The Science of Ice Cream

Special Libraries Association
Science Technology Division
June 14, 2011
The Science of Ice Cream

- Historical Background
- Composition, Properties and Standards of Identity
- Ice Cream Ingredients
- Primary Flavoring Materials/Inclusions and Coloring
- Pasteurization Equipment
- The Freezing Process
- Food Safety
Historical Background

- Wines and fruit juices with honey were cooled with ice and snow brought from the Apennines to the Roman emperor Nero in 100 AD.
- *L’art de Faire des Glaces* written about 1700.
Historical Background

- Crystalline sugar dates from Persia in 627AD and by the eighth century a process of refining was used in Egypt, Mesopotamia and Spain.
- Development of beet sugar in the 19th century caused prices to drop so the masses could afford the sweetener.
Historical Background

Arrived in America with early English colonists.
In 1774 a guest of Governor Bladen of Maryland wrote “a dessert no less curious...was some fine ice cream with the strawberries and milk, eat most deliciously”.

Ice cream became a sensation at the White House in 1812 when First Lady Dolly Madison served ice cream at the second inaugural ball.
Historical Background

- Ice cream industry was largely developed in the United States from Europe.
- In 1843 Nancy Johnson was issued patent #3254 for the first ice cream freezer.
- In 1851 Jacob Fussell established the first ice cream plant in Baltimore.
Historical Background

- In 1892 the Pennsylvania State College offered instruction in ice cream manufacture.
- In World War II dictator Mussolini of Italy thought ice cream as “too American” and banned its sale in Italy.
Today the annual production of frozen desserts in the United States exceeds 1.6 billion gallons!

The history of frozen desserts shows we have made great efforts to produce and consume these highly enjoyable foods.

Those who first consumed them were the elites of society.

Though truly “fit for royalty” this delicious food is egalitarian, a remarkable buy for the nutrition and appetite satiation that it brings.
Ice Cream Characteristics

- Frozen when eaten.
- Melts to cool and refresh.
- Tastes sweet.
- Aroma suppressed until eaten.
- Creamy and smooth.
- Appearance important.
- Always a choice of flavor.
FDA Standard of Identity

- Not less than 10% milkfat and not less than 20% total milk solids.
- Must contain not less than 1.6 pounds of total solids per gallon.
- Must weigh not less than 4.5 pounds per gallon.
- Frozen Custard –not less than 1.4% egg yolk solids.
- Must be frozen under agitation.
- Mix must be pasteurized.
- Must be sweetened with “safe and suitable” sweeteners.
Composition and Properties

- Comprised of a mixture of air, water, milkfat, nonfat milk solids, sweeteners, stabilizers, emulsifiers and flavors.
- An ice cream mix is the unfrozen blend of the ingredients used to supply these constituents sans air and flavoring material.
- Standards for ice cream vary among the major ice cream producing countries.
## Composition and Properties

<table>
<thead>
<tr>
<th>Country</th>
<th>Percent Milkfat</th>
<th>Percent total milk solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Australia</td>
<td>10</td>
<td>N/A</td>
</tr>
<tr>
<td>Japan</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Italy</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Canada</td>
<td>10</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Choices, Choices, Choices

- Ice Cream
- Frozen Custard
- Reduced fat
- Lite
- Lowfat
- Nonfat
- Gelato
- Bulky flavored ice cream
....and more choices

- Soft Serve
- Mellorine
- Paravine
- Frozen Yogurt
- Sherbet
- Water Ice
- Frappe`
- Italian Ice
- Sorbet or Sorbetto
Roles of the ingredients

- Milkfat: Satisfy legal standards, richness of flavor, a good synergist for added flavor compounds, smooth texture, desired melting properties, lubricates the palate and has insulating properties.
Nonfat milk solids

- Enhance the texture of ice cream, increased chew resistance to the finished product, prevents snowy or flaky textures.
- Milk proteins contribute to structure development including ability to foam. Foaming is important because air is incorporated to about 50% of the phase volume.
Sweeteners

