WHAT’S ON YOUR PLATE?
Exploring Food Science
UNIT 1
THE SECRETS OF BAKING
YOUTH SCIENCE JOURNAL
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Unit 1 is just one part of exploring What’s on Your Plate? Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
INTRODUCTION

WELCOME TO WHAT’S ON YOUR PLATE? EXPLORING FOOD SCIENCE!

Why does a muffin rise? Why do some recipes have so many ingredients in common? Why do foods change color during cooking? What can be done to keep them looking good? Have you ever wondered how new foods you see at the grocery store are developed? The idea of food science may be new to you, so take a close look at your next meal. There’s food science and food technology behind every bite you take, all the way from the farm to the end of your fork.

What’s on your plate? It’s a mixture of chemistry, biology, and physics. Exploring food science is a hands-on experience. Doing activities, you will discover and learn the basic building blocks of food science in a kitchen “laboratory.” The activities are more than learning to cook; it’s learning why and how things happen in all kinds of foods: breads, muffins, eggs, fruit, vegetables, cheese, candy, beverages, and more.

The first of four units uncovers “The Secrets of Baking” with activities exposing the gluten generated by different types of flour, experimenting with different types of leavening, and exploring how different ingredients and mixing affects the final results of baked goods. Be sure to check out the other units to learn more about “The Power of Protein Chemistry” in Unit 2, “The Inner Mysteries of Fruits and Vegetables” in Unit 3, and “Be a Food Scientist” in Unit 4.

With your Youth Science Journal, you get to conduct experiments, collect and analyze data, practice sensory science (tasting), investigate career opportunities, and amaze your friends and family with what you’ve learned about food! To make sure your experiments come out right, follow the directions carefully. Then take some time to think about what happened in the experiment—doing so will open the doors of food science for you!

Your Youth Science Journal has information in the “Be a Food Scientist” section that will help you understand and remember the concepts behind the experiments—this way you can share it with others. You may even find yourself thinking about a career in food science and food technology.

There’s a special website for you, too. Learn more online and have virtual fun by visiting websites with videos that show you behind-the-scenes food science. Log on to http://www.4-H.org/curriculum/FoodSci or use your mobile device to connect.

Enjoy exploring What’s on Your Plate?
ACTIVITY 1.1
Flour’s Secret Ingredient: Great Globs of Gluten

1. What is the main ingredient in these breads? ___________________________________________

2. Feel and taste bread samples. Which has the most tender texture? _______________________

3. Which has the most flavor? ________________________________________________________

4. Which one do you prefer? _________________________________________________________

5. Why do you think the breads have different tastes and textures? ________________________
   _______________________________________________________________________________

6. What component in flour allows it to “rise” and become bread? (Tip: Find out the answer by following the clues and doing the activities, then come back and answer this question.)
   _______________________________________________________________________________
WHAT WILL WE DO?
Discover the secret ingredient in flour that forms the basis of all the flour products you like to eat—from pancakes to muffins, pizza crust to bread, one special ingredient holds the key to success. You get to discover this “secret” ingredient, a certain kind of protein, by adding water to flour, mixing, and kneading it. Then you’ll wash away starch from your mixture to leave behind the “secret” ingredient common to all foods made with wheat flour.

What is this protein and how does it work? Follow the clues and do the activity to find out!

WHAT DO WE NEED TO KNOW?
A special protein provides the structure in baked goods. It “develops” when mixing flour with water. During stirring and kneading, two proteins in wheat flour join together to form it. You will be able to see it and feel it during this activity.

CLUE #1
A kernel of wheat has three parts.

Components of Wheat
A wheat kernel is made up of these components:
- The bran contains fiber.
- The endosperm contains mostly starch (carbohydrate) and protein.
- The germ contains vitamins, minerals, and a tiny amount of fat.
CLUE #2
The major components of wheat flour are starch (carbohydrate) and protein. There is very little fat in a wheat kernel—just a bit in the germ which is removed when making white flour. Generally, the higher the protein content of flour, the more structure and “body” in the final food product. In some products, such as pasta or pizza crust, a firm product is desired. In cakes or pie crusts, a tender product is preferred. While there are many things that influence baked goods, the protein content of flour is one of the most important. Look at the chart. Compare the percentage of protein in the different types of flour and note their different uses.

<table>
<thead>
<tr>
<th>TYPE OF FLOUR</th>
<th>PERCENT PROTEIN</th>
<th>COMMON USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cake flour</td>
<td>6.8—8.0</td>
<td>Cakes</td>
</tr>
<tr>
<td>Pastry flour</td>
<td>7.0—9.5</td>
<td>Tender pastries</td>
</tr>
<tr>
<td>All-purpose flour</td>
<td>9.5—11.5</td>
<td>Bread, muffins, cookies, cakes, pancakes, pizza dough,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>biscuits, etc.</td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td>11.0—14.0</td>
<td>Bread, muffins, cookies, denser cakes, pizza dough,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>biscuits, etc.</td>
</tr>
<tr>
<td>Bread flour</td>
<td>11.5—13.5</td>
<td>Bread</td>
</tr>
<tr>
<td>Durum flour</td>
<td>12.0—15.0</td>
<td>Pasta</td>
</tr>
<tr>
<td>Gluten flour</td>
<td>40.0—45.0</td>
<td>Bagels, chewy pizza crust, or added to other flours,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>such as rye or whole wheat, to improve rising and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>texture</td>
</tr>
</tbody>
</table>
CLUE #3
Do the following three steps to reveal flour’s secret ingredient!

STEP 1
Take a small amount of each flour and rub it between your thumb and forefinger. Is it soft, smooth, rough, grainy? Is one coarser than another, heavier, whiter, darker? Describe your observations in the chart.

Flour Observation Chart

<table>
<thead>
<tr>
<th>Text</th>
<th>Texture of Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
<td></td>
</tr>
<tr>
<td>Cake flour</td>
<td></td>
</tr>
<tr>
<td>Bread flour</td>
<td></td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td></td>
</tr>
</tbody>
</table>
STEP 2
1. Each learner chooses either all-purpose flour, whole wheat flour, bread flour, or cake flour.
2. Measure one cup of chosen flour into medium bowl, using proper measuring technique.
3. Add about 2 tablespoons of water and stir with a heavy or wooden spoon. Add more water gradually to make a stiff dough—add just a tablespoon or two at a time.
4. Use hands to form the dough into a ball. You may need to put a little flour on your hands so the dough doesn’t stick. Use as little additional flour as possible.
5. Mix and knead dough for 10–15 minutes until texture is very smooth and surface is silky.

MEASURING DRY INGREDIENTS
To properly measure dry ingredients, spoon ingredient, such as flour, into measuring cup. Do not pack or tap the cup. Fill to slightly overflowing, then slide the back of a table knife across the top of the measuring cup to level the flour, as in the picture. Discard excess flour.

NEED HELP KNEADING?
To knead dough, press, fold, and stretch it repeatedly on a flat surface. Using the heels of your hands, push down on the dough, stretching it away from you. Fold it in half. Give the dough a quarter turn and repeat.
**ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)**

**Dough Texture Observation Chart**
Share information with other learners to complete this chart.

<table>
<thead>
<tr>
<th></th>
<th>WHAT DID THE DOUGH FEEL LIKE BEFORE KNEADING?</th>
<th>WHAT DID THE DOUGH FEEL LIKE AFTER 10-15 MINUTES OF KNEADING?</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cake flour</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STEP 3**
Rinse the dough in cool water to remove the starch, leaving behind the protein called gluten.

1. Pull and squeeze the dough while it is in the water. When water becomes very white, pour it out and add clean water. Repeat as many times as necessary for water to remain clear.
2. When water is clear or nearly clear, the process is complete—the starch is gone.
3. Observe and note differences in gluten from the different flours.

What color is the dough before rinsing in cold water?
____________________________________________________________________

What color is the gluten after the starch has been rinsed away?
____________________________________________________________________

Rinse the starch out of the flour in cool water. As the water gets full of the white starch, pour it out and get fresh water. Keep rinsing the dough until the water is almost clear.
Why did the color change after rinsing?

Place gluten on small paper plates labeled “Whole Wheat Flour,” “Cake Flour,” “All-Purpose Flour,” and “Bread Flour.” Observe visual differences. Press and stretch each type. Record your observations in the chart below.

**Gluten Observation Chart**

Share information with other learners to complete this chart.

<table>
<thead>
<tr>
<th>TEXTURE OF GLUTEN</th>
<th>APPEARANCE OF GLUTEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
<td></td>
</tr>
<tr>
<td>Bread flour</td>
<td></td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td></td>
</tr>
<tr>
<td>Cake flour</td>
<td></td>
</tr>
</tbody>
</table>

Compare and rank how much gluten was produced by each type of flour.

MOST  LEAST

Based on the amount of gluten produced, which flour do you think a food scientist would use to make light and airy bread? ______________________ Dense, hearty bread? ______________________
1. What are the two ingredients you mixed together?

2. How did the dough look and what did it feel like when you first mixed it together?

3. How did the dough look and feel as you continued to mix it and to knead it?

4. What did you observe as you rinsed the dough in cool water?

5. When the water eventually turned clear, what did the gluten look like? Were some amounts of gluten bigger than others? Which were smaller? Which were larger?
REFLECT

Explore the Science of Gluten Development

1. Which of the two ingredients you mixed together most likely provides structure to foods such as bread?

2. What happens when flour and water are mixed together and kneaded?

3. What might be happening to the flour that makes it more elastic?

Write the chemical reaction here:

_________ + ___________ + ___________ + ___________ = ___________

4. How did the gluten feel and look while you were rinsing?

5. Why are the gluten amounts different sizes after rinsing even though everyone started with the same amount of flour?
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

Terms: Gluten, flour, bread flour, all-purpose flour, cake flour, elasticity, gluten development, leavening agents, baking powder, knead

GENERALIZE

1. What are the major components of wheat flour? [See Clue #1]

   ____________________________________________
   ____________________________________________

2. What is in protein that provides structure?

   ____________________________________________
   ____________________________________________

3. How does gluten develop?

   ____________________________________________
   ____________________________________________

4. What happens to dough the longer it is kneaded?

   ____________________________________________
   ____________________________________________
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

APPLY
1. Why is flour important in products like cakes, cookies, and bread?

2. If you are going to make a firm product such as pizza crust, which is the best flour to use?
   (Refer to Clue #2 if needed.)

3. Judging from what you have learned about the components of flour and looking at the amount of gluten produced by each type of flour, which flour would be best to have at home to make a wide variety of baked goods?

BE A FOOD SCIENTIST

GETTING TO KNOW THE SECRET INGREDIENT!
While there are several types of protein found in wheat flour, the two most important for gluten formation are gliadin and glutenin. When these two proteins are mixed with water and stirred or kneaded, they form gluten. Gluten provides structure to baked foods such as yeast bread, quick breads, biscuits, cakes, muffins, pancakes, pizza crust, pie crusts, cookies, waffles, pop-overs, bagels, pastries, and cream puffs.
MAKING GLUTEN

What You SEE & What You FEEL

The Physical Reaction
As the dough was kneaded, it looked and felt smooth. Eventually it felt soft, pliable and stretchy—this is called elasticity. You physically saw and felt the gradual development of gluten!

What Happens from a FOOD SCIENTIST’S Point of View

The Chemical Reaction
When water is added to flour, it allows the gliadin and glutenin proteins in the flour to combine, producing gluten. The higher the protein content of the flour, the more water is needed to make a dough. This is because the proteins that make up gluten absorb about twice their weight in water.

The repeated compressing and stretching of the dough (kneading) aligns the protein molecules so that most of them run in the same direction. Certain molecular bonds are broken and new ones are made. This allows the gluten molecules to stretch and get longer, increasing the strength of the gluten. When this happens, the dough can be easily molded into a shape and springs back from light pressure.
SEPARATING THE GLUTEN FROM THE STARCH

What You SEE & What You FEEL

The Physical Reaction
When dough is placed in water, the starch washes away, turning the water opaque or white. When the water became clear, the starch was gone and only the protein, gluten, remained. The amount of dough was smaller than the original amount. It felt rubbery. The color was less white than in the beginning, it was more tan. At this point, stretching the dough allowed you to see the gluten fibers.

What Happens from a FOOD SCIENTIST’S Point of View

The Chemical Reaction
The water frees up the starch molecules so that they wash away. Only the gluten remains.

INGREDIENTS THAT AFFECT GLUTEN DEVELOPMENT
Ingredients in flour or added to flour affect how gluten develops. In this activity, you saw how protein content and bran affected gluten development.

• **Protein Content of Flour:** The percent of protein in flour affects gluten development—the higher the protein content, the greater the gluten development. Durum flour has a high protein content, so it is good for making firm products such as pasta or pizza dough. Cake flour is low in protein, giving cake a tender texture.

• **Bran:** Whole wheat flour contains bran. The tiny particles of bran are sharp and cut the gluten strands during mixing and kneading. Thus, there is less gluten development in whole wheat products, so the product may be more dense than if made with flour that does not contain bran. Recipes often mix whole wheat and all-purpose flour to get better gluten development and make a less-dense product.

• **Fats and Oils:** Strands of gluten are coated by the fats and oils in a recipe so they “slide” by one another, making less of a connection. Therefore, fats and oils lessen gluten’s ability to form a strong structure; this creates a more tender product.
ALL ABOUT FLOUR

Wheat flour is milled into a variety of products used for home and commercial baking. Some of the products you may recognize in the grocery store are whole wheat flour, bread flour, all-purposed flour, and cake flour—all made from wheat. There may be a few types of wheat flour you have not heard of such as durum flour, gluten flour, and pastry flour—these are used commercially for specific uses.

Wheat from Farm to Table

• Wheat is a member of the grass family that produces a dry, one-seeded fruit commonly called a kernel.
• Wheat is a cereal grain, which by definition is any plant of the grass family yielding an edible grain, such as wheat, rye, oats, rice, or corn.
• Wheat is grown in 42 states in the U.S. Kansas and North Dakota are the largest wheat producers.
• Six classes of wheat include thousands of varieties; the six classes are: Hard Red Winter, Hard Red Spring, Soft Red Winter, Durum, Hard White, and Soft White.
• Large machines called combines harvest wheat at the rate of 1,000 bushels of wheat per hour.
• One bushel of wheat makes 42 pounds of white flour or 60 pounds of whole wheat flour.
• One bushel of wheat yields about 42 pounds of pasta.

Leavening Agents Lend a Hand to Gluten

Common leavening agents include baking soda, baking powder, yeast, and steam formed from liquids during baking. These leavening agents make flour products rise by forming gas (carbon dioxide) that expands the gluten and then gets trapped in its structure. The gluten strands form a “net” that stretches during baking. Then, when leavening agents form carbon dioxide and/or steam, the gasses are trapped in the “net” of gluten strands. This elastic net lets the dough rise yet still hold its shape. As the product cooks, the “net” structure becomes firm, giving the product its final structure.

FOOD SCIENCE, NUTRITION, AND GRAINS—WHAT’S THE LINK?

Some people have problems with gluten. If people are gluten intolerant, that means they cannot properly digest gluten and must avoid it because it will damage the intestines, leaving them malnourished. Other people may be “gluten sensitive,” which means their body’s immune system reacts to the protein and causes a reaction. Symptoms of gluten sensitivity may include bloating, abdominal discomfort or pain, constipation, and diarrhea.
Gluten is found in wheat, barley, rye, and triticale (a cross between wheat and rye). Many foods typically made with these flours are now available without gluten thanks to food scientists. How is this possible? Food scientists use flours made from grains that don’t have gluten, along with special processing techniques. For instance, they may add eggs to help bread rise. A product called Expandex (modified tapioca starch) helps provide texture similar to that of gluten-containing flours.

Food scientists also play a role in developing whole grain products. U.S. Dietary Guidelines recommend that everyone choose whole grains for about half of the grain foods they eat each day. What makes whole grains special? A whole grain contains all edible parts of the grain—the bran, the germ and the endosperm. The bran and germ contain many vitamins, minerals, phytonutrients, and fiber. These nutrients are stripped away and lost in the process of making “white” flour. Since the endosperm contains mostly starch, protein, and only a few nutrients, U.S. law requires that certain nutrients be added back to the processed flour: the mineral iron and the B-vitamins thiamin, riboflavin, niacin, and folate. The mineral calcium may also be added but is not required. This is called enriched flour, but it still does not contain all of the nutrients that were removed from the whole wheat flour.

To find whole grain foods, check the ingredient label. The first ingredient of a whole grain bread or cereal should include the word “whole” in front of the name of the grain, such as “whole wheat.” Or it might contain the name of the grain in its whole form, such as “brown rice.” Some labels will state the number of grams of whole grain, while others might carry the whole grain “stamp.” Everyone ages 9 and older should aim for 3 to 5 servings of whole grains each day.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD SCIENTIST

Have you ever thought about becoming a food scientist? There are many different jobs and career tracks within the realm of food science. You will find out about some of them as you move through the Activities in What’s On Your Plate—Exploring Food Science. For instance, there are cereal chemists who work with grain foods, as you’ve done in this activity. A food scientist interested in grains could also be a food product developer, food technologist, or work in food ingredient sales.
ACTIVITY 1.2
Baking the Best Bread: Leavening Agents in Action

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .” Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . . ______________________________________________________________
_________________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . . ________________________
_________________________________________________________________________________
_________________________________________________________________________________
WHAT WILL WE DO?
Did you know there are three distinctly different ways to “leaven” quick breads, yeast breads, and cakes? That’s just one of reasons there are so many recipe variations for baked goods that share common ingredients. You will investigate leavening agents and how they interact with gluten to provide structure in baked goods. You get to observe, describe, compare, contrast, and apply scientific principles of leavening agents and make your own soft pretzels!

WHAT DO WE NEED TO KNOW?

Leavening Agents in Action
There are three major types of leavening agents. Often recipes include one or more of these ingredients.

Biological . . . . Yeast is a living organism that feeds off of the sugar and starch (flour) in a recipe. Through a process of fermentation, yeast produces carbon dioxide (CO₂) gas, which is trapped by the gluten structure during baking.

Chemical . . . . . Baking powder, or baking soda plus an acid (e.g. cream of tartar is considered an acidic ingredient). These produce carbon dioxide gas [CO₂], which is trapped by the gluten structure during baking. Most baking powders in the US are called “double acting.” They contain baking soda and acidic ingredients that release carbon dioxide when mixing the liquid and dry ingredients together, and again when the mixture is heated during baking.

Physical . . . . . Air is trapped during the mixing of sugar and butter, as in cake preparation. This step is called creaming. The rough-edged sugar particles trap air in the fat. The air expands and rises, which stretches the gluten during baking. Foam forms when whipping egg whites for a meringue or soufflé. Foams will be explored in Activity 2.2. In addition, water as an ingredient in batters and dough changes to steam during baking which rises, stretches the dough and leavens the food product.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds before handling and mixing ingredients for soft pretzels. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips and handouts regarding food safety.
EXPERIMENT 1: WHICH INGREDIENTS PRODUCE THE MOST CO₂?

Divide into teams of 2–3 participants each. Each team is assigned one experiment. Measure the water temperature accurately.

