

# Experiments in Food Science: Laboratory Manual

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## Introduction: What Is Food Science?

This laboratory manual has two purposes. The first purpose is to describe what food science is and what food scientists do. The second purpose is to describe fun laboratory experiments that demonstrate practical applications of food science. Food science is all of the science involved in taking agricultural food products from the farmer's gate to the grocery store, restaurant, or dinner table. Food scientists generally work with all sectors of agriculture. Food science includes both basic and applied biology, microbiology, chemistry, math, business, engineering, physics, and other disciplines. A food scientist's goal is to make safe, high-quality food products that are profitable to all segments of agriculture.

Those who earn a bachelor's degree in the food science discipline have starting salaries of \$45,000 to \$55,000 per year and work for some of the largest food manufacturing companies in the country. Food science students also have opportunities to compete in national competitions dealing with food, such as dairy judging, meats judging, new product development, and the Research Chefs Association's Food Evolution Competition. These events offer participants networking and learning opportunities for future career growth.

It is also possible to pursue a career as a veterinarian through an option in the food science curriculum. This is an excellent opportunity for students interested in veterinary school to work toward an undergraduate degree while completing the pre-veterinary (pre-vet) required curriculum. The veterinary school's acceptance rate for food science majors is very

competitive compared to the acceptance rate for all pre-vet disciplines. However, students with food science backgrounds and degrees who were not accepted to veterinary school still have great job opportunities, making \$45,000 to \$55,000 a year to start, with room for rapid advancement. Such an annual income and opportunities may not be available to students who graduate from other programs with pre-vet curriculums.

Laboratory exercises in this manual demonstrate principles behind butter making (density, lipid chemistry); cheese production (acid precipitation, protein chemistry); processed meat production (use of salt in meats, protein chemistry); meat marination (use of vacuum in meat processing); sensory evaluation (principles of sensory science: appearance, taste, and smell); candy production (candy chemistry, carbohydrate crystallization); and bread production (bread texture, gluten proteins). These laboratory experiments demonstrate some simple scientific principles that apply to food and explain why and how it is possible to make certain food products.

## Experiment 1: Butter

### Purpose

This experiment demonstrates the principles of butter making.

### Materials

- ½ cup heavy cream
- measuring cups
- clean jar with secure, tight-fitting lid
- salt (½ teaspoon or to taste)
- crackers

### Procedure

1. Pour ½ cup of heavy cream into a clean jar. Cap the jar.
2. Shake the jar. Take turns shaking; you may need to shake for 15 to 20 minutes. The cream will start looking like cottage cheese (whipped cream). Continue shaking.
3. You will note a separation of solids and liquids.
4. The solid is butter, and the liquid is buttermilk.
5. Pour off the buttermilk. Add salt to the butter for more flavor. Try the butter on crackers.

## Notes

Dairy milk is composed of 87 percent water, 3.2 percent protein, 3.9 percent fat, 4.8 percent carbohydrates, and roughly 1 percent minerals and vitamins. The fat in milk is a mixture of lipids. Triglycerides are the main type of lipid. Lipids have a lower density than water, so when raw milk sits for several hours, the cream (butter) will rise to the top.