- Increase the acceptance of the product by making it sweet and enhancing the cream flavor and delicate fruit flavors.
- Lack of sweeteners produces a flat taste; too much will overshadow desirable flavors.
- Sugars do not dissociate in solution so the freezing point of solutions of them can be computed from concentration and molecular weight.
Stabilizers & Emulsifiers

- Group of ingredients (usually polysaccharides)
- Added in small amounts usually <0.4%
- Increase mix viscosity
- Produce a stable foam
- Melt resistance
- Smoothness in texture
- Slowdown moisture migration
Stabilizers and Emulsifiers

- Improve whipping quality of the mix
- Produces a dry and stiff ice cream
- Resists rapid meltdown
- Promotes entrapment of air in during extrusion.
Water and Air

- Important constituents of ice cream though their effects are easily disregarded.
- Water is the solvent and is present as a liquid and solid.
- Due to added solutes it never completely freezes in ice cream.
Water and Air

- Air is dispersed in the emulsion and the interface between the water and air is stabilized by a thin film of unfrozen material.
- Filters are used on continuous freezers to remove any particulates from air entering the freezer.
Flavor

- Most important characteristic of ice cream!
- Easily confused with *taste*, which includes the ‘feel sensation’ of body and texture as well as the true flavor.
- Blending the flavors of all the ingredients to achieve desirability of a particular flavor.
- Very subjective, depends greatly upon the individual doing the tasting.
- Delicate over harsh, only intense enough to be recognized.
Fruits in Frozen Desserts

- Ice cream is a major market for fruits.
- Fruit ice creams rank second among flavors, 9% of sales.
- Availability is very high, fresh, frozen and heat processed forms. Aseptic processing provides several advantages in use of most fruits.
  - Quality is much improved.
  - Ready-to-use and convenient.
Fruit Flavors

- Usually the best source of flavor and retain special sales appeal.
- Extracts from the prepared fruit, artificial flavors and extracts with added artificial flavors.
- Complex flavors.
  - Variegates
  - Background flavors
  - Addition of fruits, nuts and candies
Color in Frozen Desserts

- Consumers “eat with their eyes.”
- Color should be delicate and attractive.
- Readily suggests to the consumer what the flavor is.
- Must be certified (FD&C) and declared on the product label.
- “Color added” and “artificial color” are acceptable terms, “natural color” is not permitted.
Gelato

- **Mix Composition**
  - Butterfat: 0 – 8%
  - Sugars: 14 – 24%
  - SMS: 4 – 12%
  - Total Solids: 32 – 42%
  - Water: 58 – 68%

- Milk based gelatos – creams and fruit
- Water based gelatos – sorbetto
- Semifreddo – gelato cakes
Pasteurization

- The process of heating every particle of milk or milk product to the minimum required temperature and holding it continuously for the minimum required time in equipment that is properly designed and operated.
Pasteurization of Ice Cream

- Purposes of Pasteurization
  - Destruction of vegetative pathogenic microorganisms present in milk or dairy product.
  - Inactivation of enzymes, denaturation of proteins, activation of stabilizers, destruction of spoilage organisms.
Pasteurization & Homogenization

- United States Public Health Service Minimal Times and Temperatures for Ice Cream Mix Pasteurization.

<table>
<thead>
<tr>
<th>Method</th>
<th>Time</th>
<th>Temperature (°C/°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch</td>
<td>30 minutes</td>
<td>69/155</td>
</tr>
<tr>
<td>High Temperature Short-Time</td>
<td>25 s</td>
<td>80/175</td>
</tr>
<tr>
<td>High-Heat Short-Time</td>
<td>1-3 s</td>
<td>90/194</td>
</tr>
<tr>
<td>Ultra High Temperature</td>
<td>≥2 s</td>
<td>138/280</td>
</tr>
</tbody>
</table>
Pasteurization & Homogenization

- Purpose of creating a permanent homogeneous emulsion of milkfat in serum by forcing a fluid dairy product under high pressure through a specially designed valve that causes the fat globules to be broken into particles so small that the forces of buoyancy are overcome by the viscosity of the serum phase.
Purpose of Homogenization

