

FREEZING FOAMS

Background

The origins of ice cream manufacturing can be traced back to at least the 4th century B.C. Early references include the Roman emperor Nero (A.D. 37-68), who ordered ice to be brought from the mountains and combined with fruit toppings. This was one of the early techniques used for refrigeration. In fact, much of the history of ice cream is closely associated with developments in refrigeration and freezing, including:

1. Cooling food and drink by mixing it with snow or ice
2. The discovery that dissolving salts in water produces cooling
3. The discovery that mixing salts and snow or ice cools even further
4. The invention of the ice cream maker in the mid-19th century
5. The development of mechanical refrigeration in the later 19th and early 20th centuries—which led to the development of the modern ice cream manufacturing industry

Commercial Ice Cream Manufacturing

Commercial ice cream manufacturing has many steps to ensure that a uniform product is made, and that it is stable and safe to eat over a long period of time. To produce ice cream commercially:

- First, the **milk products, stabilizers (such as gums and/or gelatin), and emulsifiers** are mixed together and *homogenized* to form a stable emulsion.
 - An emulsion is a colloid (a mixture of very tiny particles that are dispersed in another substance, but do not settle out of that substance), in which liquids that do not normally mix are spread throughout each other. To prevent the mixture from separating, an ingredient, known as an emulsifier, which is attracted to both oil and water, is added, thus allowing the two to mix. In ice cream, an emulsion is formed as the milkfat is dispersed in the water. Milk naturally contains the emulsifier, lecithin; however emulsifiers and stabilizers (such as gums or gelatin) may be added to improve the stability.
- Homogenization occurs in two stages:
 - In the first stage of homogenization, the mixture is subjected to high pressure (2,000-3,000 psi) to reduce (or squish) the fat globules to 1/10 their original size. This process stabilizes the fat globules in the emulsion and improves the mouthfeel of the ice cream.
 - In the second stage, the mixture is placed under pressure again (500-700 psi) to prevent the fat globules from coalescing (sticking together).
- Next the homogenized mixture is *pasteurized* at either 150°F for 30 minutes or at 166°F for 15 seconds. Then the mixture is cooled.
 - The pasteurization process kills pathogenic organisms, improves the flavor and shelf life, and enhances uniformity.
- The next step is *aging*, in which the mixture is usually stirred overnight.
 - This process increases the viscosity (or thickness) of the mixture, allows time for complete hydration of the stabilizers (gelatin and/or gums) and crystallization (solidification) of the fat, and improves the whippability (ability to add air).
- After the mixture has matured or aged, the **flavors and colors** are added just before freezing.



- The final stage, *freezing*, is typically a two stage-process.
 - First, in the *soft serve stage*, the mixture is frozen in a continuous freezer where it is also whipped so that small bubbles of air become trapped in the aqueous solution, forming a foam.
 - A foam is a type of colloidal dispersion in which very tiny particles of gas are dispersed (scattered) in a liquid or solid substance and do not settle out of that substance.
 - As large amounts of air are incorporated into the mixture, the volume increases. The percent increase in volume is known as overrun. The expected overrun is much greater in commercial preparations of ice cream (80-100%) than for homemade ice cream (30-50%) because of the mechanical whipping.
 - After the soft serve stage, the ice cream is then extruded between 21-27°F into the desired food packaging (tubs, cups). **Variiegates** (such as caramel sauce) and **inclusions** (such as fruit, nuts, chocolate chips) can be added at this point.
 - In the next phase, *hardening*, the ice cream is hardened without agitation as it passes through a ventilated tunnel at about -24°F to the point where about 90% of the water is frozen.
 - To create a smooth texture, it is important that both stages of freezing occur quickly so that small ice crystals are formed. If the ice cream is frozen too slowly, large ice crystals will form, which give a coarse, grainy texture.
- Now the ice cream is ready to be distributed to grocery stores, convenience stores, and foodservice establishments (like restaurants)!
- Ice cream may also be manufactured commercially using liquid nitrogen. Dippin' Dots® is an example of an ice cream snack that is created by flash freezing ice cream mix in liquid nitrogen. Because the product is frozen so quickly, small ice crystals form, resulting in a smooth mouth-feel (texture). Even though there is no whipping, the ice cream is aerated as the liquid nitrogen evaporates.

How It Works:

As the liquid nitrogen is poured onto the ice cream mix, it changes state from a liquid into a gas, a phase change known as evaporation. This process requires heat, so as the liquid evaporates it essentially absorbs heat from the ice cream, which in turn cools the ice cream down. Other liquids, like water, will not work because they evaporate at much higher temperatures than liquid nitrogen, which evaporates at temperatures above -196°C!