Variable 1
Put ¼ cup water (110º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), and 2½ teaspoons sugar into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 2
Put ¼ cup water (110º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), and 2½ teaspoons sugar into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 3
Put ¼ cup water (140º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), and 2½ teaspoons sugar into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 4
Put ¼ cup water (110º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), 2 tablespoons flour into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 5
Put 1 tablespoon baking powder and ¼ cup room temperature water into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 6
Put 2 teaspoons baking soda, 1 teaspoon cream of tartar, and ¼ cup room temperature water into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.
CO₂ PRODUCTION OBSERVATION CHART

Record the amount of CO₂ production at the listed time intervals. Use a scale of 1–10:

- 1 = NO production of CO₂ bag is flat
- 5 = Quite a bit of CO₂ production, bag is about half full
- 10 = Large amount of CO₂ production, bag is tightly full (like a very full balloon)

<table>
<thead>
<tr>
<th>Variable 1</th>
<th>5 MINUTES</th>
<th>10 MINUTES</th>
<th>20 MINUTES</th>
<th>30 MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yeast and 110º F water</td>
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</tbody>
</table>

<table>
<thead>
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<th>Variable 2</th>
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<th>10 MINUTES</th>
<th>20 MINUTES</th>
<th>30 MINUTES</th>
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<tbody>
<tr>
<td>Yeast, 110º F water, sugar</td>
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<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable 3</th>
<th>5 MINUTES</th>
<th>10 MINUTES</th>
<th>20 MINUTES</th>
<th>30 MINUTES</th>
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<tbody>
<tr>
<td>Yeast, 140º F water, sugar</td>
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<tr>
<th>Variable 4</th>
<th>5 MINUTES</th>
<th>10 MINUTES</th>
<th>20 MINUTES</th>
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<tr>
<td>Yeast, 110º F water, flour</td>
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<th>20 MINUTES</th>
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<td>Baking powder and room temperature water</td>
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</table>

<table>
<thead>
<tr>
<th>Variable 6</th>
<th>5 MINUTES</th>
<th>10 MINUTES</th>
<th>20 MINUTES</th>
<th>30 MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baking soda, cream of tartar, and room temperature water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While waiting for CO₂ production, do the experiment and/or two activities on the following pages.
EXPERIMENT 2—MAKE SOFT PRETZELS IN A BAG

**Ingredients**
- 1 cup all-purpose flour
- 1 cup whole wheat flour
- 1 tablespoon quick rising yeast
- 1 teaspoon sugar
- ½ teaspoon salt
- 1 tablespoon vegetable oil
- ¾ cup (water at 110–115º F)
- Coarse salt, optional

**Directions**
1. Put dry ingredients into a 1-gallon food-grade plastic re-sealable bag.
2. Close the bag and shake to mix.
3. Add the oil and water to the bag. Close again and manipulate with fingers to mix well.
4. Wash hands again using proper hand-washing technique.
5. One learner removes the dough from the bag and divides it into 6 to 8 equal pieces.
6. Each learner gets one piece of dough. Roll dough between hands to form a rope-like shape 12 inches long.
7. Form into a pretzel and place on a greased baking sheet. Let proof (rest) in a warm place for 10 minutes.
8. Using a pastry brush, brush lightly with water. Sprinkle with salt if desired.

What is happening inside the dough during proofing?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

What would happen if you forgot to let the dough proof?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Describe what is happening to the yeast and gluten as the pretzel bakes:

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
**ACTIVITY 1—RECIPE RESEARCH**

Using cookbooks, find three recipes for yeast bread (not quick bread). Put a check mark in the box if the recipe contains the listed ingredient. These ingredients are essential for producing a good loaf of yeast bread.

Did each bread recipe contain the essential ingredients? _______________________________________

Which ingredients are not essential? ______________________________________________________

<table>
<thead>
<tr>
<th>BREAD RECIPE 1</th>
<th>BREAD RECIPE 2</th>
<th>BREAD RECIPE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yeast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid—water or milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat—butter or oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ACTIVITY 2—TASTE UNLEAVENED BREADS**

Flatbreads, which can be unleavened breads, occur in many cultures around the world. If available, taste some unleavened breads such as tortillas from Mexico, chapatti from India, matzo from the Jewish tradition, or Norwegian lefse.

Compare unleavened breads to leavened breads. What are the differences you notice in tastes and textures?

_________________________________________________________________________________
_________________________________________________________________________________
SHARE

1. What did you do to find out which ingredients produce carbon dioxide?

**Experiment 1**

______________________________________________________________________________

______________________________________________________________________________

Variable 1: ________________________________________________________________

______________________________________________________________________________

Variable 2: ________________________________________________________________

______________________________________________________________________________

Variable 3: ________________________________________________________________

______________________________________________________________________________

Variable 4: ________________________________________________________________

______________________________________________________________________________

Variable 5: ________________________________________________________________

______________________________________________________________________________

Variable 6: ________________________________________________________________

**Experiment 2**

______________________________________________________________________________

______________________________________________________________________________
REFLECT
1. What is CO₂?
_______________________________________________________________________________

2. What does CO₂ do in bread? What does it do to the gluten?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

3. What conditions and/or ingredients are necessary for CO₂ production from yeast?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

4. What is CO₂ production from yeast called?
_______________________________________________________________________________
_______________________________________________________________________________

5. Name a biological leavening agent you can use to make bread or soft pretzels.
_______________________________________________________________________________

6. What is a chemical leavening agent that you could use in a recipe for banana bread?
_______________________________________________________________________________

7. What are the ingredients that are essential and found in all bread recipes?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

8. What is the main difference in texture between leavened and unleavened breads?
_______________________________________________________________________________
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

TERM & Concept Discovery

Terms: Yeast, leavening agent, baking soda, baking powder, cream of tartar, carbon dioxide (CO₂), maltose, sucrose, fermentation, baking soda, baking powder, recipe formulation, proofing

GENERALIZE

1. To make bread successfully, what are the ideal ingredients and optimum temperature?

_______________________________________________________________________________

APPLY

Two friends call to ask if you can help with a recipe. They printed a recipe for soft pretzels from a website, but the printing is poor—only some of the letters of the ingredients are legible. They need help figuring out the ingredients. Fill in the missing letters to determine the names of the ingredients.

After you help them figure out the ingredients, they ask whether all those ingredients are essential. Is there anything that can be left out? What is your answer?

Then they ask you why each of the ingredients is needed. Write what you would tell them about the function each ingredient.

SOFT PRETZEL RECIPE INGREDIENTS

<table>
<thead>
<tr>
<th>COMPLETE THE INGREDIENT NAME</th>
<th>DESCRIBE THE INGREDIENT FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>l</strong> p__ <strong>p</strong> <strong>e f</strong> __ ur</td>
<td></td>
</tr>
<tr>
<td>S______ r</td>
<td></td>
</tr>
<tr>
<td>A__ti__ __ ry ye __ __</td>
<td></td>
</tr>
<tr>
<td><strong>al</strong></td>
<td></td>
</tr>
<tr>
<td>W__t__ r</td>
<td></td>
</tr>
<tr>
<td>__ __lk</td>
<td></td>
</tr>
<tr>
<td>O__l</td>
<td></td>
</tr>
</tbody>
</table>
Fermentation

Flour (starch) + yeast + water = CO₂ + ethyl alcohol + flavoring components

(Note: The ethyl alcohol evaporates during baking.)

Factors Affecting Yeast

- Water temperature is important. Too cold of a temperature, under 100º F, leads to slow fermentation, which means the bread will be very slow to rise. Too hot of a temperature, over 140º F, kills most yeast cells, making fermentation impossible. Water temperatures between 100º and 115º F are just right.

- Sugar is needed for the yeast fermentation process. There are typically a couple of sources of sugar in a recipe:
  1. The maltose in flour is a naturally occurring sugar in wheat.
  2. Table sugar (sucrose) is often added to recipe formulations to enhance the rate of fermentation. Fermentation is slower without added sugar.

- Salt moderates yeast’s activity so fermentation occurs at a consistent rate. Salt also enhances flavor.

- Proofing (sometimes called rising) is the process of letting dough “rest” during which time the yeast continues to ferment, produce CO₂ and further raise the dough product. Proofing is best done in a warm place. To prevent a crust from forming on the surface of the dough, cover it with a clean, damp towel or plastic wrap lightly coated with cooking spray. Some recipes call for proofing one, two, or more times.

Essential Elements for Baking the Best Bread

To make a good loaf of bread, adequate leavening, good structure, and great flavor are essential. The typical ingredients in bread are flour, water and/or milk, yeast, sugar, salt, and a small amount of fat or oil. Here’s the science behind the recipe—how ingredients work together for a good loaf of bread.

Leavening is primarily due to carbon dioxide produced by yeast. Water also converts to steam during baking and contributes to leavening. Sugar and maltose in flour, plus salt, control the rate of fermentation.
Structure of bread comes from gluten development. As learned in Activity 1.1, gluten development requires flour, water, and manipulation (mixing and kneading). Leavening gases, CO₂, and steam are trapped by the gluten “net” and the product rises.

Flavor in bread comes from the end products of yeast fermentation, sugar, salt, and a browning reaction that occurs during baking.

**FOOD SCIENCE, NUTRITION, AND CARBOHYDRATES—WHAT’S THE LINK?**

Have you ever heard someone say, “I don’t do carbs . . .”? Perhaps you’ve seen “low-carb” tortillas or crackers or other foods that typically have a lot of carbohydrates in them. Food scientists are behind the scenes, making low carbohydrate foods that look and taste similar to the original foods, for those who want or need them.

What are carbohydrates? They are the starch, fiber, and naturally occurring sugars that make up many foods. Carbohydrates are abundant in fruits, vegetables, dairy products, beans, nuts, foods made from grains, and more. The only foods that do not contain carbohydrates are meat, fish, shellfish, poultry, and fats and oils.

Carbohydrates are essential to life—they provide the energy the body needs to do everything it does! It’s a good idea to focus on eating “complex carbohydrates.” Complex carbohydrates have starch and fiber along with vitamins and minerals.

**IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD QUALITY SPECIALIST**

A food quality specialist may have many roles in food processing and food safety. During food processing, they made sure that product quality standards are met during manufacturing. Quality includes things like shape, color, texture, flavor, and appearance of food products. Many quality assurance careers also involve product food safety.
STATEMENT: THESE FOOD PRODUCTS HAVE MANY SIMILAR INGREDIENTS.

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.

My experiment will be . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_________________________________________________________________________________
WHAT WILL WE DO?
This activity brings together the things you discovered in the previous activities in this unit. You found out in 1.1 that gluten develops when flour and water are mixed, then stirred or kneaded. In activity 1.2, you investigated leavening agents such as yeast, baking soda, and baking powder, and how they interact with gluten. Now you explore how different ingredients and mixing influence gluten development and texture of the final product, as well as see leavening agents in action as you make muffins using several variables.

WHAT DO WE NEED TO KNOW?
Amount of Sugar, Fat, and Mixing Alters the Final Product
The variables in this activity explore how the amount of mixing or stirring a batter may affect the end product, especially if the recipe is low in sugar and fat. Remember that manipulation of dough (as in kneading or stirring) develops the gluten in flour. The more the gluten is developed, the stronger it is, resulting in a firmer product which may seem tough or rubbery.

The addition of increased amounts of sugar and fat interfere with gluten formation. So the more fat and sugar that are in the muffin recipe, the more likely it is to be tender, even if over-mixed.

MUFFIN MANIA
Make muffins using a variety of ingredients and techniques to find out how to make magnificent muffins.

Prepare a muffin tin (one with 12 muffin cups) by coating each cup lightly with cooking spray and mark according to variations (see below). There will be 12 muffins. The control for size will be filling each muffin cup to within 1⁄8 inch of the top.


BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. In addition, after handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg. Visit www.FightBac.org for tips and handouts regarding food safety.
EXPERIMENT 1

Ingredients
1 cup all-purpose flour
1 tablespoon sugar
1 ½ teaspoons baking powder
½ teaspoon salt
½ cup milk
½ teaspoon vanilla extract
½ egg, well beaten (½ egg = 1 ½ tablespoons)
1 tablespoon oil

Directions:
1. Preheat oven to 425º F.
2. Before measuring, sift flour, using a sifter or by shaking it through a sieve.
3. Measure flour by lightly spooning it into measuring cup. Do not pack or tamp down. Place flour in a medium bowl.
4. Add the rest of the dry ingredients to the flour. Mix gently.
5. Sift dry ingredients together onto waxed paper or paper towel and return to bowl.
6. Mix together milk, vanilla, egg, and oil with fork, making sure egg is thoroughly mixed.
7. Add liquid mixture to dry ingredients. Mix as instructed below for each variable then place in appropriately labeled muffin cups.

VARIABLE 1.A
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill one muffin cup within ¼ inch of top—one only in tin.

VARIABLE 1.B
1. Using a rubber spatula, stir an ADDITIONAL 12 strokes.
2. Fill one muffin cup within ¼ inch of top—one only in tin.

VARIABLE 1.C
1. Using a rubber spatula, stir an ADDITIONAL 35 strokes.
2. Fill one muffin cup within ¼ inch of top—one only in tin.
EXPERIMENT 2

**Ingredients**
1 cup all-purpose flour
2 tablespoons sugar
1 ½ teaspoons baking powder
½ teaspoon salt
½ cup milk
½ teaspoon vanilla extract
1/2 egg, well beaten (1/2 egg = 1 1/2 tablespoons)
2 tablespoons oil

**Directions:**
1. Preheat oven to 425º F.
2. Before measuring, sift flour, using a sifter or by shaking it through a sieve.
3. Measure flour by lightly spooning it into measuring cup. Do not pack or tamp down. Place flour in a medium bowl.
4. Add the rest of the dry ingredients to the flour. Mix gently.
5. Sift dry ingredients together onto waxed paper or paper towel and return to bowl.
6. Mix together milk, vanilla, egg, and oil with fork, making sure egg is thoroughly mixed.
7. Add liquid mixture to dry ingredients. Mix as instructed below for each variable then place in appropriately labeled muffin cups.

**VARIABLE 2.A**
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill one muffin cup within 1/8 inch of top—one only in tin.

**VARIABLE 2.B**
1. Using a rubber spatula, stir an ADDITIONAL 12 strokes.
2. Fill one muffin cup within 1/8 inch of top—one only in tin.

**VARIABLE 2.C**
1. Using a rubber spatula, stir an ADDITIONAL 35 strokes.
2. Fill one muffin cup within 1/8 inch of top—one only in tin.
EXPERIMENT 3—COMMERCIAL MUFFIN MIX

Directions
Place muffin mix in a bowl and add additional ingredients as instructed on the package but do NOT stir. Mix as instructed below for each variable. Place in appropriately labeled muffin cups.

VARIABLE 3.A
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill two muffin cups within ¼ inch of top. Make 2.

VARIABLE 3.B
1. Using a rubber spatula, stir an additional 12 strokes.
2. Fill two muffin cups within ¼ inch of top. Make 2.

VARIABLE 3.C
1. Using a rubber spatula, stir an additional 35 strokes.
2. Fill two muffin cups within ¼ inch of top. Make 2.

Place muffin tin in a 425º F oven and bake for 15–20 minutes or until a toothpick inserted into the middle of a couple of the muffins comes out clean.

COOLING INSTRUCTIONS FOR ALL MUFFINS
1. When done, place on cooling rack for 10 minutes.
2. Carefully remove muffins from tin; put on plate with same label as that of the muffin tin.
3. Cool an additional 5 minutes.
4. Cut each muffin in half.
5. Observe and taste; record observations.
### ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

#### The Secrets of Baking

<table>
<thead>
<tr>
<th>NUMBER OFSTROKES</th>
<th>EXTERIOR APPEARANCE (Shape, volume, browning)</th>
<th>INTERIOR APPEARANCE/TEXTURE</th>
<th>TENDERNESS 1-5 (1 = coarse, tough or rubbery, 5 = fine and tender)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1.A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 1.B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 1.C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 2.A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 2.B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 2.C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 3.A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 3.B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 3.C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compare and contrast the recipe formulations in Experiments 1 and 2.

1. Which formulation had the most sugar and fat?

__________________________________________________________________________
2. How did the number of strokes affect the exterior appearance?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

3. How did the number of strokes affect the texture and tenderness?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

4. How did the amount of sugar and fat affect the exterior appearance?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

5. How did the amount of sugar and fat affect the texture and tenderness?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

6. After examining your results in the Muffin Observation Log, what are your conclusions about the optimum amount of sugar, fat, and mixing to produce a good muffin?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

SHARE
1. Generally speaking, what did you do in this experiment?

_______________________________________________________________________________
_______________________________________________________________________________

REFLECT
1. What effects does stirring have on muffins that contain:
   a. Not much fat and sugar? Why?

_______________________________________________________________________________
_______________________________________________________________________________

b. Large amounts of fat and sugar? Why?

_______________________________________________________________________________
_______________________________________________________________________________

2. Between the muffins from Experiment 1 and 2, which one did you like the best and why?

_______________________________________________________________________________
_______________________________________________________________________________

3. Judging from your results, is it possible to over-mix muffins made from a commercial mix? Why?

_______________________________________________________________________________
_______________________________________________________________________________
ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

GENERALIZE
1. In your opinion, what is the most important factor in making a good muffin?

_______________________________________________________________________________

2. In your opinion, what is the second most important factor in making a good muffin?

_______________________________________________________________________________

APPLY
1. Imagine you are helping to judge muffins at a 4-H event. The first muffins have peaked tops and tunnels inside. The 4-H member who made them is present and very excited about his muffins. What do you tell him in a way that won’t dampen his enthusiasm but that will motivate him to try again and get a better result?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

2. If you wanted to make up a new recipe for moist cookies using three cups of flour, about how much liquid would you need? _____________

What would the liquid to dry ratio be? _____________

What type of batter or dough would this be? _________________
1. Ratio and Function of Ingredients

The ratio of liquid ingredients to flour is one of the important factors that determine whether a recipe produces a pancake, a cake, a cookie, bread, or a pie crust. A ratio shows the relative proportions of two or more amounts. Ratios are often shown using a colon “:” to separate amounts. For instance, if there is 1 cup of water and 3 cups of flour, the ratio would be written as 1:3.

The ratios in the chart below read “about” because formulations may vary slightly. For instance, a drop batter may have one-half to three-quarters of a cup liquid to dry ingredients and still be considered a drop batter.

<table>
<thead>
<tr>
<th>RATIO (Liquid Ingredients : Flour)</th>
<th>TYPE OF BATTER OR DOUGH</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>About 1:1</td>
<td>Pour batters</td>
<td>Pancakes, popovers</td>
</tr>
<tr>
<td>About 1:2</td>
<td>Drop batters</td>
<td>Muffins, quick breads, cakes</td>
</tr>
<tr>
<td>About 1:3</td>
<td>Soft dough</td>
<td>Biscuits, moist cookies, yeast bread</td>
</tr>
<tr>
<td>About 1:4</td>
<td>Stiff dough</td>
<td>Pie crusts, noodles/pasta, cookies</td>
</tr>
</tbody>
</table>
2. What do the ingredients do?

Batters and soft dough have different liquid to flour ratios but contain many similar ingredients, many of which have similar functions in the product.

<table>
<thead>
<tr>
<th>INGREDIENT</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>• Structural “net” of gluten.</td>
</tr>
<tr>
<td>Liquid (Water, milk,</td>
<td>• Necessary for gluten development.</td>
</tr>
<tr>
<td>cream, fruit juice,</td>
<td>• Produces steam for leavening.</td>
</tr>
<tr>
<td>beverages, and</td>
<td>• Dissolves sugar, salt and baking powder.</td>
</tr>
<tr>
<td>flavorings)</td>
<td>• The ratio of liquid to flour determines type of batter or dough.</td>
</tr>
<tr>
<td>Leavening Agents</td>
<td>• Steam (from liquid)</td>
</tr>
<tr>
<td></td>
<td>• CO₂ from baking powder or baking soda with an acid (e.g. cream of</td>
</tr>
<tr>
<td></td>
<td>tartar, fruit juice, or buttermilk).</td>
</tr>
<tr>
<td></td>
<td>• CO₂ from yeast.</td>
</tr>
<tr>
<td></td>
<td>• Air incorporated during mixing.</td>
</tr>
<tr>
<td>Fat or Oil</td>
<td>• Fat inhibits gluten formation by coating flour particles and</td>
</tr>
<tr>
<td></td>
<td>shortening gluten strands.</td>
</tr>
<tr>
<td></td>
<td>• Tenderizing ingredient.</td>
</tr>
<tr>
<td>Sugar</td>
<td>• Sweetness and flavor.</td>
</tr>
<tr>
<td></td>
<td>• Ties up water in formulations so there is less gluten development.</td>
</tr>
<tr>
<td></td>
<td>• Tenderizing agent (due to less gluten development).</td>
</tr>
<tr>
<td></td>
<td>• Aids in browning of batters and dough.</td>
</tr>
<tr>
<td></td>
<td>• Stabilizer in egg white foams.</td>
</tr>
<tr>
<td>Salt</td>
<td>• Flavor</td>
</tr>
</tbody>
</table>

When you understand recipe formulation ratios and the function of ingredients, there are endless variations for batters and dough. That’s one of the reasons there are so many cookbooks and online recipes—people like new foods and it’s easy to create a recipe once ratios and functions of ingredients are understood.
Use amounts from Experiment #2 recipe formulation. Write in the amount of liquid and dry ingredients. In your own words, describe the function of the ingredients in the recipe.