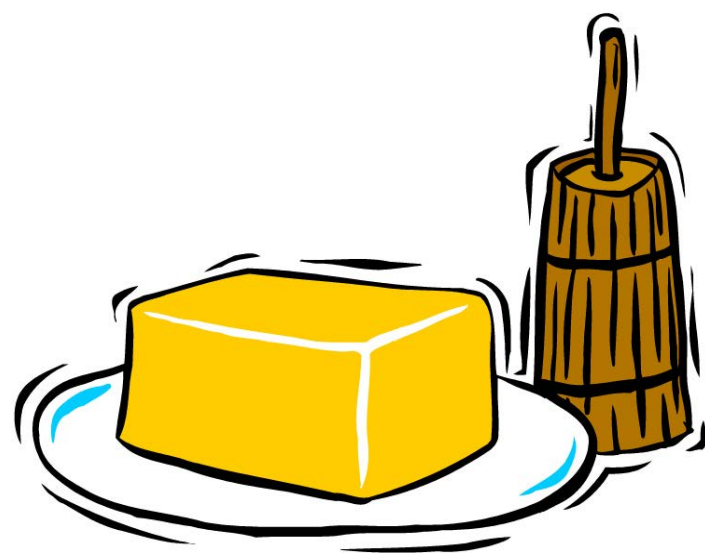
The density of cream is the basis for butter making. The cream is churned to separate the butter (solids) from the buttermilk (liquid). Butter contains at least 80 percent milk fat by weight. The butter can be salted and poured into molds for further processing. Butter remains solid when refrigerated but softens to a spreadable consistency at room temperature and melts to a thin liquid consistency at 90 to 95°F. Butter is generally pale yellow but can vary from deep yellow to nearly white. The yellow color is the result of the b-carotene in the grass that dairy cows eat.

Homogenizing milk prevents the cream (butterfat) layer from separating from the milk. Homogenizing breaks down the fat beads into smaller beads and disperses them evenly in the milk. The smaller beads will not rise to form cream during normal storage conditions.

## Experiment 2: Casein (Milk Protein)

### Purpose

This experiment demonstrates (1) the precipitation of protein (casein) from milk with an acid (vinegar) and (2) the effectiveness of casein as a bonding agent to make casein glue.



## Materials

- measuring cups and spoons
- ¼ cup milk
- 400 milliliter beaker
- stir bar
- pH meter
- thermometer
- hot plate
- stir plate
- 1 teaspoon vinegar
- cheesecloth
- weigh boats
- ½ teaspoon household ammonia
- glass rod
- wooden craft sticks

## Procedure

1. Pour ¼ cup of milk into a 400 mL beaker. Place stir bar into beaker.
2. Measure the pH of the milk. Place a thermometer in the beaker.
3. Heat the milk to 158°F on a hot plate. Remove the beaker from the heat. Remove the thermometer.
4. Place the beaker with the warm milk on a stir plate and add 1 teaspoon vinegar. Stir for 2 minutes. Allow the milk to sit for a few minutes. The casein will precipitate into heavy white curds. The remaining liquid is the whey.
5. Measure the pH of the liquid portion again.
6. Cover the top of the beaker with a piece of cheesecloth. Drain off the vinegar and whey over a sink. Carefully remove the cheesecloth and collect the curds (casein) in the cheesecloth. Rinse the cheesecloth containing the casein in cool water and squeeze the cheesecloth until the casein is almost dry. Spread out the cheesecloth to let the casein dry for a few minutes.
7. After drying them, place the curds into a weigh boat.
8. Very carefully add ½ teaspoon ammonia solution to the curds. **(Caution: ammonia is an irritant.)** Slowly stir with a glass rod until the mixture becomes thick and creamy in texture.
9. Rub the casein glue onto two wooden craft sticks and join them together. Allow the glue to dry for a few minutes.

## Notes

Milk is composed of many proteins. The main groups are casein and whey proteins. Caseins are very digestible when compared to other food proteins, making it a very important human food. Casein is negatively charged in its natural state. This negative charge permits the casein to disperse in milk. When you add an acid, the H<sup>+</sup> concentration neutralizes the negatively charged casein. When you acidify milk, its pH is allowed to reach 4.6, which brings casein to its isoelectric point. The isoelectric point is the point at which all charges are neutral. When casein loses its negative charge, it precipitates as curds. This acid casein is the basis for the manufacture of cottage cheese and cream cheese. Acid casein is also used in the chemical industry to produce adhesive products, textiles, and cosmetics, and as a binding agent in food products.

Casein can also be precipitated with rennin, an enzyme found in calves' stomachs. This rennin coagulum is made of casein, whey protein, fat, lactose, and minerals. It has a fluffier and spongier texture than the acid precipitate. This is the basis for manufacturing cheese.