Homemade Ice Cream Manufacturing

Most household freezers for ice cream are designed so that an ice-and-salt mixture can be packed around a metal container into which the ice cream mixture is poured.

How It Works:

When a salt solution touches the surface of ice, it lowers the vapor pressure of the ice and causes it to melt. As the ice melts, it absorbs heat from the surrounding brine and the ice cream mixture. As the heat is withdrawn, the freezing point is lowered.

While the mixture is freezing, it is also stirred to incorporate air into the ice cream. As previously discussed, the amount of air incorporated, also called overrun, is much less for homemade ice cream.

References

Himich Freeland-Graves, J and Peckham, GC. 1996. Foundations of Food Preparation. 6th ed. Englewood Cliffs: Prentice Hall. 750 pgs.

Goff, D. Ice Cream. Dairy Science and Technology Education Series: <http://www.foodsci.uoguelph.ca/dairyedu/icecream.html>. Accessed on August 8, 2007.



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Administrator's Guide

The following experiment was adapted from *The Science of Ice Cream* by Jason Bolton. *The Science of Ice Cream* was developed as part of the University of Maine's NSF GK-12 Sensors Fellowship.

Grade levels: 3-12

Estimated Preparation Time: 30 minutes

Estimated Activity Time: 1 hour

Standard Addressed: Content Standard E (Understandings about Science and Technology)

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Creativity, imagination, and a good knowledge-base are all required in the work of science and engineering.

Reference:

Himich Freeland-Graves, J and Peckham, GC. 1996. *Foundations of Food Preparation*. 6th ed. Englewood Cliffs: Prentice Hall. 750 pgs.

Objectives:

- To introduce food processing and food science to students
- To demonstrate the effects different processing methods have on the sensory properties of food products

Materials:

- 5 - 1 lb. Coffee Cans¹
- 5 - 3 lb. Coffee Cans
- 10 – 1 ½ cup servings (1 gallon) half and half
- 10 – 1 ½ cup servings (1 gallon) heavy cream
- 1 bottle vanilla extract

- 10 – ½ cup servings (2 lb. bag) sugar
- Rock salt, kosher salt, or table salt
- Ice
- Newspaper
- 5 measuring cups (liquid and dry measure)
- 3 teaspoon measuring spoons
- 100 small cups (6-8 oz.)
- Plastic spoons
- Store-bought vanilla ice cream
- Duct tape

(Note: Be aware that some students may have food allergies or sensitivities)

If also preparing ice cream using liquid nitrogen, you will need:

- Approximately 5 liters liquid nitrogen and special container to hold the liquid nitrogen in (to purchase, try contacting your local university or ask if the school's science department has some available; the cost should be about \$1.50 to \$2.00 per liter).
- Non-porous rubber gloves (elbow-length if possible)
- Safety goggles
- 1 wooden spoon
- 1 large metal bowl

Set-up Instructions:

1. Cover a table at the front of the classroom with newspapers.
2. Set up stations for each ingredient with measuring cups and spoons.

Procedure:

Students can voluntarily participate, but should not be forced to participate because all sensory tests that include human subjects must be conducted on a voluntary basis.

Coffee Can Ice Cream

1. Divide students into 5 groups.
2. Have one student from each group measure 1 ½ cups half and half,

¹ If coffee cans are not available, quart size Ziploc® and gallon size Ziploc® freezer bags can be used. See **Alternatives** at the end of the Administrator's Guide for further instructions.

- 1 ½ cups heavy cream, 1 tsp. vanilla, and ½ cup sugar into the one pound coffee can. Instruct students to mix the ingredients and place the lid on securely. You may want to have students duct tape the can.
3. Have students set the 1 lb. can inside the 3 lb. can.
 4. Have another student from each group add ice, and alternate layers of ice and salt outside the small can and inside the large can. When totally full, secure the lid on the large can. Have students take turns rolling the can back and forth for at least 15 minutes. Have each student put some ice cream into a cup and taste. Have students record their perceptions in the data table provided.

Liquid Nitrogen Ice Cream

1. Put on safety gear: rubber gloves and goggles.
2. Mix 3 cups cream, 3 cups half and half, 2 tsp. vanilla, and 1 cup sugar together in a bowl (adjust recipe according to class size).
3. Pour 1 to 2 liters of liquid nitrogen into the bowl slowly and mix with the wooden spoon constantly until the ice cream is completely frozen.
4. Continue to stir until the nitrogen has evaporated (the fog has disappeared).
5. Serve each student a sample of the ice cream made with liquid nitrogen. Have students taste the ice cream and record their perceptions in the data table provided.