<table>
<thead>
<tr>
<th>LIQUID INGREDIENTS AMOUNT</th>
<th>DRY INGREDIENTS AMOUNT</th>
<th>INGREDIENT</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flour</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baking powder</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Salt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sugar</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milk</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vanilla</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Egg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td></td>
</tr>
</tbody>
</table>
MEASURING MATH—CALCULATE RATIO
Are muffins made with a batter or a dough? Find out by using the recipe from Experiment 2 to do the calculations below.

Hints: 1 cup = 16 tablespoons 1 tablespoon = 3 teaspoons

Calculate amount of milk: ______________ tablespoons

Calculate amount of flour: ______________ tablespoons

Write the ratio of these two primary ingredients: ______________

Using the chart on page 38, determine the type of batter or dough you made._________________________

3. Dry Mixes
Muffins mixes, cakes, brownies, corn bread, biscuits, and pancakes are just a few examples of dry mixes available at the grocery store. While they can be a timesaver, you can make your own mixes at home to save money and take advantage of what you know about function and ratio of ingredients. In addition, you can often make them healthier by including whole grains, slightly reducing fat and/or sugar, and using healthier types of fat.

FOOD SCIENCE, NUTRITION, AND MUFFINS – WHAT’S THE LINK?
Food scientists can use their knowledge to make foods healthier. To make a reduced-fat muffin, ingredients and manufacturing methods need to be altered so that the muffin has less fat but still has good taste and texture. For instance, a food company may want a large-size muffin to have only a certain amount of calories, so food scientists must adjust the ingredients to meet the calorie requirement.

What size were the muffins you made in these experiments? Traditionally, a muffin is about 2¼ inches across, 1.5 inches high, and weighs 1.5 to 2 ounces. Many muffins are larger than that—about 4 inches across and weighing in at 5.5 to 6.5 ounces. The larger muffins can have nearly as many calories as a small meal! Yet many people eat the large muffin as a quick snack—which can lead to too many calories.

Over the years, the serving sizes for many foods have become larger. Being smart about portion size is important for energy balance. Energy balance is when the amount of calories consumed in food and beverages is the same amount as the calories expended by the body in metabolism and physical activity. When energy, or calories, is balanced, body weight stays the same. If a person consumes more calories than they expend, weight gain occurs. The opposite is also true—using up more calories than consumed will result in weight loss. Consuming appropriate portion sizes is important to energy balance.
### ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

<table>
<thead>
<tr>
<th>DAILY INTAKE FOR TEENS</th>
<th>TYPICAL MUFFIN MIX—1.5 OUNCE MUFFIN</th>
<th>TYPICAL BAKERY MUFFIN—6 OUNCE MUFFIN</th>
<th>MUFFIN AS PREPARED FROM BOXED MIX TODAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>2000 (recommended average)</td>
<td>250</td>
<td>670</td>
</tr>
<tr>
<td>Total Fat (g)</td>
<td>60 (daily maximum)</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>Saturated fat (g)</td>
<td>16 (daily maximum)</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>30 (daily maximum)</td>
<td>15</td>
<td>40</td>
</tr>
</tbody>
</table>

Caloric and fat recommendations from 2010 U.S. Dietary Guidelines for Americans. Sugar recommendation from American Heart Association because Dietary Guidelines do not have a specific sugar recommendation.

Using the chart above, compare the recommended intake of nutrients with a typical bakery muffin. Answer these questions:

1. A bakery muffin uses up ____________% of my total recommended caloric intake for one day.*
2. A bakery muffin uses up ____________% of my maximum total fat intake for one day.
3. A bakery muffin uses up ____________% of my maximum saturated fat intake for one day.
4. A bakery muffin uses up ____________% of my maximum sugar intake for one day.

(*Hint: To calculate percentage, divide the amount in the bakery muffin by the recommended amount then multiply by 100. For example, to calculate percent calories, 670 ÷ 2000 = .335 x 100 = 33.5%)

**Optional:**
1. Fill in the final column of the chart using the “As Prepared” information from the Nutrition Facts label on the muffin mix box. Calculate the above percentages again using those amounts.

2. Also calculate the above percentages using the 1.5 ounce muffin in the chart. Which muffin would be best to have as a snack, not a meal?
IN FOOD SCIENCE AND FOOD TECHNOLOGY—
CEREAL CHEMIST
Grains are a type of grass. Botanically, grasses are called cereals. “Cereal” doesn’t always mean the crunchy stuff you pour milk over in the morning! The term “cereal” can refer to grains in general. Some food scientists specialize in cereals. Cereal chemists often work in food processing or food manufacturing facilities that produce fresh and frozen baked goods, snack foods containing cereal grains, prepared grain mixes (such as a baking mix or muffin mix), pet foods, and animal feed. A food scientist specializing in cereals also has career opportunities in research, university teaching, sales, and with government agencies.

LEARN MORE!
VIRTUAL FUN
For videos on commercial muffin production and several other online resources including the Better Baking Mix from Washington State University and many associated recipes and tips, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
NOTES
"I Pledge my **Head** to clearer thinking,
my **Heart** to greater loyalty,
my **Hands** to larger service,
and my **Health** to better living,
for my club, my community, my country,
and my world."
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Unit 2: The Power of Protein Chemistry is just one part of exploring What’s on Your Plate? Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
INTRODUCTION

WELCOME TO WHAT’S ON YOUR PLATE? EXPLORING FOOD SCIENCE!

Why does a muffin rise? Why do some recipes have so many ingredients in common? Why do foods change color during cooking? What can be done to keep them looking good? Have you ever wondered how new foods you see at the grocery store are developed? The idea of food science may be new to you, so take a close look at your next meal. There’s food science and food technology behind every bite you take, all the way from the farm to the end of your fork.

What’s on your plate? It’s a mixture of chemistry, biology, and physics. Exploring food science is a hands-on experience. Doing activities, you will discover and learn the basic building blocks of food science in a kitchen “laboratory.” The activities are more than learning to cook; it’s learning why and how things happen in all kinds of foods: breads, muffins, eggs, fruit, vegetables, cheese, candy, beverages, and more.

Here in Unit 2, you’ll explore “The Power of Protein Chemistry.” Activities include cracking, separating, and different ways of cooking eggs, using egg whites to make soufflés, and making Queso Fresco, a fresh cheese. Be sure to check out the other units to learn more about “The Secrets of Baking” in Unit 1, “The Inner Mysteries of Fruits and Vegetables” in Unit 3, and “Be a Food Scientist” in Unit 4.

With your Youth Science Journal, you get to conduct experiments, collect and analyze data, practice sensory science (tasting), investigate career opportunities, and amaze your friends and family with what you’ve learned about food! To make sure your experiments come out right, follow the directions carefully. Then take some time to think about what happened in the experiment—doing so will open the doors of food science for you!

Your Youth Science Journal has information in the “Be a Food Scientist” section that will help you understand and remember the concepts behind the experiments—this way you can share it with others. You may even find yourself thinking about a career in food science and food technology.

There’s a special website for you, too. Learn more online and have virtual fun by visiting websites with videos that show you behind-the-scenes food science. Log on to http://www.4-H.org/curriculum/FoodSci or use your mobile device to connect.

Enjoy exploring What’s on Your Plate?
STATEMENT: COOKING CHANGES EGGS FROM LIQUID TO SOLID.

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .”
Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.
My experiment will be . . .

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_______________________________________________________________________________
_______________________________________________________________________________
EGGS AND FOODBORNE ILLNESS
Some eggs contain the bacteria called Salmonella enteritidis (SE), which causes foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE, so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.

WHAT WILL WE DO?
When cooking scrambled eggs, have you ever wondered why the liquid mixture becomes solid? Or wondered why so many recipes contain eggs? Eggs have many special, functional properties that make them unique in the study of food science. This activity shows how heat affects the proteins in eggs. You’ll cook eggs several different ways. You’ll become an egg expert!

WHAT DO WE NEED TO KNOW?
First, identify the parts of an egg.
Getting to Know a Good Egg
Eggs contain protein. Heat used in cooking changes an egg’s protein from liquid form to solid. This is called coagulation. When used in recipes, the coagulated protein helps give structure to the food product.

Utensils
These are some of the utensils used in this activity. From top to bottom: wooden spoon, wire whisk, and three “spatulas.” Each type of spatula has a very different use: straight spatula (cake spatula), silicone rubber spatula, grill spatula. The silicone spatula is used in this activity. Silicone can withstand cooking temperatures.

HOW TO CRACK AN EGG
Tap firmly on hard surface. Insert thumbs into crack and pull apart. Still not sure? Check out the video at www.4-H.org/curriculum/foodsci.
EXPERIMENT 1—SCRAMBLED EGGS

Ingredients
3 eggs
¼ cup 1% or 2% milk
Cooking spray

Directions
1. Crack three eggs into a bowl
2. With a wire whisk, rapidly whisk the eggs for 45–60 seconds. Whisking adds air and makes scrambled eggs fluffy.
3. Add milk and whisk to mix.
4. Lightly spray a medium, non-stick skillet with cooking spray; place on low to medium heat.
5. Pour whisked eggs and milk into skillet. Using a utensil that won’t scratch the skillet, such as a plastic, heat-resistant spoon or spatula, stir occasionally during cooking. Scrape the egg from the bottom of the pan and stir gently. Break up large pieces. Eggs are done as soon as they have become solid and no liquid remains.
6. Carefully remove skillet from heat.
7. Place half of the scrambled eggs on paper plate for taste-testing. Label: Cooked to Solid. Taste and record your observations.
8. Place the skillet back on the heat. Continue to cook the remaining eggs for an additional 7 minutes.
10. Place remaining scrambled eggs on paper plate for taste-testing. Label: Overcooked.
11. Using proper technique, taste and record your observations.

SCRAMBLED EGG OBSERVATIONS

<table>
<thead>
<tr>
<th>COLOR</th>
<th>TASTE</th>
<th>TEXTURE</th>
<th>RATE TOUGHNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked to Solid</td>
<td></td>
<td>Moist? Dry? Fluffy? Flat?</td>
<td></td>
</tr>
<tr>
<td>Overcooked</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EXPERIMENT 2—HARD BOILED EGGS

Ingredients
One egg
Water

Directions
1. Place egg in saucepan. Add cold water to cover egg by 1 inch. Heat over high heat just to boiling. Remove from burner. Cover pan.
2. Let egg stand in hot water to cook:
   • Medium eggs: 9 minutes
   • Large eggs: 12 minutes
   • Extra-large eggs: 15 minutes
3. Cool completely under cold running water or in bowl of ice water; remove shell, cut in half, place on a paper plate for observation.

HARD BOILED EGG OBSERVATION
Touch the hardboiled egg. Describe the consistency of the hardboiled egg (liquid or solid? Soft or firm?).

To peel a hardboiled egg, tap each end to crack it, then gently roll. Slip thumb beneath the shell and thin membrane to slide off the shell.
EXPERIMENT 3—MODIFIED POACHED EGG

**Ingredients**
1 egg  
4 tablespoons water  
Cooking spray  
Clock or watch with second hand for timing

**Directions**
1. Lightly spray a small, non-stick skillet with cooking spray; place on medium-low heat.  
2. Carefully crack one egg into the skillet, being careful not to break the yolk. Note time and begin to make observations as indicated in chart below.  
3. As soon as the egg begins to cook, add 4 tablespoons water.  
4. When water boils, reduce heat to low, cover for 3 minutes, then carefully spoon water over white and yolk. Do this continually as cooking progresses. Observe changes.  
5. Cook until white and yolk have both coagulated.  
7. Using a non-stick grill spatula, place egg on paper plate. Note observations in log.

**MODIFIED POACHED EGG OBSERVATIONS**
Describe the appearance of the white and yolk at these time intervals.

<table>
<thead>
<tr>
<th></th>
<th>1 MINUTE</th>
<th>2 MINUTES</th>
<th>3 MINUTES</th>
<th>5 MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg white</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Egg yolk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EXPERIMENT 4—STIRRED CUSTARD
To make custard, eggs need to be separated. Here's how to do it:

Separating Whites from Yolks
Some recipes, such as the custard recipe in Experiment Four, require
the separation of whites and yolks.

Ingredients
5 egg yolks, beaten
1½ cups 1% or 2% milk
¼ cup sugar
1½ teaspoons vanilla

Directions
1. Separate eggs using the technique demonstrated by the facilitator
or as shown in the video. Cover egg whites and refrigerate for
another use.
2. Put egg yolks in small bowl and beat lightly with wire whisk or fork.
3. Use a rubber spatula to scrape beaten yolks into a heavy, small
size saucepan. Use a heat-resistant or wooden spoon to stir
together egg yolks, milk, and sugar.
4. Place mixture in saucepan over low heat. Cook and stir
continuously over low to medium-low heat just until mixture coats a
clean metal spoon; check frequently by dipping a metal spoon into
mixture (see picture). Use an instant-read thermometer to monitor
cooking temperature. Final temperature will be above 165 degrees
and below 170 degrees. Remove pan from heat immediately.
Record temperature. Stir in vanilla.
5. Pour all except about half a cup of custard into medium mixing
bowl.
6. Some learners need to continue cooking the half cup of custard
over low heat until the custard curdles. Record temperature. Pour
into a small custard cup for observation and tasting.

Use two small bowls or custard
cups. Gently crack the egg over
one bowl holding the two cracked
halves up so that the white drops
into the bowl.

Then pour the yolk into the other
half of the shell back and forth a
time or two to let the entire egg
white drop into the bowl. Gently
shake it a little so that the egg
white is cut on the edge of egg
shell, and drops into the bowl.

Put egg yolk into second bowl.
Wash hands thoroughly with soap
and warm water after touching
raw eggs.
7. At the same time, other learners quickly cool the custard in the mixing bowl by placing bowl into a larger bowl filled with ice and water. Be sure cooling water does not get into the custard. Cool for about 5 minutes, stirring frequently. Remove from ice water.

8. Using proper technique, sample the cooled custard. You may also sample the curdled custard if desired.

9. If any custard is left over, cover the surface with plastic wrap to prevent a skin from forming. Normally, custard should chill at least 2 hours without stirring. Custards are often served over fresh fruit or other desserts. Makes about 2 cups, total.

### CUSTARD OBSERVATIONS

<table>
<thead>
<tr>
<th>FINAL COOKING TEMPERATURE</th>
<th>COLOR</th>
<th>TASTE</th>
<th>TEXTURE</th>
<th>RATE TASTE Use 1–5 scale: (1= Very poor, 5 = Excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked to Doneness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overcooked</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SHARE

1. Briefly describe what you did in each experiment and your observations of what happened to the eggs during the cooking process.

_______________________________________________________________________________

_______________________________________________________________________________

REFLECT

1. Describe what you saw happening in each of the experiments as the eggs cooked.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

2. Is this a physical or chemical reaction? ________________________

3. Describe the physical reaction.

_______________________________________________________________________________

_______________________________________________________________________________
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)

4. Describe the chemical reaction.
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

5. Determine the average taste rating from your group for the stirred custard.
   (To determine average, add up all responses then divide by the number of responses.)

   • Cooked to doneness average rating: ________________________________
   • Overcooked average rating: _________________________________

GENERALIZE

1. What happens to the proteins in eggs when heat is applied and they are cooked?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

2. What happens when eggs proteins are overcooked?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Terms: Protein denaturation, coagulation, yolk, egg white (albumen), chalazae, syneresis, functional properties of eggs
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)

APPLY
If you were teaching someone how to cook scrambled eggs, what tips would you give them? Explain the reasons for your tips using some of the scientific terms learned in this activity.

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

BE A FOOD SCIENTIST

EGGS ARE EXCEPTIONAL!
Few foods are as versatile as the egg. Eggs’ properties lend themselves to a variety of functions, which make them vital to the successful outcome of many recipes and types of foods. Here’s an overview of the many functions that make eggs exceptional in food science.

• Eggs provide structure: when heat changes the eggs’ protein from liquid to solid, it leads to coagulation, giving structure to a product. You observed coagulation in this activity.

• Eggs act as emulsifying agents, binding liquid and oil in baked goods or in salad dressings such as mayonnaise. An emulsifying agent helps to keep oil and water ingredients from separating. Recipes that include oil and a liquid generally have egg, specifically egg yolk because the yolk contains the emulsifying agents.

• Eggs provide leavening when the whites are whipped to incorporate air and create a foam, such as in soufflés and meringues. (This is a different example of coagulation that is explored in Activity 2.2.)

• Eggs control crystallization in certain candy products.

• Eggs provide color, texture, and nutrition in foods.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)

What You **SEE** & **FEEL**

**The Physical Reaction**
The scrambled egg changes from liquid to solid during application of heat.

---

What Happens from a **FOOD SCIENTIST’S Point of View**

**The Chemical Reaction**
There are more than 40 types of protein in eggs. Each of the egg proteins has a specific structure as a result of strong bonds or connections. With heat, the proteins change their structure. The white (albumen) and yolk denature and coagulate at different temperatures. When cooking a modified poached egg, you noticed the white changed to a solid first.

- **Protein in its natural state**
- **Unfolded, denatured protein**
- **Coagulated protein**
Effect of Heat on Proteins

Heat used in cooking changes an egg’s proteins from liquid form to solid.

All proteins, whether in meat, eggs, milk, or other foods, are made up of amino acids. Amino acids are molecules that are strung together in long chains that fold into distinct structures due to chemical bonding. (See Process of Coagulation graphic.) When proteins are heated, as in cooking, changes occur in a two-step process:

The first step is denaturation. The proteins begin to unwind and unfold. Denaturation is the un-folding process.

The next step is coagulation. With continued heating, the denatured protein chains make new bonds and connections with other protein chains to form a solid gel as seen during the heating of scrambled eggs, poached eggs, and baked/stirred custard. Coagulation is the gelling process. Overcooking with high heat, or heating too long, over-coagulates the protein, making it tough and dry. Egg proteins are 75% water. Over-coagulation (called syneresis) squeezes the water out of the proteins. In the case of scrambled eggs, the water evaporates, making the final product dry and tough. In the case of overcooked stirred custard, clumps (curds) are formed and liquid separates from the protein. Overcooked boiled eggs may have a tough white and dry yolk.

Key points to remember:

• Heating eggs causes the protein to change from liquid to solid. This is a two-step process. First, heat denatures protein. Then the proteins reform in a different way, which is coagulation. The physical change (coagulation) occurs because of alterations in the protein molecules.

• With excess heat, protein can over-coagulate and become tough and dry. This is illustrated with the scrambled eggs experiment.

• Egg coagulation is also illustrated with the preparation of stirred custard. If custard is overheated and/or not cooled quickly, the custard will over-coagulate or curdle. When excessive coagulation causes the liquid to separate from the protein, it is called syneresis.

FOOD SCIENCE AND EGGS—WHAT’S THE LINK?

Eggs have many functions in recipes, so if a person does not want to eat eggs, how can a recipe be made successfully? Food scientists can develop recipes and foods that don’t use eggs. They may substitute other ingredients that have the same function that eggs did in that particular recipe or food. For instance, if an egg were used for leavening in muffins, changing the amount of baking powder and/or baking soda may give a similar result. Or a food might have eggs in it to give it structure or to help liquid ingredients mix together without separating. Food scientists then use other ingredients that can do the same thing as eggs to make foods such as salad dressings, dry baking mixes, puddings, and baked goods. Check out products in your pantry and see how many of them contain eggs.
Sometimes people want to avoid eating egg yolks because they contain cholesterol and saturated fat. Eating too much saturated fat and cholesterol can lead to clogged arteries, which in turn may lead to heart attacks and strokes. The Dietary Guidelines for Americans state the following:

Moderate evidence shows a relationship between higher intake of cholesterol and higher risk of cardiovascular disease. Independent of other dietary factors, evidence suggests that one egg (i.e., egg yolk) per day does not result in increased blood cholesterol levels, nor does it increase the risk of cardiovascular disease in healthy people. Consuming less than 300 mg per day of cholesterol can help maintain normal blood cholesterol levels. Consuming less than 200 mg per day can further help individuals at high risk of cardiovascular disease.

Since the Dietary Guidelines for Americans suggest no more than 300 milligrams per day of cholesterol from the foods you eat, let’s see how much cholesterol is in an egg. Look at the Nutrition Facts Panel on the back or inside flap of an egg carton.