Source: <https://www.ift.org/community/educators/k12-teaching-resources>

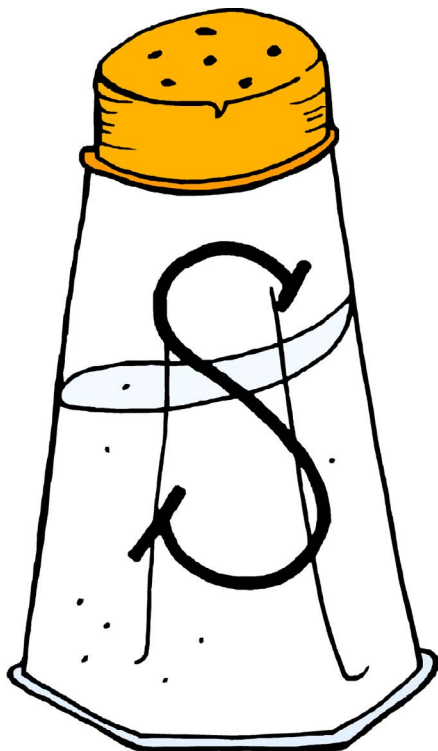
## Experiment 3: Role of Salt in Meat Processing

### Purpose

This experiment demonstrates the importance of salt in meat processing.

### Materials

- food preparation gloves
- food scale that measures in metric units
- 100 grams raw ground beef, divided equally
- small food processor
- 20 milliliters water, divided equally
- 2 grams salt
- spoons
- large white paper such as butcher paper
- paper towels
- newspapers



### Procedure

Wear gloves when working with raw meat. Keep meat away from other food products. Wash hands and work station after completing the experiment.

1. Place 50 g ground beef into a small food processor.
2. Add 10 mL water. Chop the meat for 15 seconds.
3. Remove the meat from the food processor. Form it into a ball. Flatten it like you are making a hamburger patty.
4. Now, put the slightly flattened meat in the palm of your gloved hand (palm up). Turn your hand over (palm down). What happens? Does the meat stick to your hand, or does it fall down?
5. Repeat step 1 in this procedure with the other half of the meat. In step 2, dissolve 2 g salt into the 10 mL of water before adding the water to the meat. Follow steps 3 and 4 with the new mixture.
6. Tape a piece of white (butcher) paper to the wall. Place plenty of newspaper on the floor below. Throw the two meat patties at the white paper. Does either one stick to the paper?

### Notes

In this experiment, ground meat without salt probably did not stick to your hand or to the target. When you added salt to the ground meat, it made the salt-soluble proteins come to the surface of the meat. In scientific terms, it extracted the salt-soluble proteins from the cellular structure. The proteins then acted like glue.

Salt serves many purposes. It brings out natural flavors, slows growth of spoilage microorganisms, and enhances a food's color, odor, and appearance. This experiment shows that salt also creates the protein structure necessary to make processed meats like hot dogs and deli meats. Salt helps bind meat by extracting its proteins, which "glue" together adjacent pieces of meat. Salt also increases water-binding properties, which reduce cook losses—the percentage of weight lost in meat during cooking—and contribute to enhanced texture. It also helps give a smooth, firm texture to processed meats. In addition, it helps with the color development of ham, bacon, hot dogs, and other processed muscle food products.

## Did You Know?

Without salt, it would be impossible to make hot dogs, deli meats, and other processed meats. Can you explain why?

## Experiment 4: Exploding Marshmallows

### Purpose

This experiment demonstrates (1) the principles of air pressure, (2) how changes in air pressure can affect food products, and (3) the principle behind applying a vacuum in meat processing.

### Materials

- vacuum pump
- glass jar suitable to be attached to the vacuum pump (The jar should have a rubber stopper with a hole in it to insert a tube. The tube connects to the vacuum pump. You could also use a capped Erlenmeyer flask with a side arm to attach a tube that will connect to the vacuum pump.)
- marshmallows (different sizes)

### Procedure

1. Place a marshmallow inside the glass jar.
2. Cap the jar. Connect the tube from the rubber stopper to the vacuum pump.
3. Turn on the vacuum pump. What happens?
4. Turn off the vacuum pump. What happens now?
5. Discuss your results.

