

---

---

# MAKING ICE CREAM

---

**Unit:** Food Science

**Problem Area:** Agricultural Processing Systems

**Lesson:** Making Ice Cream

**Student Learning Objectives.** Instruction in this lesson should result in students achieving the following objectives:

- 1** Describe the physical changes that occur in the ice cream mixture during freezing.
- 2** Explain the effects of sugar, salt, or similar molecules on the freezing of liquids.
- 3** Describe the ingredients and factors that give ice cream its characteristic smooth and creamy texture.



**List of Resources.** The following resources may be useful in teaching this lesson:

Seperich, George J. *Food Science and Safety*. 2<sup>nd</sup> Edition. Upper Saddle River, NJ: Pearson Prentice Hall Interstate, 2004.

Cooper, Elmer L., Burton, L. DeVere. *Agriscience Fundamentals and Applications*, 3E. Albany, New York: Delmar Publishers, 2002.

Lee, Jasper S., Turner, Diana L. *AgriScience*. 3<sup>rd</sup> Edition. Upper Saddle River, NJ: Pearson Prentice Hall Interstate, 2003.

Morgan, Elizabeth M., Lee, Jasper S., and Wilson, Elizabeth. *AgriScience Explorations*. 3<sup>rd</sup> Edition. Upper Saddle River, NJ: Pearson Prentice Hall Interstate, 2004.

Parker, Rich. *Introduction to Food Science*. Albany, New York: Delmar Publishers, 2003.

<http://www.foodsci.uoguelph.ca/dairyedu/icecream.html>

<http://www.makeicecream.com/>

<http://www.ice-cream-recipes.com/>

<http://science.howstuffworks.com/question58.htm>

<http://science.howstuffworks.com/question96.htm>

## List of Equipment, Tools, Supplies, and Facilities

- ✓ Writing surface
- ✓ Overhead projector
- ✓ Transparencies from attached masters
- ✓ Copies of student lab sheet
- ✓ Copies of technical supplement

**Terms.** The following terms are presented in this lesson (shown in bold italics):

- ▶ Conduction
- ▶ Convection
- ▶ Crystallization
- ▶ Emulsifier
- ▶ Emulsion
- ▶ Freezing
- ▶ Homogenization

**Interest Approach.** Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

*Have students participate in a taste test of several types of ice cream and frozen desserts. Include all-natural brands, ice milk, newly purchased ice cream, old ice cream, homemade ice cream, sherbet, and others. Challenge students to identify the differences in each type (taste, texture, and other characteristics). What factors caused these differences?*

## SUMMARY OF CONTENT AND TEACHING STRATEGIES

**Objective 1:** Describe the physical changes that occur in the ice cream mixture during freezing.

**Anticipated Problem:** What are the physical changes that occur in the ice cream mixture during freezing?

- I. Physical changes occur within the ice cream mixture during the freezing process that are critical to the formation of ice cream.
  - A. Ice cream is produced by dynamically freezing a pasteurized mixture of milk, cream, nonfat milk solids, sugars, and stabilizers. **Freezing** is a change in physical condition from a liquid to a solid state. Heat is transferred from a warm substance to a cooler substance by one of two means.
    1. **Conduction** is the transfer of heat that takes place between two bodies or objects that are in direct contact with each other.
    2. **Convection** is the flow of heat from a warmer area to a cooler area through air or water.
  - B. Ice cream is actually partially frozen foam. The ice cream mixture is an **emulsion**, a finely divided mixture of two immiscible liquids; a stable colloidal suspension, such as milk, that consists of an immiscible liquid dispersed and held in another liquid by emulsifiers. An **emulsifier** is an agent that supports the formation of an emulsion.

The ice cream emulsion has an aqueous phase containing a solution of lactose, mineral salts, and added sugars. The non-aqueous phase consists of dispersed solids such as stabilizers, proteins, and fat globules.
  - C. During the freezing process, churning causes some milk fat to be released from the fat globules and form a thin layer around air cells. During freezing, only part of the water content of the mix is frozen into small ice crystals. The percentage of water changed into

ice depends upon the temperature and the concentrations of sugars and milk salts in solution. **Crystallization** is the formation of regular geometric shapes (crystals) found in a solid (in this case ice) in which the component particles are arranged in an orderly, three-dimensional, repeating pattern.