How much cholesterol is in one egg? ____________

Is that more or less than half of the daily recommended amount of cholesterol? ____________

If you want to eat more eggs than recommended, mix several egg whites with one whole egg to get a great serving of high-quality protein without too much cholesterol and saturated fat. Separate egg whites from yolks using the technique you learned in this activity.

What type of milk did you use to make the custard? You might want to consider switching to fat-free or 1% milk if you haven’t already done so. This one switch will greatly reduce the amount of saturated fat and cholesterol you eat every day, especially if you’re drinking the three cups of milk each day that the Dietary Guidelines recommend.

Did You Know?

- Sometimes hard-cooked eggs have a greenish ring around the yolk. This occurs as a result of a reaction between sulfur in the egg white and iron in the yolk. It occurs more often when eggs have been cooked too long or at too high a temperature. The instructions in this experiment minimize the greenish ring reaction by proper cooking and immediate cooling.
- Using eggs that are 7–10 days old are easier to peel. Peeling under cool, running water also helps to get the shell separated from the egg.
- If you live at altitudes above 10,000 feet, it is almost impossible to hard-cook eggs.
COOKING UP FOOD SCIENCE AT HOME
Heart Healthy Scrambled Eggs

**Ingredients**
1 whole egg
3 tablespoons egg whites (use pasteurized liquid egg whites or dried egg whites)
2 tablespoons milk

**Directions**
1. With a wire whisk, rapidly whisk the egg and whites for 45–60 seconds. Whisking adds air and makes scrambled eggs fluffy.
2. Add milk and whisk to mix.
3. Lightly spray a small, non-stick skillet with cooking spray; place on medium to low heat.
4. Pour whisked mixture into skillet. Using a utensil that won’t scratch the skillet, such as a plastic heat-resistant spoon or spatula, stir occasionally during cooking. Scrape the egg from the bottom of the pan and stir gently. Break up large pieces. Eggs are done as soon as they have become solid and no liquid remains.
5. Carefully remove skillet from heat. Makes 1 serving.
STATEMENT: RAW EGG WHITES CHANGE FROM LIQUID TO SOLID.
BEATEN EGG WHITES CAN BE COOKED TO MAKE A SOUFFLÉ.

Ask as many questions as you can about these pictures and this statement. Start your first question with
“I wonder . . .” Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My
experiment will be . . .
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .
_______________________________________________________________________________
_______________________________________________________________________________
ACTIVITY 2.2: Make Sense of Soufflés: Eggstrme Egg Makeover (cont.)

EGGS AND FOODBORNE ILLNESS
Some eggs contain the bacteria called Salmonella enteritidis (SE) which cause foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE, so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.

WHAT WILL WE DO?
In this activity, you get to use some of the skills you practiced in Activity 2.1. You will crack and separate eggs, then find out how to beat egg whites to make a foam. You’ll make three stages of egg white foams, use various ingredients and equipment to stabilize egg white coagulation, and then make a chocolate soufflé!

WHAT DO WE NEED TO KNOW?
There’s more than one way to change egg whites from a liquid to a solid! In Activity 2.1, heat was used to coagulate egg protein in the yolk and white. In this activity, you will use an electric mixer to beat the egg whites. Beating is a mechanical action; it is another way to coagulate egg protein.

There are many proteins in albumen (egg white). Some of the proteins coagulate during beating. The science behind foods made with egg whites, such as soufflés, meringues, and angel food cakes, focuses on egg white protein coagulation. As you learn the food science in this activity, the ingredients and recipe instructions for soufflés will make sense.

To coagulate egg protein with beating, you start with a foam. As beating begins, air is trapped in large bubbles. With continued beating, the proteins in albumen change structure. Coagulation starts as the proteins “coat” the air bubbles.
PREPARATION ACTIVITY

Using the technique demonstrated by the facilitator, crack an egg and separate the egg white from the egg yolk by carefully pouring the yolk back and forth between the egg shell halves while letting the white drop into the bowl.

EXPERIMENT 1—STABILIZING EGG WHITE FOAMS

Divide into groups; one group per variable. Share results to fill in Observation Log.

**Variation A: Whole egg**

Use an egg white and yolk from Preparation Activity.

1. Place one egg white and one yolk into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. At the end of 7 minutes, stop beating.
5. Describe appearance of mixture in Observation Log.

**Variation B: Plain Egg White**

Use an egg white from Preparation Activity.

1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.

HOW TO BEAT EGG WHITES

Place beaters of hand mixer in bowl so that the beaters touch the bottom of the bowl. Start on low speed. Move beaters slowly around the bottom of the bowl and/or turn the bowl continuously. As egg white begins to foam, put on medium speed. Continue moving beaters and turning bowl. Keep beaters low in the bowl so that product does not fly off the beaters into the room.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

3. After one minute, change speed to medium.
4. Beat to stiff peak stage. Be careful not to over-beat. The change from soft peak to stiff peak occurs rapidly. Stop beaters about every 30 seconds. When beaters have stopped completely, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage. If foam forms a peak and stays standing, it is stiff peak stage.
5. Record time that stiff peak stage is achieved.
6. Describe appearance of foam in Observation Log.

Variation C: Egg White with Acid—Cream of Tartar
Use an egg white from Preparation Activity.
1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. Beat to the foamy stage, then add 1/8 tsp. cream of tartar.
5. Beat to stiff peak stage. Be careful not to over-beat. Stop beaters about every 30 seconds. When beaters have stopped completely, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage. If foam forms a peak and stays standing, it is stiff peak stage.
6. Record time that stiff peak stage is achieved.
7. Describe appearance of foam in Observation Log.

Variation D: Egg White with Sugar
Use an egg white from Preparation Activity.
1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. Beat to soft peak stage. Be careful not to overbeat—stop beaters about every 30 seconds. When beaters have stopped, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage.
5. Add 2 teaspoons sugar. Beat for about 20 seconds. Repeat two times until a total of 6 teaspoons of sugar have been added.
6. Continue beating until stiff peak stage is reached. With beaters stopped, lift some egg white foam. If foam forms a peak and it stays standing, it is stiff peak stage.
7. Record time that stiff peak stage is achieved.
8. Describe appearance of foam in Observation Log.
**EXPERIMENT 2: EAT AN EGG WHITE FOAM—CHOCOLATE SOUFFLÉ!**

This experiment helps you put the principles you learned in Experiment 1 into action by making a delicious dessert using an egg white foam.

**WHAT IS “FOLDING”?**

Folding is more gentle than mixing or stirring. It is typically used with ingredients that have been whipped to incorporate air, such as egg whites or whipped cream. It is usually done with a broad plastic spatula or other flat utensil. To fold, move the spatula along the inside of the bowl, going down to the bottom of the bowl and twisting the wrist so that the spatula stays flat, and gently bring ingredients up from the bottom all in one movement. Then “fold” the mixture on top of itself. Repeat a few times just until combined, being careful to maintain as much of the air and fluffiness of the whipped item as possible.

---

**EGG WHITE FOAM OBSERVATION LOG**

<table>
<thead>
<tr>
<th>Variation A: Whole egg</th>
<th>BEGINNING TIME</th>
<th>ENDING TIME</th>
<th>DESCRIBE THE APPEARANCE OF THE EGG WHITE FOAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation B: Plain egg white</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variation C: Egg white with acid (cream of tartar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variation D: Egg white with sugar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)**
### ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

**Ingredients**

<table>
<thead>
<tr>
<th>CHOCOLATE SOUFFLÉ</th>
<th>FUNCTION OF INGREDIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooking spray</td>
<td></td>
</tr>
<tr>
<td>3 tablespoons granulated sugar</td>
<td>Egg white foam stability, flavor</td>
</tr>
<tr>
<td>½ cup semi-sweet chocolate chips</td>
<td>Flavor</td>
</tr>
<tr>
<td>2 large eggs, separated</td>
<td>Structure, steam leavening</td>
</tr>
<tr>
<td>1 tablespoon heavy cream</td>
<td>Flavor</td>
</tr>
<tr>
<td>1 teaspoon all-purpose flour</td>
<td>Structure</td>
</tr>
<tr>
<td>½ teaspoon ground cinnamon</td>
<td>Flavor</td>
</tr>
<tr>
<td>½ teaspoon salt</td>
<td>Flavor</td>
</tr>
<tr>
<td>2 teaspoons confectioner’s sugar</td>
<td>Flavor and visual appeal</td>
</tr>
</tbody>
</table>

**Directions**

Learners divide into four groups—when not active, observe the group actively doing the preparation.

**Group One:**

1. Preheat oven to 375º F. Position oven rack in center of oven.
2. Determine the holding capacity of your ramekin or oven-safe bowl. Use a 2-cup liquid measuring cup showing ounces. Place water in a ramekin and measure. It should hold about 10 ounces. Dry ramekin.
3. Spray two ramekins lightly with cooking spray. Sprinkle interior sides and bottom of ramekins with 1½ teaspoons granulated sugar.
4. Use eggs from Preparation Activity or
   - Separate two eggs; discard one of the yolks.
   - Place one yolk in a mixing bowl.
   - Place the two egg whites in a different mixing bowl (give to Group Three).
5. Using a wire whisk, whisk together the cream and one egg yolk in mixing bowl (give to Group Two).

**Group Two:**

1. Melt chocolate in a small microwave-safe bowl. Stir every 15 seconds. Watch carefully. Overheated chocolate is crumbly and not useable. Should it overheat, discard and start over with more chocolate.
2. Drizzle melted chocolate into egg yolk mixture (given to you by Group One) slowly while constantly whisking. Whisk until smooth.
3. Add cinnamon and flour and whisk again until smooth.

---

**Unit 2: The Power of Protein Chemistry**

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**Group Three:**
1. Get the two egg whites from Group One. Add salt. Using a hand mixer, beat to soft peak stage.
2. Add remaining sugar in three parts (2 teaspoons at a time, then beat for a short time. Repeat twice). Beat until stiff peak stage.
3. Pour about half of chocolate mixture into egg whites.
4. Gently fold chocolate mixture into egg whites just until combined.
5. Add remaining chocolate mixture and gently fold just until combined.

**Group Four:**
1. Divide mixture equally between two 10-ounce ramekins. Place ramekins on baking sheet.
2. Carefully place baking sheet into oven and bake 18–22 minutes.
3. Check at 18 minutes with a clean toothpick. When toothpick inserted into center comes out clean, soufflé is done; remove from oven.
4. Dust souffle lightly with confectioner’s sugar. (“Dust” by placing a small amount of sugar in a spoon. Hold spoon over soufflé. With one hand, tap the hand holding the spoon so that sugar falls gently off the edge of the spoon.)
5. Serve immediately. Spoon out a small amount onto paper plates so that everyone can sample the soufflé.
   - Soufflés are usually served immediately in the dish in which they were baked because they stay puffy for only a short amount of time. As the soufflé cools, it will fall slightly. It is not as pretty, but still delicious!

Describe the appearance of the soufflé when it comes out of the oven:

________________________________________________________

Describe the texture of the inside of the soufflé:

________________________________________________________

Describe the texture of the soufflé in your mouth:

________________________________________________________

This soufflé was a dessert. Most soufflés start with a white sauce of milk/cream, flour, and butter. A savory soufflé using such things as cheese and finely chopped or pureed vegetables can make a main dish. Now that you have “Made Sense” of soufflés, find and try a new recipe for one at home!
SHARE
Briefly describe what you did in each experiment and your observations of the egg white foams.
__________________________________________________________________________________

REFLECT
1. What did you do that changed egg whites from liquid to solid without heat?
__________________________________________________________________________________

2. Why does this change occur?
__________________________________________________________________________________
__________________________________________________________________________________

3. What is in egg white foam that makes products rise? _________________________________

4. What helps keep egg whites stable so that they can hold air?
__________________________________________________________________________________
__________________________________________________________________________________

5. What are the best times to add stabilizing agents in order to maximize stability?
__________________________________________________________________________________
__________________________________________________________________________________

6. What is the major function of egg white foam in a soufflé?
__________________________________________________________________________________

7. What are the functions of ingredients in the chocolate soufflé?
__________________________________________________________________________________
BEAT THE EGGS!

Egg white foams are included in many recipes. For example, meringue on the top of a pie, angel food cake, puffy omelets, and soufflés are made of egg white foam. The foam adds volume to the food products by trapping air during beating. In order to keep the air trapped, the egg white foam must be stable. Creating stable foam is a two-step process.
First, as air is incorporated during beating, specific proteins in egg whites (albumen) coagulate and undergo structural changes. The proteins then re-align and create a new structure, a protein film. The protein film surrounds and traps air bubbles created by beating.

Added ingredients such as sugar and acid [e.g. cream of tartar] stabilize the foam, helping maintain the trapped air bubbles. The trapped air helps to leaven the product, making it light and fluffy. At the same time, such stabilizers help to prevent the breakdown of the foam. In addition, the liquid in egg white foam changes into steam during cooking. As the water portion of the egg white becomes steam, it expands and rises in the trapped air, stretching the other ingredients that help form the structure. The heat of cooking further coagulates the protein, thus making the structure of the food more firm.

FOUR STAGES OF EGG WHITE FOAM

There are four stages of egg white foam formation. You will experiment with the first three of these stages. In the first stage, as beating begins, air is trapped in large bubbles. With continued beating, the proteins found in albumen changes structure. Coagulation starts as the proteins “coat” the air bubbles.

Stage One: Air is incorporated and trapped in large bubbles. Mixture is foamy; bubbles are large. It is referred to as foamy.

Stage Two: Air cells in the foam become finer. If you stop beating at this stage and pull up the beaters, the peak of the foam flops over. This is called the soft peak stage. The photo on the left shows early soft peak stage. The photo on the right still shows soft peaks, although they are not as soft as the previous photo. Note how they have fallen over.

Stage Three: Continued beating makes the air bubbles smaller, so the foam becomes very fine. When you pull up the beaters, the egg white foam holds a peak. This is called the stiff peak stage.

Stage Four (Not Shown): Continued beating without extra ingredients to stabilize the egg white foam may result in the foam breaking apart and appearing dry and chunky. Liquid egg white begins to separate from the foam; this is called syneresis. When this happens, the foam can no longer provide leavening action.
RECIPE INGREDIENTS THAT INFLUENCE EGG WHITE FOAMS

- **Fat**: The fat present in egg yolks will stop or greatly delay foam from forming. Therefore, one must be very careful when separating egg whites from egg yolk. Even a small amount of fat from the yolk, if mixed with egg whites, will decrease the final volume.

- **Acid**: Acid stabilizes the egg white foam so other ingredients can be added in a recipe without decreasing the final size of the product. The most common acid added to egg white foam is cream of tartar. Typically it is added at the beginning of beating. When added to egg white, the foam is more stable, but it will take longer to achieve stage three—stiff peaks. The stabilized foam provides good leavening action in the final product.

- **Sugar**: Like cream of tartar, sugar stabilizes egg white foams while slowing formation of the foam. Sugar stabilizes the foam to hold incorporated air. Generally, sugar is added after the foam has reached the soft peak stage. Sugar is added gradually to minimize time needed to obtain stiff peak. It also protects the foam from being whipped to the dry stage, thus preserving its ability to provide leavening.

EQUIPMENT INFLUENCES EGG WHITE FOAMS—BEATERS, BOWLS, AND MORE

These things are often mentioned in recipe directions for soufflés, angel food cakes, and similar foods. At other times, these details are not mentioned but are still important in how the food comes out, so it’s good to be aware of them.

**Beaters, Bowls, and Temperature**

- **Beaters**: The finer, or thinner, the wires are in a whisk or beater, the finer the texture of the egg white foam. However, with a wire whisk or typical electric hand mixer, the foam becomes finer the longer it is whipped. A stand mixer with a wire whisk attachment produces egg white foams very quickly; care must be taken not to overbeat.

- **Bowls**: Bowls with small rounded/flat bottoms allow the beater to pick up more egg white. Thus, the foam forms more quickly. Don’t use plastic bowls because fat residue from previous uses can stick on the surface even after washing. The tiniest amount of fat interferes with foam formation. Fat coats the proteins, preventing the structural changes that make it coagulate.

- **Temperature**: Whites whip more quickly at room temperature than if cold from the refrigerator. It’s best to set out eggs to be whipped for about 20–30 minutes before beating. Remember for food safety purposes that perishable foods such as eggs should not be left at room temperature for more than two hours.
Key points to remember:

- Cream of tartar or sugar stabilizes foams for a properly leavened product.
- The stage of the foam and the timing when ingredients are added to a foam are important for the final product.
- Use the correct equipment and eggs at the right temperature to make a stable, fine foam.

**ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)**

What You **SEE** & **FEEL**

The Physical Reaction in Egg White Foams

What Happens from a **FOOD SCIENTIST’S** Point of View

**EGG WHITE FOAMS**

- LIQUID
- AIR TRAPPED
- PROTEIN STRUCTURAL CHANGES
- REACTION CONTINUES
- OVER-COAGULATION
- ADDITION OF SUGAR OR CREAM OF TARTAR
- DELAYS OR PREVENTS OVER-COAGULATION
FOOD SCIENCE, NUTRITION, AND EGG PROTEIN—WHAT’S THE LINK?

Food scientists can use the protein from eggs to make special foods such as protein powders or high protein snack bars.

The protein in eggs is very high quality. It is one of the most easily digested and perfectly balanced proteins for humans. Compared to other proteins, only those in milk are as good as the protein in eggs. A typical large egg contains 7 grams of protein. To compare, the Recommended Dietary Allowance for protein is as follows:

- Children ages 9—13 ............. 34 grams of protein
- Girls ages 14—18 ............... 46 grams of protein
- Boys ages 14—18 ............... 52 grams of protein

Now that you know eggs are a good source of protein, you may want to eat more of them without getting all the saturated fat and cholesterol that come along with the yolk. Besides separating eggs and discarding most of the yolks, you can purchase pasteurized liquid egg whites. They come in a small carton in the refrigerated section at the grocery store. They are usually sold alongside the whole eggs. Look for ones with egg whites only.

In addition, many grocery stores carry dried egg whites. These come in handy if you run out of eggs, or if you just want egg whites for a recipe. Pasteurized egg white powder is pure albumen that has been dried. They are mixed with water to use them.

LEARN MORE!

VIRTUAL FUN
For videos on working with eggs, recipes, and additional resources about the use of eggs in the food industry, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
STATEMENT: MILK CAN SEPARATE INTO SOLIDS AND LIQUID. 
THE SOLIDS MAKE CHEESE.

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

_______________________________________________________________________________
_______________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_______________________________________________________________________________
_______________________________________________________________________________

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. In addition, after handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg. Visit www.FightBac.org for tips and handouts regarding food safety.
WHAT WILL WE DO?
In this activity, you get to make cheese. You’ll find out how milk turns into cheese. Do you think cheesemaking might be a complicated and mystifying process? It’s not! Making a soft, “fresh” cheese, such as queso fresco, is actually simple. Here’s a quick overview:

- Start with pasteurized whole milk. Add buttermilk and vinegar.
- Heat to 90°F.
- Add rennet enzyme, then let set until curd forms.
- Curd is cut into pieces. Liquid whey is released.
- Heat to 115°F to boost release of whey.
- Strain through cheesecloth. Drain off whey. Remaining curds are the soft cheese.
- Add salt, mix, and hand-form cheese.

WHAT DO WE NEED TO KNOW?
Milk proteins are a combination of 80% casein and 20% whey. To make cheese, the protein in milk needs to be thickened, or coagulated. The casein coagulates when acid (vinegar and buttermilk) and rennet (an enzyme) are added. During coagulation, casein becomes a solid, called cheese curd. The coagulated protein curds are the base of almost all cheeses.

The whey protein in milk is not changed by acids or rennet, so it stays liquid. It is drained away after the casein coagulates, leaving behind the cheese curds.

MAKE QUESO FRESCO CHEESE!
This is a popular cheese in Mexico; queso fresco means “fresh cheese” in Spanish. It is a crumbly, mild-tasting cheese used as an ingredient or topping in Mexican cooking. It’s easy to make and you’ll learn more about the unique powers of protein.