**Variations:** You can place several marshmallows inside the glass jar or make a marshmallow man. You can also try expanding chicken meat.

### Notes

Marshmallows are a mixture of sugar, air, and gelatin. The sugar makes them sweet, the air makes them fluffy, and the gelatin is a protein that holds everything together. By volume, marshmallows are mostly air. When subjected to vacuum, the air from around the marshmallow is removed. This decrease in pressure causes the air trapped inside the marshmallow to push outward, expanding it. Eventually the vacuum is strong enough to pull air from inside the marshmallow, causing it to shrink. When the air in the jar returns to normal atmospheric pressure, you end up with a “mallow grape” because the air has been removed from inside the marshmallow.

This same principle is used in the meat and poultry industry to marinate chicken and other pre-marinated meats. Vacuum meat tumblers marinate meat in a very short time. Under vacuum, the foods' fibers stretch, becoming more porous. This allows the marinade to penetrate evenly throughout the product. Vacuum tumbling allows meat to absorb up to about 20 percent of its starting weight in marinade without extended

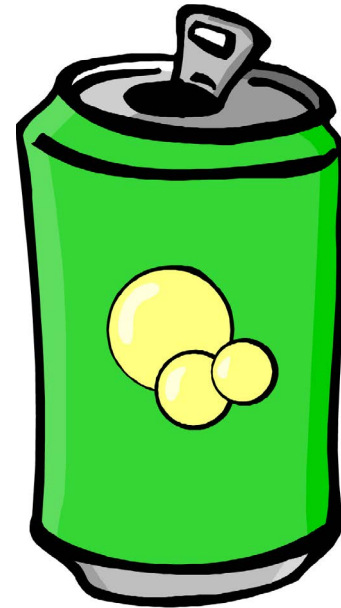
preparation. There is an increased yield in the raw product, which means increased yield after cooking and a product that is juicy and tasty.

Source: <https://www.higp.hawaii.edu/spacegrant/old/ScienceDemos/vacuumDemos.html>

## Experiment 5: Food Flavors

### Purpose

This experiment demonstrates how appearance influences our perception of how foods taste.



### Sports Drink Materials

- small sampling cups with lids (2 oz size is ideal)
- sports drinks (lemon-lime and orange flavors)
- red food coloring

### Procedure

1. Add a few drops of red food coloring to the lemon-lime flavored sports drink. Mix until the color resembles the orange of orange-flavored sports drink.
2. Pour the two orange-colored sports drinks, lemon-lime and orange, into sampling cups. Label each cup using a code to identify each type of drink.
3. Give students both samples.
4. Ask students to pinch their noses and taste each sports drink sample. Record the response.
5. Ask students to release their noses and taste each sports drink sample. Record the response.

### Soft Drink Materials

- small sampling cups with lids (2 oz size is ideal)
- Sprite or other clear soda
- Coca-Cola or other brown cola
- caramel color

## Procedure

1. Add a few drops of caramel color to Sprite until the color is similar to that of Coke.
2. Pour both drinks (Coke and colored Sprite) into labeled sampling cups. Each cup should have a code to identify its drink.
3. Provide students with both samples.
4. Ask students to pinch their noses and taste each soda sample. Record the response.
5. Ask students to release their noses and taste each soda sample. Record the response.

**Variation:** If you cannot find caramel color, you can try a red-colored soda like cherry and an unflavored clear soda like club soda or seltzer water. Add a few drops of red color to the clear soda until it looks like the red soda, pour the sodas into the sampling cups, and ask the students to taste both drinks.

## Did You Know?

Most of the time we assume things about a food's flavor based on its color. Changing the color of a lemon-lime sports drink can make it look like the orange-flavored sports drink, but it still tastes like lemon lime. However, your mind can play tricks on you and convince you that it is orange flavored. Similarly, the color of Sprite is changed so it looks like Coke, but it does not taste like Coke.

