening freezer - the colder the temperature, the faster the hardening, the smoother the product. Maintain high $\Delta T$.
- Circulation of air - increases convective heat transfer.
- Temperature of ice cream when placed in the hardening freezer - the colder the ice cream at draw, the faster the hardening; - must get through packaging fast.
- Size of container
- Composition of ice cream - related to freezing pt. depression.
- Method of stacking containers to allow air circulation - no 'dead air' spaces (round vs. square packages).
Ice crystals after draw at -5°C
- Crystals are small and numerous

Ice crystals after rapid hardening to -25°C
- No further nucleation
- Crystal size increases
- Crystal numbers preserved
Ice cream warms up before hardening

- Smallest crystals melt.
Hardening to -25°C

- No further nucleation
- Crystal size increases to larger size than above
- Crystal numbers reduced

(heat shock)

(same ice phase volume)
Slow Hardening to -25°C

- Recrystallization during hardening
- Crystal size increases to larger sizes than above
- Crystal numbers reduced
Food Freezing: conversion of water to ice

- Initial ice crystal size distribution is controlled by freezing and hardening equipment
  - Small crystals: smooth texture

- Freeze-concentration of the sugars - controls ice content/hardness
  - More sugar: softer ice cream

- Ice Recrystallization and Heat shock
  - Controlled by adding stabilizers and minimizing temperature fluctuations
Recrystallization of ice in ice cream

Moving towards a more stable state, never goes in reverse!

Change is slow at low temperature but speeds up dramatically at higher temperatures.

Change is slow at constant temperature but speeds up dramatically with temperature fluctuations.
The Freezing Curve

Heat shock
(melting and refreezing water by raising and lowering the temperature)
The Freezing Curve

Heat shock
(melting and refreezing water by raising and lowering the temperature)
Ice cream: the effects of heat shock

![Before and After images with labels](Image)

**Before**

**Recrystallization**

**After**

**Accretion**

Caldwell and Goff, 1992
Ice crystal size cumulative distribution in fresh and stored ice cream

45 μm sensory threshold

Percent of ice crystals less than size on the x-axis

Ice Crystal Size (μm)

-10°C/12 hrs; -20°C, 12 hrs
Sensory quality depends on ice crystal size

Ice crystal detectability

Smoothness

Mean crystal size (μm)

8% fat ice cream

Recrystallization rate depends on storage temperature, freeze-concentration and stabilizers!

Hagiwara and Hartel, 1996
Ice Crystal Size

Low, constant temperature storage

Increasing rates of recrystallization

Sensory threshold

Large starting size

45 µm

Time (days)

Critical shelf-life
Ice Cream Shelf-Life

-10°C: hours
-15°C: 1-2 days
-20°C: 1-2 weeks
-25°C: Several weeks
-30°C: Several months

But, depends also on freeze-concentration (sugars), stabilizers, initial starting size of crystals (manufacturing conditions), and temperature fluctuations.
Summary: Freezing concepts

- Fast freezing = small crystals; small crystals = smooth texture
- Solutes freeze-concentrate, dictates ice phase volume as a function of temperature (freezing curve); ice phase volume affects firmness, scoopsability
- Solutes in unfrozen phase can go through a glass transition; storage at T<Tg = long term stability
- At T>Tg, small ice crystals are unstable and recrystallize; recrystallization causes coarsening of texture, loss of smoothness, limits shelf life
What is the optimum cabinet temperature?
What is the optimum scooping temperature?

Temperature

Scoopability

Too hard  Just right  Too soft
Optimum scooping temperature leads to short shelf-life!

<table>
<thead>
<tr>
<th>Scoopability</th>
<th>Shelf-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too hard</td>
<td></td>
</tr>
<tr>
<td>Just right</td>
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Temperature
Optimum scooping temperature leads to short shelf-life!

Products with differing levels of freezing point depression

Shelf-Life

Too hard  Just right  Too soft

Temperature

Scoopability
**RIGHT WAY**

Dispenser moves sharp-edged dipper in circle...cuts ribbon of ice cream off surface. Rolls it into smooth, round ball. Ice cream is not compressed.

Dispenser continues to cut ice cream as above...keeps surface level...uses moderate pressure...cuts out nice, round dips.

Dispenser continues to cut ice cream from nearly level surface right to bottom of can. Obtains greatest number of dips.

**WRONG WAY**

Dispenser jabs dipper into ice cream...draws to side of can with main force...presses a lot of ice cream against inside of can into small looking dip...

Dispenser keeps jabbing with dipper...makes a hole way down in center...uses heavy pressure...digs the cream out by main force.

Dispenser shoves ice cream down to fill up hole...pocks ice cream still more further reduces number of 'dips' obtainable.

Courtesy of C.P. Gundlach & Co.

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Marshall, Goff and Hartel, 2003
What does it take to make good ice cream?

- Good quality ingredients and balanced formulations
- Desirable flavours
- Rapid freezing and hardening
- Good control of cold-chain

What can go wrong?

- Coarse/icy textures
- Sandiness
- Shrinkage
- Flavour issues: oxidation, rancidity
Lactose:
- Milk sugar
- Not very soluble
- Can crystallize in ice cream
  - Crystals are hard and dissolve slowly
  - 16 µm detection threshold
Sandiness

- Sandy Texture:
  - lactose crystals that do not dissolve readily and produce a rough or gritty sensation in the mouth.
  - can be distinguished from "iciness" because the lactose crystals do not melt in your mouth.
  - usually prevented from crystallizing by stabilizers and low temperature.
Shrinkage
Surface sublimation and formation of dry, gummy, discoloured layers

Prevention:
- Minimize headspace (cutting tubs?, surface covers)
- Stabilizers
- Low temperature storage
Quality is the goal!
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