**Ingredients**
- 1 tablet Junket rennet
- ½ cup cold water
- 2 quarts, plus 1 cup pasteurized whole milk
- 1 quart buttermilk
- 2 tablespoons plus 1 teaspoon white vinegar
- 1¾ teaspoons salt

EXTRA FOOD SAFETY FOR CHEESE!
Begin with clean equipment and new cheesecloth. All equipment used in making the cheese, including the cheese cloth must be sanitized using a water-bleach solution of ½ tablespoon unscented bleach added to ½ gallon of cool water. Everything must be soaked in the solution for two minutes and air dried.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

Directions

1. Place one tablet Junket rennet into ½ cup cool water. Stir until dissolved. Set aside.
2. Pour pasteurized milk into large saucepan. Stir gently. Note texture and record in Observation Log.
4. Add 2 tablespoons plus 1 teaspoon white vinegar to the milk mixture and mix well. Stir gently. Note texture and record in Observation Log.
5. Using low heat, heat milk mixture to 90º F. Use a thermometer to check temperature; don’t let it touch the sides or bottom of the pan. Remove pan from heat.
6. Add dissolved rennet to mixture and stir gently for 2 minutes. Note texture and record in Observation Log.
7. Let mixture stand in cool place for 30–40 minutes until curd is firm. Note cooling start time.
8. After curd is firm, cut curd into ½-inch cubes and let stand for 5 minutes. Whey will separate. Write observations in Observation Log.
9. Heat curds and whey to 115º F. Stir once or twice to ensure that the curds on the bottom do not over-cook. Remove from heat. Let stand for 5 minutes. Write observations in Observation Log.
10. Place a colander in the sink. Line it with double-layered cheesecloth. Pour mixture through cheesecloth and allow to drain for 5 minutes. Write observations in Observation Log.
11. Pull up the edges of the cheesecloth, and form curd into a ball, gently twisting the cheesecloth to squeeze out the whey.
13. Add salt to curds. Mix with table knife or fork and let stand for 5 minutes.

Cheese ripening is a process that gives cheese a distinctive flavor. Ripening agents are used, which are typically micro-organisms such as bacteria, mold, or yeast. Humidity and the environment where the cheese is stored are carefully controlled because they also influence the final flavor, as does the amount of time a cheese ages. Cheese typically ages anywhere from several weeks to a couple of years. All these factors play a role in the final taste and texture of the cheese. Queso fresco is a “fresh” cheese because it is not aged.
14. Gather edges of cheesecloth. Hold over sink or bowl; gently twist cheesecloth to squeeze out remaining whey. Open up the cheesecloth. Write observations in Observation Log.

15. Scrape the cheese onto a plate. Hand-form the cheese into flat circle or rectangle. After cheese is drained, it may be sampled immediately. Divide remaining cheese into equal portions, put into re-sealable plastic baggies to take home. Refrigerate promptly!

16. If tortillas are available, place some queso fresco on one-half of tortilla, then fold over. Heat briefly in microwave or skillet. Cut into pieces to sample.
## ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

### QUESO FRESCO OBSERVATION LOG

<table>
<thead>
<tr>
<th>STAGE OF CHEESE</th>
<th>DESCRIBE THE APPEARANCE AND CONSISTENCY</th>
<th>SEPARATION OF SOLIDS AND LIQUIDS (Use 1–5 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain milk.</td>
<td></td>
<td>1= no separation 5 = much separation</td>
</tr>
<tr>
<td>Milk with buttermilk.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk with buttermilk and vinegar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After rennet was added to mixture.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note time cheese is placed in cool area to set: ____________

Note time at which curds have formed: ________________
### ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

<table>
<thead>
<tr>
<th>STAGE OF CHEESE</th>
<th>DESCRIBE THE APPEARANCE AND CONSISTENCY</th>
<th>SEPARATION OF SOLIDS AND LIQUIDS (Use 1–5 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture after curd is cut and it stands for 5 minutes.</td>
<td></td>
<td>1 = no separation 5 = much separation</td>
</tr>
<tr>
<td>Mixture after it is heated to 115°F and stands for 5 minutes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture after it is poured into cheesecloth.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture after cheesecloth is twisted and opened.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After mixture is salted and squeezed again.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### MEASURING MATH

To make queso fresco, you need to be sure to use a pan that is large enough to hold all of the ingredients. First, calculate the total number of cups of liquid in the recipe. Then, measure that amount of water into the saucepan you are considering. Does it fit with at least an inch of space at the top? If so, then it is large enough.
SHARE
Briefly describe what you did to make cheese and your observations of the mixture.
_______________________________________________________________________________
_______________________________________________________________________________

REFLECT
1. What is in milk that turns into cheese?
_______________________________________________________________________________

2. Why do the milk curds separate from the liquid? What is happening to the casein?
_______________________________________________________________________________
_______________________________________________________________________________

3. How is this similar to what occurred to make an egg white foam?
_______________________________________________________________________________

4. What is whey? What happens to whey during the cheesemaking process?
_______________________________________________________________________________
_______________________________________________________________________________

TERM & Concept Discovery
Terms: Rennet, buttermilk, vinegar, curd, whey, queso fresco, casein, enzyme, cheesecloth, sanitation
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

GENERALIZE
In cheesemaking, what ingredients make casein coagulate?
_______________________________________________________________________________

APPLY
How would you use queso fresco at home?
_______________________________________________________________________________
_______________________________________________________________________________

FOOD SAFETY AND QUESO FRESCO
In many Hispanic communities, queso fresco is made with unpasteurized milk, sometimes resulting in many cases of foodborne illness (food poisoning). This is because the milk they used was not pasteurized (pasteurization kills germs). Food science students at Washington State University did a project working with Hispanic communities to develop a queso fresco made with pasteurized milk. After working with Hispanic cooks and many experiments, a new recipe was developed that people liked. As people in the Hispanic community started making the recipe using pasteurized milk, the rate of foodborne illness in those areas rapidly decreased. People no longer got sick from the cheese!

BE A FOOD SCIENTIST

MILK BECOMES CHEESE
Queso fresco is an unripened or fresh cheese, which means it is ready to eat right away. It does not need to age like ripened cheese. Other examples of fresh or unripened cheese include cream cheese, feta (usually made from goat milk), mascarpone, paneer, mozzarella, and ricotta. Examples of ripened or aged cheese include cheddar, Swiss cheese, Provolone, blue cheese, and parmesan. Ripened cheeses are aged from a few months to years. As a result, they have stronger flavors than unripened cheese.
COAGULATING THE CASEIN

**Acids**
To make queso fresco, coagulation of casein begins by adding lactic acid bacteria or acid to milk to get the coagulation process started.
- Lactic acid bacteria in buttermilk helps ferment lactose (the natural sugar in milk) to lactic acid and provides flavor to queso fresco.
- Acid in vinegar promotes the coagulation process since buttermilk alone does not contain enough acid to cause coagulation.

Acid changes the structure of casein. It goes from a liquid to clumps of solid curds and begins to separate from the liquid whey. When the pH of milk reaches an acidic 4.7, the reaction begins. This reaction can be observed during the cheesemaking process. This is an example of protein coagulation.

**Rennet**
To help the coagulation process, rennet is added to the acidified milk. Rennet is comprised of digestive enzymes.

There are several types of rennet:
- Rennet from animal sources (typically extracted from the lining of a calf’s stomach).
- Rennet from food-grade mold used for vegetarian cheesemaking.
- Rennet from genetically modified organisms—bacteria that have been implanted with the gene that makes a rennet which is chemically the same as that from the calf’s stomach.

Animal rennet is favored by traditional cheesemakers, but the other types of rennet make fine cheese as well. Rennet comes in liquid or tablet form. For the purposes of making queso fresco, a rennet tablet will do. A popular and relatively easy to find rennet is called Junket rennet. The tablet is dissolved in water before being added to the milk mixture. Rennet’s coagulation of casein is a complicated reaction—something that might be studied by food science students in college.
**ACTIVITY 2.3: Separating the Curds from the Whey (cont.)**

**What You SEE & What You FEEL**

The Physical Reaction
Buttermilk, vinegar, and rennet are added to milk, making it thicken; liquid separates from solids.

- **Milk**—a liquid
- **Add vinegar and buttermilk**—mixture thickens
- **Add rennet**—additional thickening
- **Tiny curds or clumps form solids, separating from the liquid**

**What Happens from a **FOOD SCIENTIST’S** Point of View**

The Chemical Reaction
Acids and rennet are added to milk to coagulate the proteins, resulting in curds and whey.

- **Protein in milk**—including casein
- **Add acids to casein**—coagulation begins
- **Add rennet**—additional coagulation
- **Curds and whey form. Curds are solids, whey is liquid**
WHAT ABOUT THE WHEY?
Once curds are formed from casein, the liquid whey is drained, squeezed, and pressed from the mixture. Whey contains water, protein, lactose [naturally occurring milk sugar], vitamins, and minerals. It has many uses:
- Make ricotta cheese
- Enhance nutritional value of beverages
- Enhance the color and crust of commercially produced baked goods
- Protein supplement in numerous foods or as “protein powder”
- Additive to animal feed

FOOD SCIENCE, NUTRITION AND CHEESE - WHAT’S THE LINK?
Food science principals are used to make cheeses. Different kinds of milk (e.g. cow milk or goat milk), plus different acid ingredients and long or short aging times result in different textures and flavors.

Since cheese is a dairy food, it contains many of the same nutrients as milk—but in concentrated form. For instance, one-third cup of grated cheese counts as one cup of milk. Cheese is high in protein and calcium.

Cheese made from whole milk contains the same amount of saturated fat and cholesterol found in whole milk. Therefore, regular cheeses should be eaten in moderation. To meet the needs of people who want to eat less saturated fat, food scientists develop cheeses that taste good and have less fat. These cheeses are typically made with 2% milk, thus reducing calories, saturated fat, and cholesterol, while retaining much of the cheese flavor, texture, and melting characteristics. They are sold right alongside the regular cheeses. Look for labels that say “Made from 2% milk” or “Reduced-fat cheese.”

Sometimes cheese can be eaten by people even though they are lactose intolerant. Lactose intolerance is the inability to digest lactose, the sugar naturally found in milk. Rennet causes coagulation of the casein portion of milk, so most of the lactose is drained off in the whey. Additionally, if the cheese is aged (cheddar, Asiago, parmesan) lactose is nearly absent, because during the aging process it has been fermented to lactic acid.

However, if a person is allergic to cow’s milk, they will be allergic to cheese as well. Allergic reactions are the body’s reaction to a certain protein, and cheese still contains casein, the protein in milk. Goat cheese, which contains proteins of slightly different structure than cow milk protein, may not cause an allergic reaction.

To meet the needs of these people who cannot eat cheese, food scientists develop “cheese” that is not made from milk. They combine non-dairy ingredients that create a food that looks and tastes somewhat like cheese, although it may not have the melting quality of true cheese.
IN FOOD SCIENCE AND FOOD TECHNOLOGY—DAIRY INDUSTRY

There are many opportunities for interesting careers with a degree in Dairy Science. You might be a milk inspector, dairy herd manager, milk plant field representative, or work on formulating nutritious animal feed. Dairy scientists may also work in cheese science and technology and in ice cream manufacturing.

VIRTUAL FUN

For videos showing the cheesemaking process, recipes, and additional resources on cheese, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
“I Pledge my **Head** to clearer thinking,
my **Heart** to greater loyalty,
my **Hands** to larger service,
and my **Health** to better living,
for my club, my community, my country,
and my world.”
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Unit 3 “The Inner Mysteries of Fruits and Vegetables” is just one part of exploring What’s on Your Plate? Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
INTRODUCTION

WELCOME TO WHAT’S ON YOUR PLATE? EXPLORING FOOD SCIENCE!

Why does a muffin rise? Why do some recipes have so many ingredients in common? Why do foods change color during cooking? What can be done to keep them looking good? Have you ever wondered how new foods you see at the grocery store are developed? The idea of food science may be new to you so, take a close look at your next meal. There’s food science and food technology behind every bite you take; all the way from the farm to the end of your fork.

What’s on your Plate? It’s a mixture of chemistry, biology, and physics. Exploring food science is a hands-on experience. Doing activities, you will discover and learn the basic building blocks of food science in a kitchen “laboratory.” The activities are more than learning to cook, it’s learning why and how things happen in all kinds of foods: breads, muffins, eggs, fruit, vegetables, cheese, candy, beverages, and more.

In Unit 3, you’ll explore “The Inner Mysteries of Fruits and Vegetables.” Activities will delve into the causes and solutions to browning in various fruits and vegetables, exploring osmosis and diffusion in preserving/preparing fruits and vegetables, and experimenting with various methods of cooking fruit to investigate osmosis and diffusion. Be sure to check out the other units to learn more about “The Secrets of Baking” in Unit 1, “The Power of Protein Chemistry” in Unit 2, and how to “Be a Food Scientist” in Unit 4.

With your Youth Science Journal, you get to conduct experiments, collect and analyze data, practice sensory science (tasting), investigate career opportunities, and amaze your friends and family with what you’ve learned about food! To make sure your experiments come out right, follow the directions carefully. Then take some time to think about what happened in the experiment—doing so will open the doors of food science for you!

Your Youth Science Journal has information in the “Be a Food Scientist” section that will help you understand and remember the concepts behind the experiments—this way you can share it with others. You may even find yourself thinking about a career in food science and food technology.

There’s a special website for you, too. Learn more on-line and have virtual fun by visiting websites with videos that show you behind-the-scenes food science. Log on to http://www.4-H.org/curriculum/FoodSci or use your mobile device to connect.

Enjoy exploring What’s on Your Plate?!
SOME FRUITS AND VEGETABLES TURN BROWN AFTER CUTTING.

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.

My experiment will be . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_________________________________________________________________________________
WHAT WILL WE DO?

You have probably noticed that some fruits and vegetables turn brown after they are peeled, cut, or bruised. Perhaps you have wondered why they do this and what you can do to stop it.

You will divide into groups with some learners working with apples and others with potatoes. Each group will prepare apples or potatoes in different ways to see which ones brown the least and which ones brown the most. The goal is to find the method that prevents browning the best so you can prepare fruits and vegetables in ways that will keep them looking their best. Become the expert in your family!

WHAT DO WE NEED TO KNOW?

A process called enzymatic browning occurs when apples, pears, bananas, peaches, grapes, avocados, potatoes, sweet potatoes, lettuce, eggplant, and mushrooms are cut. The unsightly brown color is not very appealing. To understand why this happens, you first need to know more about plant cells, and a few terms.

Plant Cells

On the outside of the cell membrane is the cell wall. The cell wall provides strength and structure to fruits and vegetables. Different cells have different substances in them; some have certain enzymes and some have phenolic (fee-nawl-ic) compounds. When a fruit or vegetable is cut, the cell wall and membrane are damaged, allowing the substances in the individual cells to leak out and mix with one another. Cutting also exposes cell contents to oxygen from the air. Exposing phenolic compounds and enzymes to oxygen leads to enzymatic (en-zahy-mat-ik) browning.
**ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)**

**Enzyme**
- Substance produced by cells such as those in fruits and vegetables that produce a certain chemical reaction. In this activity, enzymes allow phenolic compounds to react to oxygen, leading to browning. This reaction is called “oxidation” or “enzymatic browning.”

**Phenolic compounds**
- Substances in the cells of fruit that turn brown when exposed to oxygen and enzymes.

**Enzymatic browning**
- The process that occurs when some fresh fruits or vegetables are cut and exposed to air; a darkening of color is the result. Enzymes in the fruits and vegetables help the physical and chemical reactions occur. The process causes unfavorable results such as browned fruit, or favorable results such as the brown color of raisins, prunes, and tea.

**EXPERIMENT 1—APPLE SAMPLES**
1. Wash the apple, then cut it in half.
2. Slice half of the apple into five slices.
3. Shred other half of the apple using the largest holes on the grater.
4. Divide shredded apple into five equal portions.
5. Use one slice of apple and one shredded portion of apple to do each variable listed below.

**Variable 1: No Treatment—Control**
Place apple slice and portion of shredded apple on a paper plate labeled “No Treatment.”

**Variable 2: Lemon Juice**
Pour ¼ cup lemon juice into a cup; label using masking tape/pen, “Lemon Juice.” Using a spoon, put one apple slice into lemon juice for 20 seconds, turning and tilting the cup to make sure all surfaces are coated. Remove the apple slice. Place on a paper plate labeled “Lemon Juice.”

Gently submerge the spoonful of shredded apple into the solution for 20 seconds; use a spoon to hold shredded apple in place. Gently press on the shredded apple as it is taken out of the cup to remove excess solution. Place on “Lemon Juice” plate.
Variable 3: Vitamin C + Water
In a cup, mix crushed Vitamin C tablet with ½ cup water and dissolve. Label using masking tape/pen “Vitamin C.” Using a spoon, put one apple slice in to Vitamin C solution for 20 seconds, making sure all sides are coated with the solution. Remove the apple slice. Place on a paper plate with name of variable, “Vitamin C.”

Use spoon to dip shredded apple sample for 20 seconds—gently submerge the spoonful of shredded apple into the solution; use a spoon to hold shredded apple in place. Gently press on the shredded apple as it is taken out of the cup to remove excess solution. Place on “Vitamin C” plate.

Variable 4: Sugar + Water
Measure and combine 2 teaspoons sugar and ½ cup water into a cup and mix thoroughly. Label using masking tape/pen “Sugar.” Mix thoroughly. Place one apple slice and a spoonful of shredded apple into solution and let soak for 10 minutes. Remove the apple slice. Place on a paper plate with name of variable “Sugar Water.” Pour contents of cup through a small sieve to retrieve shredded apple; put on “Sugar Water” plate.

Variable 5: Cool Water
Place two ice cubes in one cup of water. Label using masking tape/pen “Cool Water.” Place one apple slice and small portion of shredded apple in cool water and let soak for 10 minutes. Remove the apple slice. Place on a paper plate with name of variable, “Cool Water.” Pour contents of cup through a small sieve to retrieve shredded apple; put on “Cool Water” plate. Wait 20 minutes. While waiting, taste a variety of apples. After 20 minutes observe apple samples and record your observations.

After 20 minutes, use the following numbers to indicate amount of browning:
1 = no browning present, natural color
2 = very light brown—mostly around edges
3 = light brown—around edges
4 = moderately brown—around edges
5 = dark brown on most surfaces
EXPERIMENTAL APPLE SAMPLES OBSERVATION LOG

<table>
<thead>
<tr>
<th>NO TREATMENT</th>
<th>LEMON JUICE</th>
<th>VITAMIN C</th>
<th>2 TEASPOONS SUGAR IN ½ CUP WATER</th>
<th>COOL WATER WITH ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple slice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPERIMENT 2—POTATO SAMPLES

1. Cut potato into thirds.
2. Make several slices from ⅓ of the potato.
3. Shred one-third of potato using the largest holes on the grater. Divide into two portions of about two tablespoons each.
4. Finely grate about two tablespoons of the remaining potato using smaller holes on grater.

Variable 1: No Treatment

Put one slice and a portion of each potato sample onto paper plate labeled with name of variable: “No Treatment.”

Variable 2: Cold Water Soak

Place two ice cubes in 1 cup of water. Place one potato slice and small portion of shredded potato in cool water and let soak for 20 minutes. Remove slice with spoon, put on plate labeled with name of variable, “Cold Water Soak.” Pour contents of cup through a small sieve to retrieve shredded potato; put on plate labeled “Cold Water Soak.” Immediately record color in Observation Log.

While waiting, taste a variety of apples. After 20 minutes, observe potato samples and record your observations.
Use the following numbers to indicate amount of browning:
1 = no browning present, natural color
2 = very light brown—mostly around edges
3 = light brown—around edges
4 = moderately brown—around edges
5 = dark brown on most surfaces

**POTATO SAMPLES OBSERVATION LOG**

<table>
<thead>
<tr>
<th>TYPE OF POTATO</th>
<th>NO TREATMENT (CONTROL)</th>
<th>COOL WATER WITH ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**APPLE VARIETIES COMPARISON LOG**

If you tasted several types of apples while waiting for browning reactions to occur, record your observations here.