## Experiment 6: Determining Flavor with Your Nose?

### Purpose

This experiment demonstrates how your mouth and nose work together to perceive different flavors.



## Materials

- jelly beans of different colors
- small sampling cups

## Procedure

1. Place two jelly beans of the same color in the sampling cup.
2. Ask a student to pinch their nose and taste a jelly bean from the cup. Record the response.
3. Ask the student to release their nose and taste another jelly bean from the same cup. Record the response.

## Notes

You cannot determine flavor without your nose. Without the sense of smell, foods would not be tasty. You would not be able to tell the difference between foods with the same texture. A food's odor allows us to determine its flavor. About 80 to 90 percent of what we perceive as "taste" is actually due to the sense of smell. This is why foods taste bland when you have a cold or a stuffy nose.

There are four different types of true tastes: sour, sweet, salty, and bitter. The salty/sweet taste buds are near the front of the tongue, the sour taste buds line the sides of the tongue, and the bitter taste buds are at the very back of the tongue. Children are very sensitive to the flavors in foods. As people age, their taste buds become less sensitive.

## Experiment 7: Candy Making (Hard-Crack Stage, 300°F)

### Purpose

This experiment demonstrates (1) the chemistry of candy making and (2) the effect of temperature on the texture of candies.



## Materials

- shallow baking pan (8x8x2 inch)
- heavy duty aluminum foil
- oil spray
- 435 grams (about 2½ cups) sugar
- ½ cup light corn syrup
- ½ cup water
- 2-quart saucepan or 1,000 mL beaker
- candy thermometer
- stove (for saucepan) or hot plate (for beaker)
- food coloring
- ½ teaspoon oil flavoring
- spatula

## Procedure

1. Line an 8x8x2-inch pan with heavy duty aluminum foil, extending foil over the edges of the pan. Oil the pan lightly.
2. Combine sugar, corn syrup, and water in a 2-quart saucepan or a 1,000 mL beaker. Place a candy thermometer in the pan. The thermometer should not touch the bottom of the pan or beaker. Stir the mixture over high heat until it boils.
3. Reduce heat to medium. Continue cooking over medium heat. Do not stir the mixture while it is cooking. When the syrup reaches 260°F, add food coloring. Do not stir; boiling action will incorporate color into the syrup. Remove from heat precisely at 300°F. Remove thermometer.
4. Once boiling has stopped, add flavoring. Pour syrup quickly but carefully into prepared pan. (**Caution: mixture is very hot.**) Let it stand for 5 minutes.

5. Using a broad spatula, mark candy surface in ½ inch squares. Retrace previous lines and press the spatula deeper each time until you can press the spatula to the bottom of the pan.
6. Cool completely. Use foil to lift candy out of the pan. Break candy into squares and store in plastic bags.

**Variation:** You can use plastic molds for hard candy or lollipops. Lightly oil the molds before pouring the hot mixture. Twist the lollipop stick to make sure it is covered with the syrup. Let lollipops cool until hardened before removing from molds.

## Notes

Sucrose, or table sugar, and other sugars are the main ingredients in candy. Sucrose is made of two simple sugars, glucose and fructose, that are bound together. Sugar crystals are solid at room temperature. When sugar crystals are dissolved in water, the sugar goes into solution. At a particular temperature, water can dissolve only a certain amount of a particular sugar. The solution reaches the point where no more sugar can be dissolved, and extra sugar will just sink to the bottom. This point is called the saturation point.