Hardening completes the ice crystallization process, which improves storage quality and final texture development. Rapid freezing results in the formation of smaller ice crystals. Aging promotes the crystallization of fats and adsorption of smaller proteins on fat globules surfaces.

*Use a variety of techniques to master this objective. Use a lecture/discussion technique to introduce the objective. Have students write concepts and vocabulary definitions in their notebooks. Use TM–A as a visual aid with the discussion of this objective.*

**Objective 2:** Explain the effects of sugar, salt, or similar molecules on the freezing of liquids.

**Anticipated Problem:** What are the effects of sugar, salt, or similar molecules on the freezing of liquids?

- II. Sugar, salt, and other similar molecules have various effects on the freezing of liquids.
  - A. The ice cream mixture freezes due to the transfer of heat from the mix to the ice/water mixture. Heat transfer occurs from warm to cold until both environments are in balance (the same temperature). The addition of salt to the ice/water mixture lowers the freezing point of the water, allowing a greater temperature difference between the ice cream mixture and the ice/water mixture. The salt interferes with the formation of ice crystals and as ice is formed, the concentration of salt in the solution increases, preventing further freezing. Sugar, sand, table salt, and other substances have the same effect on the freezing point of water.
  - B. Lowering the temperature of the ice/water mixture allows for a faster freezing of the ice cream. Water is added to the salt/ice mixture to melt the ice and allow better contact between the salt and the solution.
  - C. Cane and beet sugar, corn sweeteners, honey, and other sweeteners can be used in making ice cream. A greater concentration of sugars in the mixture lowers the freezing point of ice cream.

*Use a variety of methods to master this objective. Use TM–B as a visual aid. Discuss how the addition of substances to the ice cream mixture will have an effect on the ice cream and the salt/ice mixture.*

**Objective 3:** Describe the ingredients and factors that give ice cream its characteristic smooth and creamy texture.

**Anticipated Problem:** What are the ingredients and factors that give ice cream its characteristic smooth and creamy texture?

- III. Ice cream is given its characteristic smooth and creamy texture by production factors and the addition of certain ingredients.
- A. Milk fat contributes to the rich and creamy texture of ice cream. During churning, fat particles are dispersed throughout the mixture, giving a smooth feel. Ice cream with high fat content has smaller ice crystals and a slower rate of air incorporation.
1. Ice cream must have at least 10% milk fat, while ice milk only contains between 2% and 7% milk fat.
  2. Ice cream mix normally contains 10–15% sucrose, 5–7% corn sweetener, .2–.3% stabilizer, .1% emulsifier, and natural and/or artificial flavors or colors.
- B. Milk proteins stabilize the foam or air cells and help to emulsify the milk fat. **Homogenization** is the process of reducing the size of fat globules by forcing the mixture through a small gauge screen. After homogenization, milk proteins attach to fat globules, making the finished product more stable and smooth.
- C. Milk also contains casein and whey proteins, and some natural stabilizing and emulsifying material. Thus, excellent ice cream products can be made without adding artificial substances. Egg yolks can be used as an emulsifier, which will help produce smaller ice crystals and air cells, and give the final product a stiffer and smoother texture.
- D. The rate at which the ice cream mixture is frozen will have an effect on the texture of the final product also. Quickly freezing the mixture results in smaller ice crystals, giving a smooth texture. Slow freezing results in the formation of larger ice crystals, which will give a grainy texture to the ice cream. Fluctuations in temperature when freezing ice cream can cause ice crystals to freeze, thaw, then refreeze into larger crystals, again resulting in a grainy texture.
1. Stabilizers prevent the formation of larger ice crystals by binding water that forms when melting occurs. Too much stabilizer however, will result in a gummy product as sodium alginates are widely used as commercial stabilizers.