<table>
<thead>
<tr>
<th>TYPE OF APPLE</th>
<th>DESCRIBE TEXTURE (DRY, JUICY, FIRM, MEALY, ETC.)</th>
<th>DESCRIBE TASTE (SWEET, TART, ETC.)</th>
<th>HOW MUCH I LIKED IT</th>
<th>OTHER COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

SHARE
Which apple samples browned the least? Which browned the most? Which potato samples browned the least? Which browned the most?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

REFLECT—LEARN ABOUT THE SCIENCE OF THE BROWNING REACTION

1. Why do cut apples and potatoes brown?
   • First, consider what were the untreated samples exposed to.
     _______________________________________________________________________
   • What is happening between the air and the untreated samples to cause browning?
     _______________________________________________________________________
     _______________________________________________________________________
     _______________________________________________________________________
     _______________________________________________________________________

2. Why do samples that are treated not brown as much as untreated ones?
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________

Talk It Over

SHARE
Which apple samples browned the least? Which browned the most? Which potato samples browned the least? Which browned the most?
3. Describing the physical reaction, explain what happened to your apple and potato samples? Hint: Compare and contrast untreated slice, shredded, and grated potato.

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

4. As a food scientist, describe the chemical reaction.

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Terms: Fruit, vegetables, produce, enzyme, phenolic compounds, brown, browning, enzymatic browning, vitamin C (ascorbic acid), lemon juice, oxygen, oxidase, oxidation, antioxidants, melanin
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

GENERALIZE
Considering what you’ve learned in this activity, how should freshly cut fruits and vegetables be handled and stored?

__________________________________________________________________________________

APPLY
1. Taking apple slices in your lunch could be one way to help you eat the recommended two cups of fruit each day. Describe how you would prepare apple slices to take with your lunch so that they would not brown and still taste great!

_______________________________________________________________________________
_______________________________________________________________________________

2. Imagine you want to make baked oven fries for dinner. You want to slice the potatoes before going to a movie and then cook them when you get back. To prevent browning while you’re away, what could you do?

_______________________________________________________________________________
_______________________________________________________________________________

BE A FOOD SCIENTIST

DOWN WITH BROWN!
More about Enzymes in Fruit and Vegetable Cells
Enzymes help chemical reactions occur. One kind of enzyme found in fruits and vegetables is called an oxidase (ok-si-deys), which acts together with oxygen. In whole, uncut fruit, the phenolic compounds and oxidase enzymes do not mix or react with one another, so browning does not occur. However, when produce is cut, it damages the cells, allowing these substances to mix and be exposed to air (oxygen). When phenolic compounds and oxidase enzymes mix and are exposed to air, enzymatic browning occurs. It is easy to see this chemical reaction when cut fruits or vegetables turn brown. The brown color is a pigment (coloring substance) called melanin (mel-uh-nin).
WHAT INFLUENCES BROWNING?

Food Scientists work to control chemical reactions so that unfavorable physical reactions do not happen. Below are some of the ways the unfavorable reaction can be avoided or prevented.

A. Use Anti-oxidants or Anti-browning Agents or Treatments

- **Acid.** Common acids found in most kitchens and food development labs include lemon juice and orange juice. Both juices contain citric acid, which prevents enzyme action. Apple slices treated with acids stay fresh looking for a long time before browning.

- **Antioxidants.** Vitamin C (ascorbic acid) is an antioxidant. It stops oxygen from being used in the reaction. Citrus juices contain vitamin C so they help prevent browning in two ways: 1) Their acid interferes with the browning enzymes, and 2) their antioxidant action interferes with oxygen.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce

• **Cool temperatures.** Storing cut produce in a refrigerator or placing sliced or grated produce in cold water slows down the browning process.

• **Heat.** Heat changes the structure of the enzymes [protein] so they cannot cause a reaction. Cooked produce will not brown—but then it is no longer raw. This would not be a good solution for produce that is going to be served fresh such as sliced apples, avocados, or lettuce.

B. Limit Contact With Oxygen

• **Water.** When cut produce is put in water, the water limits the amount of oxygen that comes into contact with cut surfaces. Cold water works best.

• **Sugar solutions.** Sugar coats the surface of the produce, keeping oxygen from mixing with enzymes and phenolic compounds.

What’s the Best Solution?

• **Vitamin C (Ascorbic Acid)** is inexpensive and usually works the best. It is used in the food industry to prevent browning of sliced fruit. For example, McDonald’s uses vitamin C to treat the packaged apple slices served in kid’s meals.

• **Lemon juice** may change flavor. Orange and pineapple juice work, but not as well since their acid content is lower. Use juice only for foods where a slight citrus flavor is acceptable.

• **Sugar + Water** coats the surface, but is not as good as vitamin C or lemon juice to control browning. Use only for foods where a slightly sweet taste is acceptable.

• **Water** slows the reaction. It is least effective as treatment for fruit, but is highly effective for potatoes.

Cool temperatures are also good for food safety! Once produce is cut, it must be handled properly to prevent foodborne illness. Refrigerate fruit and vegetables within two hours of cutting to prevent harmful bacteria from growing.
ENZYMATIC BROWNING CAN BE GOOD!

The enzymatic browning of fresh produce can make it unappealing to eat. But browning isn’t all bad. It’s a helpful part of processing some foods. Food scientists use enzymatic browning in positive ways to make foods such as raisins, cider, prunes, figs, and tea. Enzymatic browning adds an appealing brown color and a certain flavor to these foods.

Raisins

The next time you eat raisins, think like a food scientist. You are seeing and tasting the results of enzymatic browning. Most commercially produced raisins are processed by placing grapes on large trays and allowing them to dry in the sun for several weeks. During the sun drying, the grapes lose water (dehydrate) and cell walls weaken. The same enzymatic process that makes apple slices brown occurs in the grapes, turning them into raisins and giving them the dark brown color and flavor we have come to expect. Golden raisins have been treated with sulfur to prevent browning.
FOOD SCIENCE AND FRUIT FOR HEALTH—WHAT’S THE LINK?

Fruits and vegetables have many nutrients, including phytonutrients. Phytonutrients are natural substances that have antioxidant or other healthful properties. Treating fruit and vegetables to prevent browning saves nutrients such as these. Knowing how to prepare and serve fruits and vegetables so that they maintain their color and nutrients is important!

Overall, the nutrients in fruits and vegetables help skin to be stretchy, hair to shine, and eyes to glow—fruits and vegetables are often called “glow” foods! Here are some of the nutrients found in fruit and vegetables:

**Vitamin A:** Essential for growth, reproduction, healthy skin, immune function, and vision.

**Vitamin C (Ascorbic Acid):** Essential for providing strength to all body tissues such as skin, ligaments, and muscles. Important for immune function. Increases iron absorption when eaten with foods that contain iron.

**Potassium:** Necessary for heart health. Helps maintain a regular heart beat and normal blood pressure.

**Fiber:** Fiber helps to keep the intestines clean and working properly.

The 2010 U.S. Dietary Guidelines recommend that most people eat about two cups of fruit, and 2½–3 cups of vegetables each day.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD BIOCHEMISTRY

A food biochemist has a wide variety of career opportunities. Some work to determine the nutrient composition of foods, develop new less costly sources of nutritious foods, or work with food to improve nutritional quality of products, or extend shelf life. Food biochemistry combines many sciences: biology, organic chemistry, inorganic chemistry, and physical chemistry.

LEARN MORE!

VIRTUAL FUN

Find out about apples and processing, how raisins are manufactured, recipes, and how to handle knives safely by visiting the links maintained at: www.4-H.org/curriculum/foodsci
STATEMENT: SOME VEGETABLES CHANGE COLORS WHEN COOKED.

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.

My experiment will be . . .

_________________________________________________________________________________
_________________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_________________________________________________________________________________
WHAT WILL WE DO?

The demonstration and experiments highlight three vegetables. Your objective as the Food Scientist is to observe what happens to the vegetables when cooked in different ways. Then figure out the best way to cook vegetables so they look appealing and keep as many nutrients as possible.

First, do the Perfect Pea demonstration and answer the questions. Then divide into two groups and do the experiments.

WHAT DO WE NEED TO KNOW?

Have you ever appreciated the beauty of the produce department at the grocery store? Next time you are there, look carefully at the vast array of colors. Compounds called pigments create these beautiful colors! This activity explores three of these pigments:

- **Yellow/orange—carotenoids** (kuh-rot-n-oidz)
- **Green—chlorophyll** (klawr-uh-fil)
- **Purple/blue—anthocyanin** (an-thuh-sahy-uh-nin)

Pigments may change color when they are heated or have other ingredients added. The orange, green, and reddish-blue pigments highlighted in this activity react differently to heat, acids (vinegar), and alkali (baking soda). Sometimes the change in color makes them look more appealing. Other times, the change makes them look less appealing. In this activity, you will see, feel, and sometimes taste vegetables prepared with different heating times and ingredients. See for yourself the best way to prepare vegetables you and your family will enjoy eating!
DEMONSTRATION: PERFECT PEAS

This demonstration is an example of how a green pigment, chlorophyll, changes color when cooked. Compare the color of frozen peas to that of canned peas.

1. Open canned peas. Place them in a small bowl along with some of the water in the can.
2. Open frozen peas and place them in a small bowl.

Evaluate the peas by circling the number which best describes what you observe.

<table>
<thead>
<tr>
<th>Color</th>
<th>Least Natural</th>
<th>Most Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Frozen, thawed peas</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2. Canned peas</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Consider your ratings.
Which form of peas is most visually appealing to you?

_________________________________________________________________________________

Using a fork to poke the canned and thawed peas, are there any differences in texture? Why?

_________________________________________________________________________________

_________________________________________________________________________________

Why is There A Difference?

Heat causes changes in texture, color, and nutrients. Heat breaks down the cell walls of plants. When vegetables are heated for an appropriate cooking time, it softens cell walls, making them easier to chew and digest. Excessive heat during cooking or keeping vegetables at hot temperatures for a long time (like when keeping dinner warm for a late family member) causes more severe damage, especially to green vegetables, which have chlorophyll. This leads to unappealing changes in color. With excessive cooking times, vegetables also undergo undesirable changes in texture (get soft and mushy) and lose nutrients (vitamins are destroyed and minerals move into the cooking water, which often gets drained away).
EXPERIMENT 1—CRAZY FOR CARROTS

Predict which form of carrots—fresh, frozen, or canned—has the color, taste and texture you prefer.

1. With vegetable brush, wash one pound of fresh carrots under cool, running water. Peel and cut into bite-sized coins of equal thickness, approximately ¼-inch.

2. Place about one cup of fresh carrots in custard cup or small bowl. Use for taste testing.

3. Place about one cup of fresh carrots in one cup of boiling water. Bring back to a boil as quickly as possible with the lid on. Cook over medium heat until the carrots are fork tender, approximately eight minutes. Place cooked carrots in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.

4. Follow package directions for cooking one cup of frozen carrots. Place in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.

5. Follow label instructions for heating canned carrots using the liquid in the can. Place in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.

6. Using the two-spoon method, taste-test each type of carrot. Record data in the Observation Log.

7. Read the nutrient information provided in the Observation Log for the various forms of carrots. Answer the questions.

CARROT OBSERVATION LOG

Evaluate the carrots by circling the number which best describes what you think.

<table>
<thead>
<tr>
<th>Flavor</th>
<th>Least Appealing to You</th>
<th>Most Appealing to You</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fresh (cooked)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>B. Frozen (prepared)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C. Canned (prepared)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D. Fresh/raw carrots</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Texture

Which carrots have the softest texture? ____________________________

Which carrots have the firmest texture? ____________________________

Color

Which carrots have the most natural color? ____________________________

Which carrots have the least natural color? ____________________________

Fork tender means to cook a food until it is tender enough that it can be easily pierced with a fork or tip of a sharp knife.
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

Evaluate the carrot cooking waters by circling the number which best describes what you observe.

<table>
<thead>
<tr>
<th>Cooking Water Color</th>
<th>None</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fresh (cooked)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B. Frozen (prepared)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>C. Canned (prepared)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Consider your ratings: Which form of carrots do you prefer to eat? _______________________________

Canned Carrots with juice: Some carotene (yellow/orange) pigment leaches into the cooking water. Carotene is not very water-soluble. This only happens when carrots are exposed to high heat for long cooking periods such as in canning. The cooking water in the fresh carrots and frozen carrots will be nearly clear.

NUTRIENTS IN VARIOUS FORMS OF CARROTS

<table>
<thead>
<tr>
<th>CARROTS 100 grams (about 3.5 ounces)*</th>
<th>VITAMIN A, I.U.**</th>
<th>VITAMIN C (MG)</th>
<th>SODIUM (MG)</th>
<th>POTASSIUM (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh (cooked)</td>
<td>17,033</td>
<td>4</td>
<td>58</td>
<td>235</td>
</tr>
<tr>
<td>Frozen (prepared)</td>
<td>16,928</td>
<td>3</td>
<td>59</td>
<td>280</td>
</tr>
<tr>
<td>Canned (prepared)</td>
<td>11,170</td>
<td>3</td>
<td>242</td>
<td>179</td>
</tr>
<tr>
<td>Fresh/raw</td>
<td>16,706</td>
<td>6</td>
<td>69</td>
<td>320</td>
</tr>
</tbody>
</table>

*3.5 ounces by weight, not by liquid measurement. **I.U.= International Units, a unit of measurement.
1. Which form of carrots has the most Vitamin A? ____________________ The least? __________________

2. Why do you think there is a difference? (Hint: Think about the effect of heat on vitamins.) ______________

3. Which form of carrots has the most Vitamin C? ____________________ The least? __________________

4. Considering a single orange has about 90 mg of vitamin C, are carrots a good source of vitamin C? ______

5. Which form of carrots has the most potassium? ____________________ The least? __________________

6. Why do you think this is so? (Hint: Heat does not destroy minerals. Also consider the color of the cooking waters.) _______________________________________________

7. Which form of carrots has the most sodium? ____________________

   Note: Too much sodium can be bad for heart health. Sodium dissolves and can be washed away with water.

8. Describe how you could get rid of some of the sodium in the carrots that have the most: ________________

**EXPERIMENT 2—RADICAL RED CABBAGE**

This experiment shows changes in pigment color. You do not taste the cabbage.

1. Wash a small head of red cabbage under cool, running water. Remove the core. Cut cabbage in half. Cut into strips about ¼ inch wide. Divide the cabbage into four portions.

2. Portion one: Place ¼ teaspoon of baking soda in saucepan with one cup water. Stir to dissolve baking soda. Bring to a boil. Add cabbage, cover, and boil for eight minutes. Place in a small bowl with a little of the cooking water. Label with masking tape/pen.

3. Portion two: Bring one cup water with ½ teaspoon of vinegar to a boil. Add cabbage, cover, and boil for eight minutes. Place in a small bowl along with a little cooking water. Label with masking tape/pen.

4. Portion three: Bring one cup of tap water to a boil. Add cabbage, cover and boil for eight minutes. Place in a small bowl along with a little cooking water. Label with masking tape/pen.

5. Portion four: Leave raw to observe contrast between raw and cooked forms.

**RED CABBAGE OBSERVATION LOG**

Evaluate the cooking water by circling the number which best describes what you observe. You do not need to taste the cooked cabbage samples.

<table>
<thead>
<tr>
<th>Color Cooking Water</th>
<th>None</th>
<th>Highly Colored</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cooked w/ baking soda</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2. Cooked w/ vinegar (acid)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3. Cooked plain</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

Texture
1. Which form of cabbage has the softest texture? _______________ The firmest? _______________
2. Which do you think would be most appealing to eat? _______________________________________

Color
1. Which form of cabbage has the most natural and appealing color? _____________
2. Which form of cabbage has the least natural and appealing color? ______________________________
3. Consider your ratings of color and texture. Which form of cabbage is most visually appealing? __________

Talk It Over

SHARE
1. Describe what you did that changed the flavor and texture of carrots.

________________________________________________________________________________

2. Describe what you did that changed the color and texture of red cabbage.

________________________________________________________________________________

3. Describe the differences in the cooking water of carrots and red cabbage.

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
REFLECT / PROCESS

1. How does heat change vegetables?

________________________________________________________________________________
________________________________________________________________________________

2. Which pigments, carotene or anthocyanin, are most soluble in water? Hint: Look at the amount of color in the cooking water.

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

GENERALIZE

Have you ever eaten cooked vegetables that did not appeal to you because of their color or texture? Thinking about what you saw today, what do you think caused the undesirable changes to the vegetables?

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

Terms: vegetable processing, pigments, phytonutrients, chlorophyll, carotenoids, carotenes, anthocyanins, flavonoids, pH, acid, base, alkali, blanching
APPLY
Thinking about the demonstration and experiments, how would you cook fresh broccoli or frozen green beans to maintain taste, texture, appearance, and nutrient value?
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

BE A FOOD SCIENTIST

Pigments give fruits and vegetables beautiful, bright colors. During cooking, it is easy to see how some pigments react to heat and the addition of acid (vinegar) or alkali (baking soda), changing their color.

Carotenoids
Carotenoids are bright yellow, red, or orange pigments. There are over 600 known carotenoids. Many carotenes [kar-uh-teenz] have important roles in protecting human health. Some carotenes are converted to vitamin A in the body. Carotenes are only slightly affected by cooking or adding acid or alkaline ingredients. Their color is stable, therefore it is easy to prepare vegetables, such as carrots and winter squash, with a desirable color.

Are the carrots in this picture real? Investigate “Colorful Carrots” and the role pigments play in the food we eat at: http://www.ars.usda.gov/is/ar/archive/nov04/carrot1104.htm
Chlorophyll
Chlorophyll is a green pigment plants use for photosynthesis. In the early stage of cooking green vegetables, the chlorophyll brightens in color. This is because the heating action removes air from the plant tissue and the underlying bright green of chlorophyll is more visible. During processing in frozen food plants, this short, initial cooking is called blanching. Blanching intensifies the color so that when you open a package of frozen peas, broccoli, spinach, or green beans, the color is bright. Canned versions are often a yellow-green color due to the heat and length of processing.

Correctly cooking green vegetables keeps chlorophyll a bright green. If green vegetables cook too long or with high heat as in commercial or home canning, chlorophyll changes from bright to an olive green color.

Overcooking changes the chemical structure of chlorophyll, as does the addition of acid and alkali ingredients. The changes in chemical structure result in color change. Because of the changes that happen to chlorophyll in cooking, it requires knowledge and skill to prepare green vegetables so that they are bright green and have a desirable texture.

Anthocyanins
Anthocyanins are in red, blue, and purple vegetables and fruits. They are water-soluble pigments. During cooking, some of the pigment (color) spreads through the cooking water. Adding an acid such as lemon juice or vinegar turns anthocyanins bright red. Adding baking soda (alkaline) turns the pigment blue-green. Recipes for cooking red cabbage always contain acidic ingredients such as vinegar, lemon juice, or other fruit juices so cabbage has an appealing color.

Note: Most tap water in the US is slightly alkaline. If used to cook red cabbage, without the addition of acid ingredients, it makes an undesirable texture and color, i.e. blue/purple.

Acid and Alkali Also Affect Cooked Vegetable Texture
Cooking vegetables with an acid (e.g. vinegar or lemon juice) maintains firmness. Cooking with an alkali (e.g. baking soda) softens the vegetables. You’ll notice that red cabbage with acid feels very firm, while the red cabbage with baking soda is soft and mushy. Acids and alkali may alter pigment color, texture, and flavor. They have limited use when cooking fruits and vegetables.
The Nutritional Value of Vegetables

Knowledge and practice of these concepts is important to prepare vegetables that are nutritious and the whole family will enjoy eating! Nutrition experts recommend most American adults and youth need to eat 2½ to 3 cups of vegetables each day to be healthy and manage weight. Vegetables are rich in vitamins, minerals such as potassium, fiber, and phytonutrients. Some pigments are phytonutrients, which have many health benefits. Experts recommend eating a “rainbow of colors” to get a wide variety of phytonutrients.

ARE FROZEN AND CANNED VEGETABLES A GOOD NUTRITIONAL CHOICE?