Commercial Ice Cream

1. Serve each student a sample of store-bought vanilla ice cream. Have students record their perceptions in the data table provided. Discuss with students the effects of the different processing methods on the appearance, odor, flavor, and mouthfeel (texture) of the ice cream. Two major factors are:
 - Overrun – Commercial ice cream tends to have higher overrun (which would make it less dense and more airy).
 - Crystal size – Products which are frozen faster (like the liquid nitrogen ice cream) will have smaller crystals which results in a smoother texture.

Mention to students that typically during sensory evaluation experiments, samples are blind coded with three-digit codes so that the subjects are not biased by knowing how the products were prepared.

Alternatives: If coffee cans are not available, quart size Ziploc® and gallon size Ziploc® freezer bags can be used. Purchase enough so that they can be doubled to prevent leaking. If using Ziploc® bags, divide the recipe for each group in half. If time and materials allow, each student can prepare their own ice cream. Follow the directions as indicated for the coffee can ice cream. Be sure the bags are sealed tightly and have students shake the bags, holding onto the edge. If available, have students wear gloves because the bags might be cold.



Data Sheet:

<i>Sample</i>			
<i>Attribute</i>	<i>Coffee Can Ice Cream</i>	<i>Liquid Nitrogen Ice Cream</i>	<i>Commercial Ice Cream</i>
<i>Appearance</i>			
<i>Odor</i>			
<i>Flavor</i>			
<i>Mouthfeel</i>			

Data Sheet:

<i>Sample</i>			
<i>Attribute</i>	<i>Coffee Can Ice Cream</i>	<i>Liquid Nitrogen Ice Cream</i>	<i>Commercial Ice Cream</i>
<i>Appearance</i>			
<i>Odor</i>			
<i>Flavor</i>			
<i>Mouthfeel</i>			

Data Sheet:

<i>Sample</i>			
<i>Attribute</i>	<i>Coffee Can Ice Cream</i>	<i>Liquid Nitrogen Ice Cream</i>	<i>Commercial Ice Cream</i>
<i>Appearance</i>			
<i>Odor</i>			
<i>Flavor</i>			
<i>Mouthfeel</i>			

FREEZING FOAMS

Student Handout

Background: Commercial ice cream manufacturing has many steps to ensure that a uniform product is made, and that it is stable and safe to eat over a long period of time. These steps include: homogenization, pasteurization, aging, and freezing. Commercial ice cream is usually frozen in two stages:

- First, in the soft serve stage, the mixture is frozen in a continuous freezer where it is also whipped so that small bubbles of air become entrapped in the aqueous solution, forming a foam. As large amounts of air are incorporated into the mixture, the volume increases. The percent increase in volume is known as **overrun**. The expected overrun is much greater in commercial preparations of ice cream (80-100%) than for homemade ice cream (30-50%) because of the mechanical whipping.
- In the second stage, called hardening, the ice cream is hardened without agitation as it passes through a ventilated tunnel at about -24°F, to the point where about 90% of the water is frozen.

To create a smooth texture, it is important that both of these processes occur quickly so that small ice crystals are formed. If the ice cream is frozen too slowly, large ice crystals will form, which give a coarse, grainy texture.

Objectives: To investigate the effects of different processing on the sensory properties of food products

Instructions:

Coffee Can Ice Cream

1. Have one student from your group measure 1 ½ cups half and half, 1 ½ cups heavy cream, 1 tsp. vanilla, and ½ cup sugar into the one pound coffee can. Mix the ingredients and place the lid on securely. You may want to duct tape the lid to the can.
2. Set the 1 lb. can inside the 3 lb. can.
3. Have another student from your group add ice, and alternate layers of ice and salt outside the small can and inside the large can. When totally full, secure the lid on the large can.

4. Take turns rolling the can back and forth for at least 15 minutes.
5. Put some ice cream into a cup and taste.
6. Record your perceptions in the data table provided.

Liquid Nitrogen Ice Cream

1. Watch as your instructor mixes cream, half and half, vanilla, and sugar together in a bowl.
2. The instructor will then pour liquid nitrogen **slowly** into the mixture while mixing with a wooden spoon until the ice cream is completely frozen.
3. Taste the sample of the ice cream made with liquid nitrogen.
4. Record your perceptions in the data table provided.

Commercial Ice Cream

1. Taste the sample of the commercial ice cream.
2. Record your perceptions in the data table provided.

Conclusion Questions:

1. Did the ice cream samples taste different?

2. If so, which attributes (appearance, odor, flavor, and/or mouthfeel) were most different?

3. What about the way in which the samples were processed might have influenced these sensory properties?