*Use a variety of methods to master this objective. Use a lecture/discussion approach to introduce students to the material. Use TM–C as a visual aid when discussing the freezing of ice cream. Use LS–A as a laboratory exercise for students to experiment with the rapid freezing of ice cream.*

**Review/Summary.** The review and summary of this lesson should be based on the three student objectives listed earlier in this lesson. Begin with a discussion on the physical changes that occur in water during the freezing process. Ask students to explain vocabulary terms that are associated with this objective. Next, have students explain why adding substances to an ice/water mixture or the ice cream mixture will have an effect on the freezing point of both solutions. Finally, review the factors and ingredients that will affect the texture of ice cream. Review all vocabulary terms and check for understanding.

**Application.** Application can occur as students consider food science, specifically the activity of making ice cream, and how this process must be understood to effectively produce, process, and handle a quality food product. Some students may be able to use their supervised agricultural experiences to expand their knowledge of food science outside of the classroom. Use the following transparency masters, lab sheet, and technical supplement to apply the information.

- ◆ TM–A: Stages of Freezing
- ◆ TM–B: Freezing Liquids
- ◆ TM–C: Relationship Between Freezing Rate and Size of Water Crystals
- ◆ LS–A: Making Ice Cream
- ◆ TS–A: Making Ice Cream

**Evaluation.** Evaluation should be based on mastery of the objectives by the students. This can occur during instruction, review, or later as students apply the information. A sample written test is attached.

## Answers to Sample Test:

### Part One: Matching

1. f
2. d
3. a
4. g
5. e
6. b
7. c

### Part Two: Completion

1. smaller
2. milk fat
3. artificial

### Part Three: Multiple Choice

1. b
2. c
3. a
4. b
5. d
6. a

### Part Four: Short Answer

Salt interferes with the crystallization of water into ice crystals, therefore lowering the freezing point of the water below 32 degrees F. This decreased freezing point creates a greater temperature difference between the ice cream mixture and the surrounding ice/water/salt solution. This temperature difference allows for a greater heat removal from the ice cream, causing a faster freeze with smaller ice crystals, and ultimately a smoother textured ice cream product.



## Test

Name \_\_\_\_\_

# MAKING ICE CREAM

### ► Part One: Matching

*Instructions:* Match the term with the correct response.

- |                    |               |                   |
|--------------------|---------------|-------------------|
| a. Conduction      | d. Emulsifier | g. Homogenization |
| b. Convection      | e. Emulsion   |                   |
| c. Crystallization | f. Freezing   |                   |

- \_\_\_\_\_ 1. The changing of a liquid substance to a solid.
- \_\_\_\_\_ 2. An agent that supports the formation of an emulsion.
- \_\_\_\_\_ 3. The transfer of heat by two substances that are in direct contact.
- \_\_\_\_\_ 4. The process that decreases the size of milk fat globules.
- \_\_\_\_\_ 5. A finely divided mixture of two immiscible liquids.
- \_\_\_\_\_ 6. The transfer of heat through water or air.
- \_\_\_\_\_ 7. The formation of regular geometric shapes (crystals) found in a solid.

### ► Part Two: Completion

*Instructions:* Provide the word or words to complete the following statements.

1. Fast freezing of ice cream results in \_\_\_\_\_ ice crystals.
2. Churning causes \_\_\_\_\_ to be released from the fat globules.
3. Because of natural stabilizers and emulsifiers, excellent ice cream can be made without any \_\_\_\_\_ substances.