- To reduce the size of the milkfat globules and change the nature of the surrounding “membrane” which prevents milk from separating into fat-rich and fat-deficient phases.
- To fully disperse added ingredients.
# Homogenization

<table>
<thead>
<tr>
<th>Property</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globule size (µm)</td>
<td>3.6</td>
<td>0.6</td>
</tr>
<tr>
<td># globules /liter</td>
<td>$4 \times 10^{12}$</td>
<td>$8.6 \times 10^{14}$</td>
</tr>
<tr>
<td>Surface Area (m²)/liter</td>
<td>162.8</td>
<td>976.8</td>
</tr>
</tbody>
</table>
Functions of Homogenization

- Smoother texture
- The emulsion obtains a more uniform globule size.
- Improved whippability inside the freezing chamber.
- Improve melt characteristics of finished product.
Aging of Ice Cream Mix

- Mix is cooled to <4°C (<40°F).
- 4 hr to 24 hr
- Allows milkfat to crystallize.
- Nearly complete crystallization is needed to promote coalescence of fat globules during ice cream freezing.
Freezing/Hardening/Storage

- Packaged Ice Cream
  - About ½ of mix water freezes under agitation in the freezer
  - Balance freezes quiescently.
- Soft Serve
  - All freezing is in the freezer.
- Frozen Confections
  - All freezing is quiescent.
What Happens in the Ice Cream Freezer?

- Crystallization of water occurs.
- Air is whipped into the system.
- Milkfat forms clumps and crystals.
- As water freezes the solutes are concentrated.
- Air –expressed as % overrun- increases the volume of the mix due to incorporation of air as vacuoles.
- When one liter of mix yields 1.8 liters of ice cream, overrun is 80%.
Continuous Freezers

- Rated in gallons per hour.
- Draw temperature 21-22°F (-6.1 to -5.5°C)
- Only 50% of the available water is frozen at this time.
- The majority of the remaining water is frozen quiescently.
The Creamery Formula

- 14.1% milkfat
- 12.5% milk solids nonfat
- 3.7% dry corn syrup solids
- 12.96% cane sugar
- 0.26% stabilizer
Microbial Food Safety

- Milk
  - Perishable.
  - Easily contaminated.
  - Must be refrigerated at all times.
- Ice Cream
  - Is not a sterile product.
  - Does not contain harmful bacteria.
  - Must be pasteurized.
  - Primary concern is post-pasteurization contamination.
Microorganisms in Raw Milk

- Milk is sterile when secreted from healthy cows.
- Contamination occurs
  - Within the udder.
  - Exterior of the teats and udder.
  - Milking, transport and storage equipment.
  - Transported from the farm held at low temperatures.
  - These conditions 5-10°C (40-50°F) allow cold-tolerant (psychrotrophic) organisms to grow.
Spoilage Organisms

- Coliforms
- Pseudomonas

And some pathogens
- Yersinia
- Listeria
Microbiology of Ice Cream

- Properly frozen, little microbial growth will occur.
- The bacterial count should be as low as possible as the ice cream exits the freezer.
- Five main factors to consider:
  - Raw materials and ingredients
  - Processing steps
  - Equipment
  - Plant sanitation
  - Employee practices
Milk and Ice Cream

- Nutritious media for growth of bacteria.
- High microbial counts indicate possible improper processing or post pasteurization contamination.
- Microbiological quality of ice cream depends on the raw ingredients, processing and equipment used.
- Dairy products are highly regulated foods and are one of the safest groups of foods consumed.
Trivial Pursuit

- Per capita consumption is 24 quarts –U.S.A.
- The U.S. produces 1.6 billion gallons of ice cream annually.
- Pennsylvania produces 105 million gallons each year.
- Ice Cream sales in the United States surpassed $4 billion.
- Penn State Creamery produces 250,000 gallons each year.
Acknowledgements


• Prof. Douglas Goff, University of Guelph.