Heating the sugar/water solution increases the amount of sugar that can be dissolved. The heat causes the crystals to break into smaller molecules. The sugar molecules move faster and farther apart, enabling the solution to dissolve more and more sugar molecules. The solution turns into a clear sugar syrup. As you add more sugar, the solution becomes super-saturated. This means that the solution has reached a delicate

**Table 1. Temperature stages for various candies.**

Temperature (°F)	Use	Description
Soft-ball stage (235–240°F) Sugar concentration: 85%	Fudge, fondant, pralines, peppermint creams, and buttercreams	Soft ball: a small amount of syrup dropped into ice water forms a soft, flexible ball but flattens like a pancake after a few moments.
Firm-ball stage (245–250°F) Sugar concentration: 87%	Caramels	Firm ball: syrup forms a firm ball that will not flatten when removed from water but remains malleable and will flatten when squeezed.
Hard-ball stage (250–265°F) Sugar concentration: 92%	Nougat, marshmallows, gummies, divinity, and rock candy	Hard ball: syrup dropped into ice water forms a hard ball, which holds its shape on removal. Can change shape when pressed.
Soft-crack stage (270–290°F) Sugar concentration: 95%	Taffy and butterscotch	Soft crack: syrup dropped into ice water separates into hard but pliable threads, which bend slightly before breaking.
Hard-crack stage (300–310°F) Sugar concentration: 99%	Toffee, nut brittles, hard candy, and lollipops	Hard crack: syrup dropped into ice water separates into hard, brittle threads that break when bent.
Caramelized sugar		Temperatures are higher than any of the candy.

balance of just enough sugar molecules and enough heat to keep the sugar molecules dissolved, but in an unstable state. The sugar molecules begin to crystallize back into a solid at the least disruption of heat or action. In other words, the sugar comes back together as sugar crystals when the syrup cools.

To make candy, you boil a mixture of sugar and water to create sugar syrup. The water evaporates, and the sugar concentrates. The higher the temperature, the more concentrated the sugar becomes. The texture of a candy (hard, soft, or chewy) depends on its cooking temperature and ingredients (Table 1).

Sources: <https://annex.exploratorium.edu/cooking/candy/sugar-stages.html>

## Experiment 8: Gluten

### Purpose

This experiment demonstrates (1) what gluten is, (2) its importance in bread making, and (3) its presence in all-purpose flour.



### Materials

- mixing bowls
- measuring cups and spoons
- ½ cup + 2 teaspoons all-purpose flour
- ½ cup soy flour
- ½ cup water, divided

### Procedure

1. Measure ½ cup of soy flour into a bowl. Measure ½ cup of all-purpose flour into a different bowl.
2. Add ¼ cup of water to each bowl of flour and mix.
3. If the all-purpose flour mixture is sticky, add up to 2 teaspoons of additional flour, 1 teaspoon at a time. Mix and knead after each flour addition. Do not add flour to the soy flour mixture.

4. Knead dough mixtures for about 5 minutes each. Note texture, appearance, color, elasticity, and flexibility of each dough ball. The soy flour dough looks clumpy, yellowish, and has no elasticity. Why? The all-purpose flour is opaque, elastic, and flexible.
5. Place the all-purpose dough ball under the faucet and run cool water over it. Squeeze the dough ball to drain white, starchy water. Continue doing this under running water for about 5 minutes. What happened? Note how the dough shrinks in size, changes color, and becomes thread-like. These are the gluten threads. The water that drains from the dough ball is white as the starch is washed out of the dough ball.

### Notes

Gluten is a protein found in wheat, rye, and barley. All breads made with wheat flour have a certain amount of gluten, depending on the type of flour. For example, cake flour has the lowest amount of gluten (5 to 8 percent), while high-gluten flour has greater than 14 percent. All-purpose flour is 11 to 12 percent gluten.

Gluten is the substance that gives bread its structure, texture, and elasticity. Gluten is made up of two main groups of proteins: gliadins and glutenins. Without these proteins, it would not be possible to make bread with an acceptable texture. Gluten is developed in the dough when gliadins and glutenins absorb water and are pulled and stretched in the kneading process. As the proteins are worked, they become long, flexible strands. The yeast produces gases in the dough, mostly carbon dioxide. These strands trap the gas bubbles, and the dough rises before it is baked.

Without gluten, bread would be very dense or flat. Rice, potato, and oat flours do not have gluten, and bread made from these flours does not turn out well.

### Did You Know?

Some people are unable to eat gluten because of either a wheat allergy or celiac disease. Gluten causes damage to the intestines and stomach of a person with celiac disease.

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