### ► Part Three: Multiple Choice

**Instructions:** Circle the letter of the correct answer.

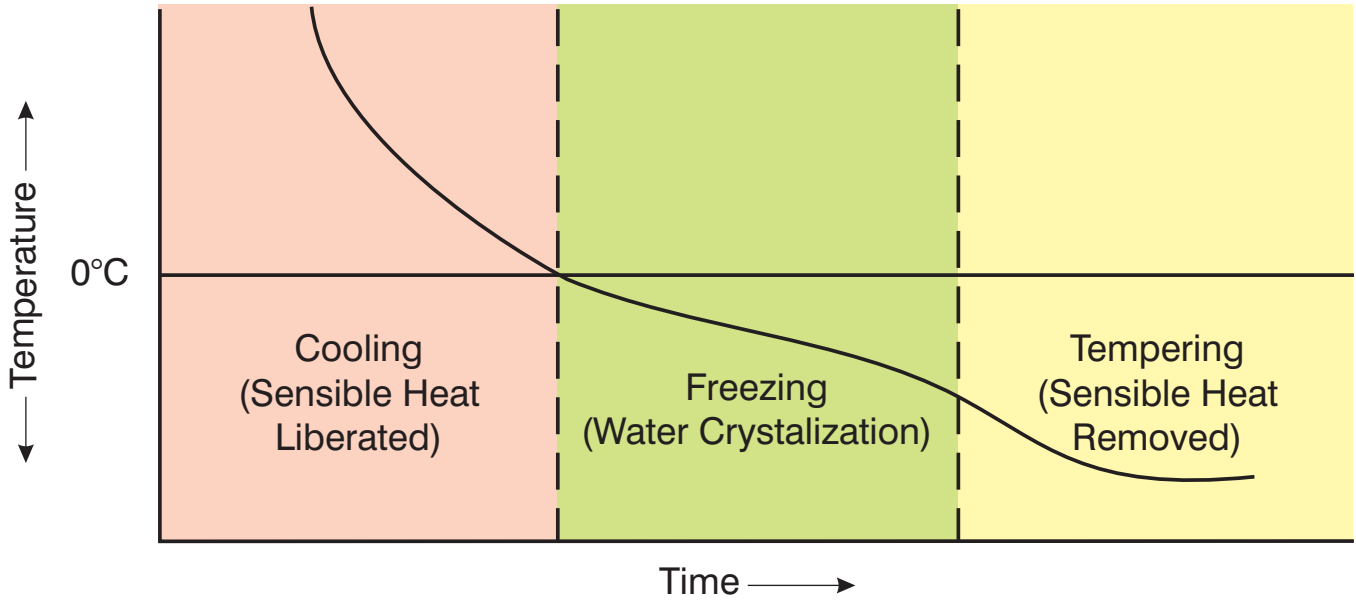
- \_\_\_\_\_ 1. Heat is normally transferred from a \_\_\_\_\_ to \_\_\_\_\_ object.
- warm to hot
  - warm to cool
  - cool to hot
  - cool to cool
- \_\_\_\_\_ 2. Which of the following is an example of convection?
- touching a hot stove with your hand
  - holding a hot cup of coffee in your hand
  - cooking a hot dog over a campfire
  - holding an ice cube in your hand
- \_\_\_\_\_ 3. Freezing ice cream slowly and having fluctuations in the freezing temperature would have which of the following effects on the final product?
- the ice cream would have a 'grainy' texture.
  - the ice cream would be smooth and delicious.
  - the ice cream would spoil quickly.
  - the ice cream would have bacteria in it.
- \_\_\_\_\_ 4. A gummy texture of ice cream is usually the result of:
- too much sugar
  - too much artificial stabilizer
  - too little homogenization
  - too quick of a freezing rate
- \_\_\_\_\_ 5. Real ice cream must have at least \_\_\_\_\_ % milk fat.
- 2
  - 4
  - 6
  - 10
- \_\_\_\_\_ 6. A greater concentration of sugars in the ice cream mixture \_\_\_\_\_ the freezing point of the ice cream.
- lowers
  - raises
  - has no effect on
  - all of the above

### ► Part Four: Short Answer

**Instructions:** Provide information to answer the following statement.

Describe why a salt/water/ice mixture was used in our ice cream laboratory experiment. Be specific about the role of the salt.