Heat, air, and light gradually destroy some vitamins and phytonutrients. Therefore, cooked vegetables and fruits may have fewer vitamins than fresh. However, many times canning and freezing processing plants are in or near fields where fruits and vegetables are harvested. Within minutes of picking, produce may be canned or frozen, thus preserving nutrients and making a high quality product. Compare this to the long journey fresh produce takes from the field to the table. Experts estimate that many foods travel an average of 1,200 miles from farm to table. Consider the conditions along the route—heat, air, and light—all of which damage some nutrients. At the grocery store, the fresh produce is stored, then displayed for a length of time while being exposed to more air and light. After purchasing, it may sit in someone’s refrigerator for a long time before being eaten. All the while, nutrients degrade. Thus, canned or frozen produce may have as much or more vitamins as fresh.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD SAFETY SPECIALIST

Food safety specialists make sure our food is wholesome and safe. “Safe” means free from contamination or bacteria and viruses that cause illness. In food processing, they apply government regulations to food and food products from the farm to the table. Food safety specialists working for food processors often develop, implement, and evaluate HACCP programs. HACCP stands for Hazard Analysis and Critical Control Points. HACCP is a set of processes that identify possible food safety hazards and controls them. HACCP along with Good Agricultural Practices (GAPS) are part of food safety in fruit and vegetable growing, harvesting, storage, processing, and transporting. HACCP also comes into play in food product manufacturing, bakery operations, meat and seafood processing, and grocery stores.
COOKING UP FOOD SCIENCE AT HOME

Would you like to cook green vegetables, such as broccoli, so that the color, taste, and crunch are just right? Do this activity and you’ll be an expert, ready to teach others in your home how to cook perfect green vegetables!

Fruits and vegetables get their wide array of beautiful colors from pigments. One pigment, chlorophyll, is green. When cooked correctly, chlorophyll remains a bright green. If green vegetables cook too long, the chlorophyll changes into another compound that has an olive/yellow green color. Adding ingredients such as lemon juice or baking soda makes a difference in the texture as well as the color of green vegetables. Cooking with an acid (e.g. vinegar, lemon juice) maintains firmness. Cooking with an alkali (i.e. baking soda) softens the tissue of vegetables.

Materials List

- **Supplies**: Paper towels, hand soap, dish soap, tasting spoons, metal fork with sharp tines for testing doneness of vegetables
- **Equipment**: Sauce pan with lid, pot holders, small bowls or custard cups, knife, cutting board, measuring spoons, clock or timer
- **Food**: Medium-size head of broccoli, salt, vinegar, baking soda, water

Personal Safety

- Before beginning each activity, clean and sanitize kitchen surfaces, cutting boards, etc. Wash hands with soap and warm water for 20 seconds. Dry with a paper towel.
- Use caution when working with hot liquids and equipment; have adult oversight.
BROCCOLI PREPARED THREE WAYS—YOU CHOOSE!

Compare the effect of heat, cooking time, and the addition of acid and a base on chlorophyll.

Wash fresh broccoli head under cool, running water. Cut into three portions of about equal size.

Variable 1
1. Bring one cup water to a boil.
2. Reduce heat.
3. Add broccoli, simmer first three minutes with lid off, then add lid, cook just until tender, about 5 more minutes. Test doneness by piercing broccoli with fork. Test frequently; DO NOT OVERCOOK.
4. Place in small bowl along with a small amount of cooking water.

Note: Salt is used to enhance flavor; it does not interact with the chlorophyll. Leaving the lid off for a few minutes at the beginning of cooking allows naturally occurring acids to escape with the steam so they don’t react with the chlorophyll; thus the broccoli will retain its bright color.

Variable 2
1. Bring one cup water with ¼ teaspoon of baking soda to a boil.
2. Reduce heat.
3. Add broccoli and simmer with lid on for 8 minutes. Place in small bowl along with a little of the cooking water.

Variable 3
1. Bring one cup water with ½ teaspoon of vinegar to a boil.
2. Reduce heat.
3. Add broccoli and simmer with lid on for 8 minutes. Place in a custard cup or small bowl along with a little of the cooking water.

Describe the effects of the different variables on color and texture; you do not need to taste them.

<table>
<thead>
<tr>
<th>COLOR</th>
<th>TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1—Plain Water</td>
<td></td>
</tr>
<tr>
<td>Variable 2—Baking Soda</td>
<td></td>
</tr>
<tr>
<td>Variable 3—Vinegar</td>
<td></td>
</tr>
</tbody>
</table>
PUTTING YOUR KNOWLEDGE TO WORK

Describe what you did that changed the color, taste, and texture of broccoli. [Use the terms heat, acid, alkali, chlorophyll, and pigment.]

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

After tasting and touching, which form of broccoli did you prefer and why?

_________________________________________________________________________________
_________________________________________________________________________________

Did You Know?  Broccoli is one of the most nutritious vegetables you can buy! It is packed with calcium, vitamin C, and phytonutrients that may help protect you from cancer.
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

**What Happens from a **FOOD SCIENTIST’S **Point of View**

The Chemical Reactions

- **Cooking in Water Only:** Chlorophyll does not change
- **Cooking in Water + Baking Soda:** Chlorophyll changed to Pheophytin
  Alkaline Cooking Water
- **Cooking in Water + Vinegar:** Chlorophyll changed to Pheophytin
  Acidic Cooking Water

Special Note: Chlorophyll can also be changed to a dull olive-green color by overcooking, holding vegetables at high temperatures for long time periods, and by the high heat of canning. Chlorophyll chemically changes to pheophytin and/or pyropheophytin.

**The Physical Reactions**

- **Cooking in Water Only:** Color brightens, natural green
- **Cooking in Water + Baking Soda:** Color intensifies, bright green
- **Cooking in Water + Vinegar:** Color is olive-green

**What You SEE & What You FEEL**

**What You SEE**

**What You FEEL**

**The Physical Reactions**

- **Cooking in Water Only:** Color brightens, natural green
- **Cooking in Water + Baking Soda:** Color intensifies, bright green
- **Cooking in Water + Vinegar:** Color is olive-green

**Virtual Fun**

On the Food Science website, www.4-H.org/curriculum/FoodSci, you’ll find lots of additional resources for this unit! See videos on how carrots and peas are harvested and processed, learn how phytonutrients are important to human health, look up the nutrients in your favorite foods at the U.S. Department of Agriculture Nutrient Database, and discover how food safety practices are established to make sure your food remains fresh all the way from the farm to your table.
APPLES CAN BE COOKED INTO A SOFT SAUCE OR FIRM RINGS.
HOW MIGHT SUGAR AFFECT THIS PROCESS?

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”
Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.
My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

BE SAFE! Follow safe practices for handling the knives and stove or hotplate. Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds, before handling produce. Wash apples thoroughly under cool, running water. Wash and sanitize area where produce will be prepared, as well as the cutting board and knives. Visit www.FightBac.org for tips and handouts regarding food safety.
WHAT WILL WE DO?
You get to see how osmosis and diffusion affect fruits and vegetables when they are raw and cooked. Sometimes, you may want cooked fruit or vegetables to be soft or, at other times, slightly firm. You’ll see firsthand that the time at which sugar is added in the cooking process makes a difference in the final texture of the food. You’ll make apple sauce, apple rings, and rehydrate dried fruit using the food science principles of osmosis and diffusion.

WHAT DO WE NEED TO KNOW?
Have you ever considered the many ways in which fruit can be prepared? For instance, apples can be turned into sauce or pie filling, or into semi-soft rings, or made into crisp chips or chewy leather, to name a few. The basic food science principles of osmosis and diffusion play a role in food processing. Osmosis happens mostly with raw fruits and vegetables. Diffusion happens mostly in cooked fruits and vegetables after the cell wall has been damaged by heat.

PLANT CELLS
You may remember from Activity 3.1 that plant cells have a cell wall and cell membrane that surround the contents of the cell. The cell membrane is pressed close to the cell wall, both of which give strength and structure to fruits and vegetables. The cell membrane is semi-permeable, which means that under some conditions, water can move across the membrane.

Cooking changes the cell wall of fruits and vegetables eventually damaging the cell membrane. Once damage occurs, water, sugar and salt can pass into and out of the fruit and vegetable cells. Length of cooking time and addition of sugar or salt during or after cooking changes texture and flavor. You’ll learn more as you experiment with diffusion and osmosis during the activity.
UNDERSTANDING OSMOSIS!

Osmosis is the movement of water across a semi-permeable membrane from an area of lower concentration to an area of higher concentration. In food science, osmosis occurs as the result of sugar and salt concentrations that influence the movement of water into and out of a cell. The unequal concentrations of things like sugar and salt create a pressure called osmotic pressure. The diagram shows what osmosis looks like using sugar in water as an example. The red dots represent sugar molecules. Water moves across the semi-permeable cell membrane, decreasing the pressure. Count the blue dots representing water molecules on the left and right sides of each drawing. Water molecules are pulled, via osmotic pressure, to the area with the most sugar, on the left. Note some water molecules remain on the right side, but fewer of them.

Count the blue water molecules in each section of the beakers.
EXPERIMENT 1: OSMOSIS IN CUCUMBER AND APPLE SLICES

Observe osmosis in raw vegetable slices.

**Ingredients:**
- 1 cucumber
- 1 apple
- Salt
- Sugar

**Directions:**
1. Wash cucumber and an apple under cool, running water.
2. Cut three cucumber slices about ¼-inch thick. Cut three apple slices about ¼-inch thick.
3. Put one slice of each on three plates.
   - Variable 1: Generously sprinkle both the slices on one plate with salt. Label “Salt Treatment”
   - Variable 2: Generously sprinkle both the slices on one plate with sugar. Label “Sugar Treatment”
   - Variable 3: Do not salt or sugar the slices on one plate. Label “Untreated”
4. After 15 minutes, compare and contrast the untreated slices with the salted and sugared slices.

Describe the surface of the salted cucumber: _________________________________________________
Describe the surface of the sugared cucumber: _________________________________________________
Describe the surface of the untreated cucumber: _________________________________________________
Describe the surface of the salted apple: ____________________________________________________
Describe the surface of the sugared apple: __________________________________________________
Describe the surface of the untreated apple: _________________________________________________

Which samples show the process of osmosis? _________________________________________________

**Why does this matter?** A special kind of pressure, called osmotic pressure, is created as a result of adding salt and/or sugar. Osmotic pressure causes movement of water across the semi-permeable cell membrane. Removing water from vegetables in this way helps them to make a less watery final product, such as cucumbers in sour cream or eggplant parmesan. Removing water like this also helps the vegetable retain its shape. At other times, a watery product is desirable. Sugar is often added to sliced strawberries to make them juice.
UNDERSTANDING DIFFUSION!

1. Put several ice cubes into a clear glass 2-cup measuring cup. Fill with water to the 1 ½ cup line.
2. In a saucepan, heat 1 ½ cups of water until almost boiling. With adult supervision, carefully pour the hot water into another clear glass 2-cup measuring cup. Have two learners simultaneously add 2 drops of food coloring to each glass. Observe. Compare and contrast how the food coloring moves throughout the cold water and hot water.

Describe the rate at which food coloring moves throughout the cold water:____________________________

Describe the rate at which food coloring moves throughout the hot water:____________________________

Why do you think the rate of diffusion is faster in one sample than the other? _________________________
____________________________________________________________________________________

As opposed to osmosis, diffusion mostly occurs after fruits and vegetables are cooked or heated. During heating, the cell walls and membranes are damaged so their structure changes. Water, salt, and sugar can then move into and out of the cells. Diffusion is the mixing or spreading of molecules equally throughout a mixture. Ingredients that are diffusing go from an area of high concentration to an area of lower concentration. For instance, when sugar dissolves in water, the molecules of sugar mix in with water molecules. Sugar molecules move throughout the water until equilibrium is achieved (see illustration). Equilibrium means that the molecules are evenly spread throughout the water.

**Diffusion**

Sugar cube is dropped into water.  
Molecules of sugar separate from the cube.  
Molecules of sugar continue to separate from the cube and move throughout the water.  
Eventually the cube dissolves—all sugar molecules have become evenly distributed in the water.
FUN WITH FRUIT—VARY THE TEXTURE AND THE FLAVOR!
The following two recipes contain apples and water, but one recipe also has sugar. These experiments show how the amount of sugar in the cooking water makes differences in the texture and flavor of the apples. The differences occur primarily as a result of diffusion.

EXPERIMENT 2: APPLESAUCE—OSMOSIS AND DIFFUSION
Apples contain naturally occurring fruit sugar called fructose. They usually have about 15% fruit sugar. Sweeter apples have more fructose than tart apples.

Ingredients
2–3 medium apples, peeled, cored and cut into 1½ inch chunks
½ cup water

Directions
1. Wash and prepare apples.
2. Put apples and water in a saucepan. Cover and cook apples over medium heat until they begin to break down, 15-20 minutes.
3. Check and stir occasionally to break up chunks.
4. Remove from heat.
5. Put in tasting bowl.

May be served hot, warm, at room temperature, or chilled. For food safety purposes, do not leave at room temperature for more than two hours. Can be covered and refrigerated for up to five days.

Use proper tasting technique to taste the applesauce.

Describe the texture of the applesauce:
_________________________________________________________________________________
_________________________________________________________________________________

Describe the flavor and sweetness of the applesauce.
_________________________________________________________________________________
_________________________________________________________________________________

WHAT’S ON YOUR PLATE? Exploring Food Science
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EXPERIMENT 3: APPLE RINGS—OSMOSIS AND DIFFUSION

How does sugar influence the firmness of cooked fruit?

**Ingredients**
- 2 medium or large apples
- 1 cup sugar
- 2 cups water

**Directions**
1. Wash apples.
2. Core apples using an apple corer if one is available.
3. Cut each apple into ½-inch thick rings.
4. If not cored, remove seeds and cores by putting apple slice flat on cutting board and cutting around seeds and core with a small knife.

**Variable 1**
1. Place 1 cup water in small saucepan.
2. Put half of the apple rings into water.
4. Carefully lift apple rings out of cooking water and arrange on a plate labeled Variable 1.
5. Save some of the cooking water in a small bowl for tasting. Label Variable 1.

**Variable 2**
1. Combine 1 cup water and 1 cup sugar in small saucepan.
2. Stir over moderately low heat until sugar is dissolved.
3. Put half of the apple rings into the sugar water solution.
5. Carefully lift apple rings out of cooking water and arrange on a plate labeled Variable 2.

Cut apple slices into pieces so everyone can sample each variable. Using proper tasting technique, also taste the cooking water for each variable after it has cooled. Record your observations in the Observation Log.
### APPLE RING OBSERVATION LOG

<table>
<thead>
<tr>
<th>THE APPLES</th>
<th>VARIABLE 1 WATER</th>
<th>VARIABLE 2 WATER + SUGAR 1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SHAPE</strong></td>
<td>Describe the shape. Did the apple rings hold their shape? Do they look like a firm ring, or a misshapen floppy ring?</td>
<td></td>
</tr>
<tr>
<td><strong>TEXTURE</strong></td>
<td>Taste the apple slice and describe the texture. (Soft, mushy, firm? Use your own words.)</td>
<td></td>
</tr>
<tr>
<td><strong>FLAVOR</strong></td>
<td>Describe the flavor. Taste an apple ring. Is it bland, flavorful or sweet? Does the flavor of the apple come through?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THE COOKING WATER</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLAVOR</strong></td>
<td>After the cooking water has cooled, taste it. Describe the flavor. Is it bland, flavorful or sweet? Can you taste the flavor of the apple?</td>
</tr>
</tbody>
</table>
EXPERIMENT 4: REHYDRATION OF DRIED FRUIT—DIFFUSION

This experiment uses dried apricots or plums, which are also called prunes. Dried fruit has been dehydrated—its water content greatly decreased. As a result of less water, the dried fruit has a higher concentration of sugar than fresh fruit.

Variable 1 needs to be started at least a few minutes before Variable 2 because the amount of water and cooking time is determined by Variable 1.

Ingredients
16 dried plums or apricots
12 tablespoons sugar
Water

Directions
Variable 1—Sugar Added After Cooking
1. Place eight dried plums or dried apricots in a small saucepan.
2. Fill a one cup measuring cup with water. Slowly add just enough water to cover the fruit. Record the amount of water it took to cover the dried plums.
3. Using medium heat, bring to a simmer (do not cover). Note the time that dried plums start to simmer.
4. Cook until tender when pierced with a fork or tip of sharp knife. Note time.
5. Remove from heat.
6. Add six tablespoons of sugar and stir gently to mix.
7. Pour cooking water into a small bowl. Place plums/apricots on a plate labeled "Variable 2" for observation and testing.

Amount of water: ___________
Cooking Time Start: ___________ End: ___________ Length of Time: ___________
Variable 2—Sugar Added Before Cooking

1. Measure out the same amount of water as used for Variable 1. Pour into small saucepan.
2. Add six tablespoons of sugar, mix to dissolve sugar.
3. Place eight dried plums or apricots into sauce pan.
4. Using medium heat, bring to a simmer (do not cover). Note time that dried fruit starts to simmer.
5. Cook for the same amount of time as in Variable 1. Note time.
6. Remove from heat.
7. Pour cooking water into a small bowl. Place plums/apricots on a plate labeled “Variable 2” for observation and testing.

Amount of water: ___________
Cooking Time Start: ___________ End: ___________ Length of Time: ___________

Cut fruit into pieces if necessary so everyone can sample each variable.

DRIED FRUIT OBSERVATION LOG

<table>
<thead>
<tr>
<th>THE DRIED FRUIT</th>
<th>VARIABLE 1 SUGAR ADDED AFTER COOKING</th>
<th>VARIABLE 2 SUGAR ADDED BEFORE COOKING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPEARANCE</strong>: Describe the appearance of the fruit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TEXTURE</strong>: Taste and describe the texture (Soft, mushy, firm? Use your own words.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FLAVOR</strong>: Taste and describe the flavor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>THE COOKING WATER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FLAVOR</strong>: Taste the cooking water. Describe the flavor. Is it bland, flavorful, sweet, or overly sweet? Can you taste the flavor of the dried plums/apricots?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SHARE

1. What made a difference in whether the food coloring spread throughout the water quickly or slowly?
________________________________________________________________________________

2. Compare and contrast the differences between treated and untreated cucumber slices and apple slices. What do you think is the reason for the differences?
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

3. Describe what you did that changed the flavor and texture of apple rings.
________________________________________________________________________________

4. Which apple rings held their shape the best?
________________________________________________________________________________

5. Describe the taste of the cooking water of the apple rings.
________________________________________________________________________________
________________________________________________________________________________

6. Describe what you did that changed the color and texture of dried fruit.
________________________________________________________________________________

7. Describe the differences in the texture of the dried fruit. (Differences will be small.)
________________________________________________________________________________
REFLECT
1. How do you use/control sugar to make cooked fruit firmer and keep its shape?

________________________________________________________________________________

2. Why does this help fruit stay firmer and keep its shape?

________________________________________________________________________________
________________________________________________________________________________

3. Why did the fruit cooked without sugar get soft and lose its shape?

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

TERM & Concept Discovery
Terms: Fruit, osmosis, osmotic pressure, diffusion, sugar, cell structure, cell membrane, semi-permeable membrane, salt, solution, permeable, simmer
GENERALIZE
1. Considering what you have learned in this activity, when is sugar necessary for cooking fruit?

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

2. Describe the difference between diffusion and osmosis.

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

APPLY
Apples ripen and are on sale in the fall. Perhaps your family buys a large amount of apples but everyone gets tired of eating plain apples. How can you prepare them in a healthful way your family might like?

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
OSMOSIS
Now that you know about osmosis, here are a couple of examples of how the concept is used in preparing food.

Strawberries, Sugar, and Osmosis
Sugar, also causes water to shift from inside the cell to the outside. When sugar is sprinkled on sliced strawberries, there is more sugar on the outside than on the inside of the strawberry cells, and osmotic pressure is created. Water moves out of the strawberry cells and the strawberries produce “juice.” Many people prepare fresh strawberries using this principle of osmotic pressure.

Eggplant, Salt—Osmosis and Diffusion
In a cookbook or online, find a recipe for eggplant parmesan that includes slicing and salting the slices prior to cooking. Why would you do this? Remember osmosis is the movement of water across a semi-permeable membrane prior to cooking which makes permanent changes in the membrane. After these changes, diffusion occurs; salt will diffuse into the cooked eggplant.

Did You Know?
Craisins® Dried Cranberries are made with an osmotic drying process that is not used by food processors very often. Osmotic drying uses a syrup with a high sugar content to osmotically draw water from the cranberries.
Here are a couple of examples of how diffusion is used in preparing food—you did these in the experiments!