# STAGES OF FREEZING



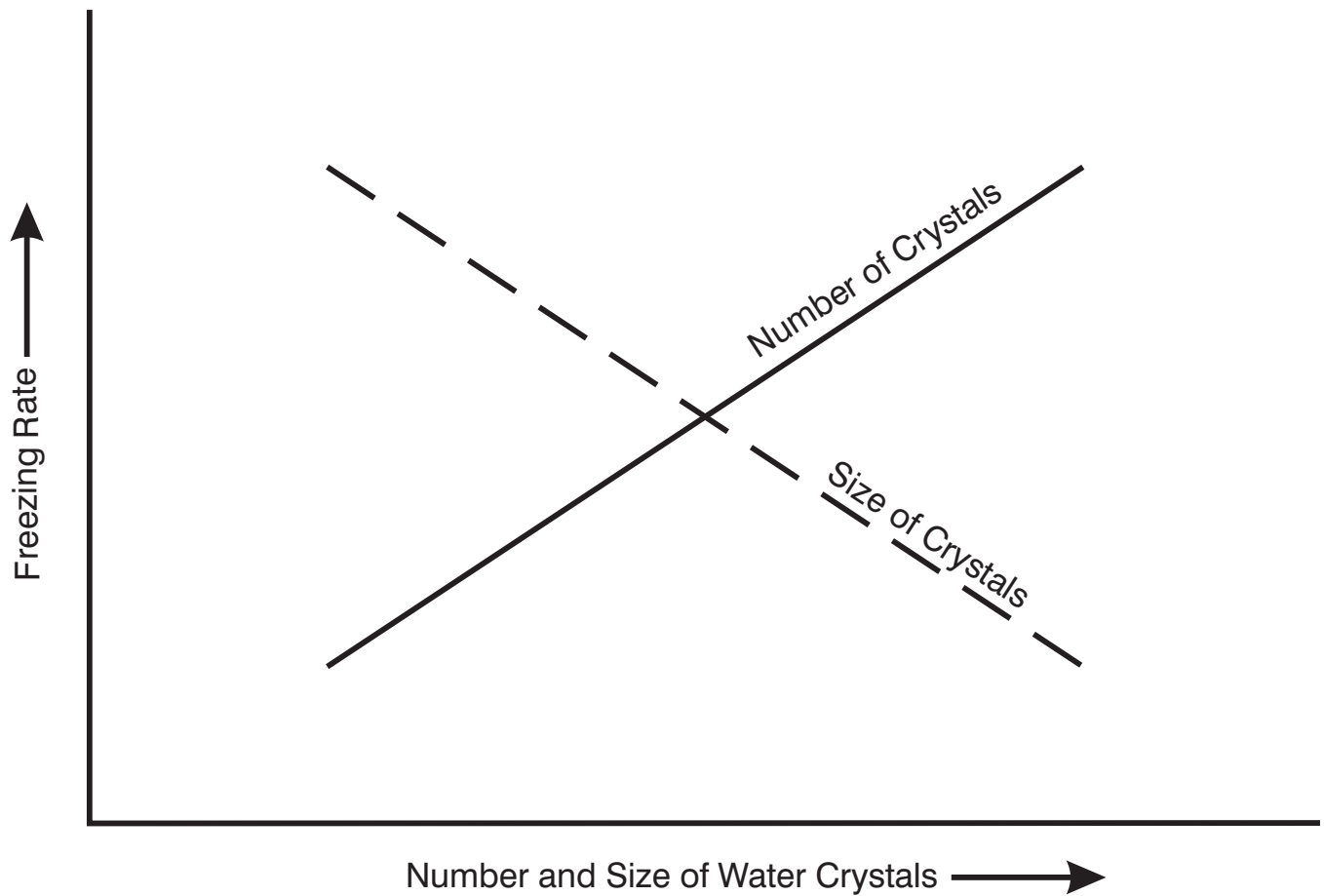
# FREEZING LIQUIDS

---

- ◆ Sugar, salt, and other similar molecules have various effects on the freezing of liquids.
- ◆ The ice cream mixture freezes due to the transfer of heat from the mix to the ice/water mixture.
- ◆ Heat transfer occurs from warm to cold until both environments are in balance (the same temperature).
- ◆ The addition of salt to the ice/water mixture lowers the freezing point of the water, allowing a greater temperature difference between the ice cream mixture and the ice/water mixture.
- ◆ The salt interferes with the formation of ice crystals and as ice is formed, the concentration of salt in the solution increases, preventing further freezing.
- ◆ Lowering the temperature of the ice/water mixture allows for a faster freezing of the ice cream.
- ◆ Water is added to the salt/ice mixture to melt the ice and allow better contact between the salt and the solution.
- ◆ Cane and beet sugar, corn sweeteners, honey, and other sweeteners can be used in making ice cream.
- ◆ A greater concentration of sugars in the mixture lowers the freezing point of ice cream.



# RELATIONSHIP BETWEEN FREEZING RATE AND SIZE OF WATER CRYSTALS



# MAKING ICE CREAM

## Agricultural Applications and Practices

Ice cream and other frozen desserts are popular items in our daily diets. Due to the nutritional qualities of milk, they also contribute to some extent to the intake of important nutrients, including calcium, vitamins, phosphorus, and protein. Since it was first served in New York City in 1777, ice cream has become known as America's favorite dessert. Over 924 million gallons of ice cream and 476 million gallons of ice milk and other frozen desserts are consumed annually by Americans—enough for nearly six gallons for every person living in the U.S. During the early part of this century, homogenization and continuous freezing were technological breakthroughs that contributed to the smooth, creamy product we enjoy today. Since then, most product improvements have focused on formulations, stabilizers, and processing systems.

Most ice creams today are made using a combination of corn syrup and sucrose. The basic steps in making ice cream include blending ingredients, pasteurization, homogenization, cooling, mix storage, flavoring, freezing, packaging, hardening, and finished product storage and distribution. Soft serve freezers represent a scaled-down version of industry methods. In the 1960s ice cream products were developed that contained only natural ingredients - no artificial stabilizers or other additives. Low fat products are becoming more popular today. As consumers' preferences for products continue to change, the food processing industry is sure to respond with more new products.

## Science Connections—Questions for Investigation

1. What processes or ingredients provide the smooth, creamy texture of ice cream?
2. Why are emulsifiers and stabilizers added to commercially prepared ice creams? Are they necessary for homemade ice cream?
3. What physical changes does the ice cream mixture undergo when making ice cream?
4. What effect does freezing temperature have on the quality of the ice cream produced?
5. What effect does sugar and other ingredients have on ice cream making?
6. Why is rock salt added to the ice water mixture when making homemade ice cream?

## Purpose of Laboratory and Student Performance Objectives

The purpose of this lab is to expose students to the ice cream-making process on a small scale and stimulate them to think about how and why the frozen product results. Students

should then be challenged to transfer this lab to the large-scale processes used in industry. Upon completion of this lab, students should be able to:

1. Describe the physical changes that occur in the ice cream mixture during freezing.
2. Explain the effects of sugar, salt, or similar molecules on the freezing of liquids.
3. Describe the ingredients and factors that give ice cream its characteristic smooth and creamy texture.

## Materials and/or Equipment

◆ (Note: For one group of two or three students)

- ◆ 1/4 cup sugar
- ◆ 1/2 tsp. vanilla extract
- ◆ 1 cup rock salt
- ◆ 1 cup 2% milk
- ◆ 1 cup half and half
- ◆ 2 lbs. ice
- ◆ 1 ziploc freezer bag (gallon)
- ◆ 1 ziploc freezer bag (quart)
- ◆ water
- ◆ duct tape or packaging tape
- ◆ cloth towels
- ◆ thermometer (0–32°F)
- ◆ quart jar or measuring cup
- ◆ measuring spoon and cups
- ◆ sundae cups and spoons
- ◆ flavorings as desired

## Procedure

Give each student or group of students a copy of the worksheet to perform the activity.

## Anticipated Findings

- ◆ The ice cream mixtures should freeze in 8–10 minutes.
- ◆ The ice/water mixture should be well below 32°F.

# MAKING ICE CREAM

## Procedure

(Note: For this investigation students will make ice cream in a plastic bag.)

1. Add the milk, half and half, vanilla, and sugar together in the quart-sized container. Stir gently for about 30 seconds to blend the mixture. Pour the mixture into a quart ziploc bag. Remove air from the bag and tightly seal. Cover the seal with tape.
2. Place the quart bag inside a gallon ziploc bag. Surround the quart bag with ice. Add rock salt and 3/4 cup water. Seal the gallon bag as before, again reinforcing the seal with tape.
3. Gently toss the bag between your hands, using cloth towels to protect your hands from the cold. (This also protects the ice cream mixture from your warm hands!) A gentle massaging action helps to ensure good contact between the mixture and the ice/water. This also helps to further blend the ingredients.
4. After about 10 minutes the ice cream mixture should be frozen. Cut the outer bag and remove the inner bag. Measure the temperature of the ice/water mixture. Wipe the outside of the inner bag, cut open, and spoon the ice cream into sundae cups. Dress with your favorite toppings and enjoy!

## Data Summary and Analysis

Note the length of time required for freezing. Was it the same for the samples made by all students? Compare the texture of the samples. Note that some samples melt quicker than others, and that all samples melt rather quickly. Why? Measure the temperature of the ice/water mixture.



## For Further Investigation

1. Vary the amount (concentration) of sugar in the ice cream mixture and compare the effects on freezing time.
2. Vary the amount of rock salt added to the ice/water mixture and compare the freezing time.
3. Test the effects of sand, table salt, and other substances on the freezing point of the ice/water mixture.
4. Compare the texture, mouth feel, and taste of skim milk, 2% milk, and whole milk. Does the use of chocolate milk affect the freezing process?

## Technical Supplement

# MAKING ICE CREAM

### 1. What processes/ingredients provide the smooth creamy texture of ice cream?

The milk fats and proteins help to provide the rich flavor and smooth texture of ice cream. The ice cream making process also develops its texture: the churning action breaks down and disperses the milk fat molecules. This is homogenization. Milk proteins then attach to smaller molecules and help to stabilize the mixture and the freezing process adds to the mixture's smoothness. Milk also contains natural stabilizers such as protein and phosphate.

### 2. Why are emulsifiers and stabilizers added to commercially prepared ice cream? Are they necessary for home-made ice cream?

Commercially produced ice cream contains these additives for a number of reasons: they increase shelf life, cover up minor flaws in the process of making the ice cream, help to maintain quality in large batches and reduce the chances of large ice crystals forming. In home-made ice cream the natural contents of milk or other occasionally added substances will perform the same actions. Most home-made ice cream will only have a short shelf life; it is consumed quickly. Therefore, no additives are necessary in home-made ice cream.

### 3. What physical changes does the ice cream mixture undergo when making ice cream?

The mixture tends to change from a liquid to an emulsified foam, then to a semi-solid, and finally to a solid. Suspended water molecules form a crystalline structure. This is a result of the mixture's loss of heat energy and consequential loss of temperature.



**4. What effect does freezing temperature have on the quality of ice cream?**

Too high of a freezing temperature could cause a delay in freezing, increasing the size of the ice crystals and producing a grainy textured ice cream. Long storage periods at low temperatures have been shown to have a similar effect. If great temperature fluctuations occur in the ice cream making process, the ice crystals could melt and refreeze, producing an undesirable grainy texture.

**5. What effect does sugar and other ingredients have on ice cream making?**

Sugar will reduce the freezing point of the mixture. Too much sugar or another sweetener will reduce the freezing point too much, producing large ice crystals and a grainy taste. Other additives such as eggs will help emulsify the liquid, resulting in smaller ice crystals. Some additives, like vanilla for example, are used to enhance the flavor of ice cream.

**6. Why is rock salt added to ice water mixture when making home-made ice cream?**

Rock salt is added to lower the freezing point of the ice water mixture. This causes the ice cream to freeze faster. Water must be present in the mixture to increase the amount of surface contact with the ice cream freezing container. This mixture of salt, water, and ice aids conduction of heat from the ice cream mixture to the salt/ice/water mixture.