Cooking Apples in Water—Applesauce
When making applesauce, a typical recipe calls for cut apples cooked in water. The cells in the apples naturally contain 15% fruit sugar and the cooking water has no sugar. Initially, osmosis occurs until the heat of the cooking water damages the cell wall and semi-permeable membrane. After those are damaged, sugar and water can move freely in and out of the cells depending on concentrations. Diffusion dilutes the concentration of sugar in the apple slice. This inflow of water causes the apple cells to soften or sauce; first with osmosis and then diffusion. Some of the sugar from the apple moves into the cooking water. You may taste a slight sweetness in the cooking water.

Cooking Apples in a Concentrated Sugar Solution—Apple Rings
When cooking apple rings in a highly concentrated sugar solution, the reverse occurs. Because of diffusion, water and sugar move in opposite directions. Water moves from the apple rings to the concentrated sugar cooking solution and sugar in the solution moves into the apple cells, creating equilibrium—similar amounts of sugar in the apple rings and in the water. While the apple rings soften during cooking, the slices maintain their shape.
FOOD SCIENCE AND SUGAR IN COOKING—WHAT’S THE LINK?
For health reasons, it’s a good idea to limit the amount of sugar consumed. However, sugar sometimes plays a functional role in food preparation that goes beyond adding sweetness. Occasionally, sugar is needed to achieve a certain result in food processing and cooking. For instance, omitting the sugar in recipes similar to the ones in this activity would change the structure and texture of the fruit.

LEARN MORE!

VIRTUAL FUN
Watch videos that describe how osmosis and diffusion work in food science. Find out more about dried plums, including recipes and learn how to make dried fruit at home. Visit www.4-H.org/curriculum/foodsci
"I Pledge my Head to clearer thinking,
my Heart to greater loyalty,
my Hands to larger service,
and my Health to better living,
for my club, my community, my country,
and my world."
WHAT'S ON YOUR PLATE?
Exploring Food Science

UNIT 4
BE A FOOD SCIENTIST!

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Unit 4 is just one part of exploring What’s on Your Plate? Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
INTRODUCTION

WELCOME TO WHAT’S ON YOUR PLATE? EXPLORING FOOD SCIENCE!

Why does a muffin rise? Why do some recipes have so many ingredients in common? Why do foods change color during cooking? What can be done to keep them looking good? Have you ever wondered how new foods you see at the grocery store are developed? The idea of food science may be new to you, so take a close look at your next meal. There’s food science and food technology behind every bite you take, all the way from the farm to the end of your fork.

What’s on your plate? It’s a mixture of chemistry, biology, and physics. Exploring food science is a hands-on experience. Doing activities, you will discover and learn the basic building blocks of food science in a kitchen “laboratory.” The activities are more than learning to cook; it’s learning why and how things happen in all kinds of foods: breads, muffins, eggs, fruit, vegetables, cheese, candy, beverages, and more.

This final unit, “Be a Food Scientist,” looks at a day in the life of a food scientist by inviting guest speakers or utilizing videos, creating a new beverage, and experimenting with sugar crystallization and caramelization.

Be sure to check out the other units to learn more about “The Secrets of Baking” in Unit 1, “The Power of Protein Chemistry” in Unit 2, “The Inner Mysteries of Fruits and Vegetables” in Unit 3.

With your Youth Science Journal, you get to conduct experiments, collect and analyze data, practice sensory science (tasting), investigate career opportunities, and amaze your friends and family with what you’ve learned about food! To make sure your experiments come out right, follow the directions carefully. Then take some time to think about what happened in the experiment—doing so will open the doors of food science for you!

Your Youth Science Journal has information in the “Be a Food Scientist” section that will help you understand and remember the concepts behind the experiments—this way you can share it with others. You may even find yourself thinking about a career in food science and food technology.

There’s a special website for you, too. Learn more online and have virtual fun by visiting websites with videos that show you behind-the-scenes food science. Log on to http://www.4-H.org/curriculum/FoodSci or use your mobile device to connect.

Enjoy exploring What’s on Your Plate?!
Imagine you are choosing a career in Food Science and Food Technology! Choose three career options that sound interesting to you and circle them.

**FOOD SCIENCE CAREERS**

- Food Scientist
- Cereal, Dairy, or Meat Product Applications
- FDA/USDA Research Scientist
- Flavor Chemist
- Food Biochemist
- Food Biotechnologist
- Food Chemist
- Food Engineer
- Food Safety Inspector
- Food Microbiologist
- Food Plant Supervisor
- Food Product Developer
- Food Science Professor
- Food Technologist
- Food Toxicologist
- Analytical Testing Laboratory Scientist
- Meat Scientist
- New Technologies
- Packaging Specialist
- Plant Operations Management
- Project Leader
- Public Health Official—Food Safety
- Research and Development
- Quality Assurance Officer
- Sales Manager
- Scientific and Regulatory Affairs
- Food Ingredient Sales
- Sensory Evaluation
- Technical Sales

Source: Washington State University and University of Idaho School of Food Science
WHAT WILL WE DO?
In this activity, you get to do in-depth career exploration of food science and food technology careers. Did you know there is a shortage of young people choosing careers in science? This includes careers in science, technology, engineering, and applied science careers such as food science and food technology. There is a constant need for new scientists, including food scientists and food technologists.

Your group’s facilitator will arrange for a discussion with a food science professional, or videos of interviews with food scientists.

WHAT DO WE NEED TO KNOW?
An amazing array of sciences is involved in producing food. Think about food science and food technology as “applying” basic science to food—sciences such as chemistry, biology, microbiology, biochemistry, engineering, and mathematics. Food science and food technology are the applications of science to food product research and product development, food manufacturing, packaging, food safety and sanitation, food transportation, labeling, advertising, and marketing. Food science careers extend from the farm to our tables.

Food Science vs. Food Technology—What’s the Difference?
The Institute of Food Technologists (IFT) defines these terms as follows:

- **Food Science** is the discipline in which engineering, biological, and physical sciences are used to study the nature of foods, the causes of deterioration, the underlying principles, and the improvement of foods for the consuming public.

- **Food Technology** is the application of food science to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious, and wholesome food.

Source: Institute of Food Technologists
**ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)**

**Information Log**
Fill out the information log before and after the discussions or watching the videos.

<table>
<thead>
<tr>
<th>WHAT DO I WANT TO LEARN?</th>
<th>WHAT DID I FIND OUT?</th>
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To find out more about a possible career in food science you could find a food scientist to visit, learn more about food science programs at a university, or search reliable Internet resources such as those listed at www.4-H.org/curriculum/foodsci. To find out more about a food science career, write an action plan with at least three steps and list three resources you’ll use.

_________________________________________________________________________________
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_________________________________________________________________________________
SHARE
1. What did you like about the activity your group did?
_______________________________________________________________________________

2. In your own words, define food science and define food technology.
_______________________________________________________________________________
_______________________________________________________________________________

REFLECT
1. What are several things you found most interesting about careers in food science and food technology?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

2. In what way did the information make you more interested in a food science career than you were before?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

3. Using a scale of 1 to 10, with 1 being least and 10 being most, how much do you think you would like to pursue a career in food science? ____________
What were you thinking when you chose that number?
_______________________________________________________________________________
_______________________________________________________________________________

WHAT’S ON YOUR PLATE? Exploring Food Science
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ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

GENERALIZE
1. Describe several steps you can do now to prepare for a career in science, food science, or food technology.

_______________________________________________________________________________
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_______________________________________________________________________________
_______________________________________________________________________________
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_______________________________________________________________________________

APPLY
1. Someone asks you what career you are considering for the future. What will you tell them?

_______________________________________________________________________________
_______________________________________________________________________________

2. What other job within the realm of food science would you like to find out more about? Make a plan of how you will learn more.

_______________________________________________________________________________
_______________________________________________________________________________

Terms: Food science careers, food technology, career preparation, career path, food technology, STE education, VoIP service, International Food Technologists (IFT)
Get Started While in High School
To be competitive for college admission, it is vital to have the correct preparatory high school coursework. Talk with high school counselors, and if possible, visit a nearby university offering degrees in food science or food technology; talk with faculty members and students about careers and programs. It’s never too early to explore a career in food science and food technology.

Typical Coursework in College
A Bachelor of Science degree in Food Science and Food Technology includes courses in inorganic and organic chemistry, math and calculus, statistics, food chemistry, quantitative analysis, microbiology, nutrition, biochemistry, physics, food law, food microbiology, food processing, sensory analysis, communication, and food engineering.

Find a list of universities worldwide with food science and food technology undergraduate degree programs recognized by the IFT (Institute of Food Technologists). The link is maintained at: www.4-H.org/curriculum/foodsci
FOOD SCIENCE AND NUTRITION—WHAT’S THE LINK?
Perhaps you like the idea of food science, and you also like the idea of eating healthy foods. These two “likes” can make a very interesting career. A nutritionist or registered dietitian may help guide food scientists to make foods lower in calories, fat, sugar or salt, or higher in beneficial nutrients such as phytonutrients, healthy fats, fiber, calcium, or iron.

Registered dietitians complete at least a Bachelor’s degree and an internship. The coursework includes nutrition, food science, math, chemistry, biology, microbiology, and biochemistry. This credential requires an unpaid internship that can range from six to 12 months. Registered dietitians then take a national exam.

LEARN MORE!
VIRTUAL FUN
To see videos of interviews with food scientists, learn about degree programs, and additional resources on careers in food science and food technology, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
STATEMENT: MY FAVORITE JUICES, TEAS, AND FLAVORINGS COULD BECOME A BEVERAGE SOLD AT THE GROCERY STORE!

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder…” Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder…

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_________________________________________________________________________________
_________________________________________________________________________________
WHAT WILL WE DO?
You will experience how beverage formulations are made—you’ll create a brand new beverage! From beginning ideas to beverage evaluation, you’ll go through the process. You’ll learn about taste, apply principles of flavor, conduct sensory evaluations, and explore packaging, label design, and marketing while creating a new beverage.

WHAT DO WE NEED TO KNOW?
Detecting flavor is complex and involves the taste and smell of food. You have probably experienced being unable to taste foods when having a cold with a stuffy nose. With eyes closed and nose held, it is almost impossible to tell what one is eating. That’s because the sense of smell is vital to the sense of taste. In food science, the “flavor experience” is so complex that it isn’t well understood; food scientists continue to research this issue. Flavor is also influenced by the temperature of food (e.g. warm apple pie tastes sweeter than cold apple pie), texture or mouth-feel, and past experiences with food—either good or bad.

Flavor Principles
Knowledge of several basic flavor principles is necessary to food and beverage development. Use this information to help evaluate the ingredients of your drink.

• SALT can mask bitterness and in small amounts enhance sweetness.
• SUGAR increases sweetness, masks saltiness, and decreases sourness.
• SOUR ingredients, used in small amounts, can increase the tastes of sweetness and saltiness.
• Herbs, spices, and extracts change taste and flavor.
FOOD SCIENTISTS—YOUR ASSIGNMENT TODAY . . .

...is to develop a new low-sugar beverage that includes juice and would be suitable for kids ages 8 to 18. Experts are concerned about the growing number of overweight children. A new, low-sugar beverage that has kid-appeal will sell well and may improve the health of the nation’s youth. Each team will present its beverage to the large group.

EXPERIMENT: BEVERAGE RESEARCH & DEVELOPMENT

A beverage company has hired your team of food scientists to develop several options for a new beverage. They will listen to your presentation about the beverage and taste it, then choose the beverage they will produce. Working in teams of 2 to 4 learners, you will play the roles of both food scientists and marketing consultants. Complete each of the following steps with your team members.

1. Marketplace Research

What’s already on supermarket shelves? What is there plenty of? What is missing? What seems to be selling well? Selling poorly? In a real setting, a marketing consultant would look at sales figures and how much money is produced by each product.
2. **Consumer Research**

Identify consumer needs and wants. What do you and your friends need and/or want to drink? What would taste good? What kind of beverage would other kids want to drink?

_______________________________________________________________________________

_______________________________________________________________________________

3. **Determine Ingredients**

From the ingredients available during this activity, discuss and list the possible ingredients your team will use. How will the Flavor Principles affect the combination of ingredients you are considering?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

4. **Product Creation**

Before making your new beverage, develop the formula for your drink. Discuss and select the type of beverage you want to develop (sweet, sour, etc.). Select possible ingredients.

- You must use at least three ingredients.
- Limit sugar to 1 teaspoon per cup or less.
- Be sure to consider the Flavor Principles.

Your team should use a 2-cup measuring cup—this is the maximum amount of drink developed during the activity. List ingredients and amounts you plan to use.

<table>
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<tr>
<th>LIST OF INGREDIENTS</th>
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Once your team agrees on the formula, make the beverage. Using tasting spoons (using the two-spoon method for tasting during beverage development), taste the beverage within your small team. What do you think about your new beverage?

_______________________________________________________________________________
_______________________________________________________________________________

Adjust flavorings if desired. If you adjust the flavorings, be sure to make a note of it in your list of ingredients. What changes, if any, did you make? Why?

_______________________________________________________________________________
_______________________________________________________________________________

5. Packaging

Working with your team, come up with a beverage name. __________________________

As a team, develop a design for the front label using name of beverage, pictures, and/or graphics. Draw the final design on a separate piece of paper to show during presentation to the larger group. List your design ideas.

_______________________________________________________________________________
_______________________________________________________________________________
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6. Marketing and Advertising Plan

With your team members, develop a brief but creative marketing and advertising plan for your new product.

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7. Presenting Your New Beverage Idea
List at least three points you will make in a presentation about your new beverage (each member of the team may present various aspects about the beverage). Write these points on 3x5 cards to use for your team’s presentation (2 minutes or less). Consider such things as what makes it different from other products already on the market, explain the health benefits of the beverage, talk about why you believe your target market (youth ages 8–18) will like it, and creative ideas you have for marketing and advertising the beverage.

_______________________________________________________________________________
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8. Consumer Testing, Ranking, and Sensory Evaluation
• Set up for Consumer Testing and Sensory Evaluation: On a tray, set out a cup for each learner and divide your beverage equally between the cups. Distribute to large group.
• Give a persuasive presentation (2 minutes or less) about your beverage to the large group.
• Make sure everyone gets to taste and rank your drink.

EVALUATION OF NEW BEVERAGE
Use a scale of 1 to 5, with 1 being least desirable and 5 being most desirable.

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ACTIVITY 4.2: Make a New Beverage (cont.)

Identify your favorite beverage from the beverage evaluation: ______________________________

What did you like most about your favorite beverage? ________________________________

Identify your least favorite beverage: ____________________________________________

Why was it your least favorite? ________________________________________________

What might you change to improve your beverage? ______________________________

Which beverage (besides your own) do you believe had the best marketing and advertising plan?
____________________________________

If you were awarding a beverage contract to one of the teams, which one would you choose (besides your own) and why?
____________________________________
____________________________________
____________________________________
____________________________________

SHARE

Briefly describe how you determined which ingredients to use.
____________________________________
____________________________________
____________________________________
____________________________________
____________________________________
ACTIVITY 4.2: Make a New Beverage (cont.)

REFLECT
How do sugar, salt, and sour ingredients change the flavor of beverages?
_________________________________________________________________________________
_________________________________________________________________________________

What kind of flavor did you want your beverage to have? Did your beverage turn out how you expected?
_________________________________________________________________________________
_________________________________________________________________________________

How could you determine whether a beverage would be liked by most kids in the country?
_________________________________________________________________________________
_________________________________________________________________________________

TERMS & CONCEPT DISCOVERY
Terms: beverage, taste, flavor, sweet, sour, bitter, salty, umami, product formulation, evaluation, marketing

GENERALIZE
What things besides taste need to be considered when making a new beverage?
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
APPLY

Your school is raising funds for a special field trip. Your group needs something to sell at the fundraiser. School wellness policies discourage selling less-than-healthy food such as soda. Your group decides to make a new low-sugar beverage, with all sales proceeds going to the special event. You speak with the principal, several teachers, and school food service staff—everyone is willing to help you. You go to the county health department and get a “Food Handler’s Permit” so you know how to prepare food safely to reduce the risk of foodborne illness. What steps will your group take to develop and sell a beverage for your school?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Food and Beverage Preferences

BE A FOOD SCIENTIST

CREATE A BEVERAGE

Taste Starts with the Tongue

The surface of the tongue has thousands of taste buds. Messages are sent from the tongue to the brain then the brain interprets the taste. There are five taste sensations: Sweet, salty, sour, bitter, and umami (ü’-mā-mē). You may not be familiar with umami taste sensation. It is the deep, mouth-filling flavor experienced when eating foods such as meat, mushrooms, aged cheese, or ripe tomatoes. Umami is sometimes described with the word “savory.”
There are many things at play that determine if you like certain foods and beverages. Sight, smell, taste, touch, and hearing influence our food and beverage choices. Examples include the crunch of a fresh carrot, the sight of juicy watermelon, the bittersweet taste of chocolate, the sound of popcorn popping in a movie theater, the mouth-feel (touch) of drinking a carbonated beverage, and the smell of a roasting turkey at Thanksgiving. Literally, all of our senses contribute to positive and negative perceptions of food and beverages.

**Developing a New Beverage**
This is a summary of the steps essential in developing a new product such as a beverage.
1. Explore the existing market
2. Identify consumer needs and wants
3. Select possible ingredients
4. Develop the beverage:
   - Determine a formula
   - Make the beverage
   - Taste-test and adjust flavorings
   - Decide on a name
   - Design a label
   - Develop a marketing plan
5. Consumer testing and ranking

**FOOD SCIENCE, NUTRITION, AND JUICE DRINKS—WHAT’S THE LINK?**
With today’s emphasis on maintaining a healthy weight, more people are looking to drink low-calorie beverages. Juice usually has a lot of calories, but juice drinks may have a lot or a little, depending on what food scientists created in the laboratory.

When is it good to choose 100% juice and when is it appropriate to choose a fruit drink? It depends on the purpose of the beverage you select. If you drink juice for the vitamins and minerals that juice has, you want to look for a beverage that states “100% Juice” on the label. Otherwise, you are paying for juice, water, and usually added sugar—and getting just a fraction of the nutrients you would otherwise get in juice.
Juice is a concentrated food, so experts recommend limiting it to 12 ounces per day. It’s concentrated because it takes a lot of fruit or vegetables to make a single glass of juice. That means you’re getting many vitamins and minerals, but also a lot of calories. For instance, a typical medium-sized orange has just 60 calories, whereas an 8-ounce glass of juice has twice that many—about 120 calories. Consider juice as a food, rather than a thirst-quencher.

If you’re looking for something to drink and quench your thirst rather than provide nutrients, then a juice drink might be a good choice as long as it has little or no added sugar. For instance, water with 5% juice would be refreshing with the juice providing a bit of flavor. However, many times sugar or high fructose corn syrup is added to juice drinks, in which case the drink provides lots of calories and few nutrients. The nutrient content of juice drinks varies greatly depending on how much juice is in the product and whether any extra nutrients were added. Check the label—avoid added sugar and make a smart choice when reaching for a drink.
STATEMENT: SUGAR IS THE MAIN INGREDIENT IN SOFT AND HARD CANDIES.

Pause for a moment and think about this statement and the pictures. Ask as many questions as you can about these. Start your first question with, “I wonder ….” Don’t stop to discuss, answer or judge any questions. Write them here then share with your group.

I wonder...

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

Because of the high cooking temperatures of candy, your facilitator is in charge of heating and handing the hot sugar solutions. Take precautions. Have pot holders and hot pads available. Avoid serious burns!

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize cooking area. Visit www.FightBac.org for tips and handouts regarding food safety.
WHAT WILL WE DO?
This activity introduces you to crystallization. Crystallization is an important, basic concept and skill for food scientists. Crystallization is an exciting process to watch! You get to apply the science of crystallization by making fondant, a crystalline candy, and caramelizing sugar to see how non-crystalline candies are made. Crystallization is a combination of science and art—knowledge of the process alone won’t make you an expert at crystallization. In addition, experimentation, observation, and skill are also important to successfully make candy.

WHAT DO WE NEED TO KNOW?
Have you ever wondered about the difference between soft candies, like those pictured above, and hard candies such as lollipops? Some of the creamy candies are made with fondant. Fondant is a crystalline candy formed by super-saturating a sugar solution with heat, then cooling so crystals are formed. In contrast, lollipops are a non-crystalline candy. Non-crystalline candies are cooked to very high temperatures and/or have ingredients that interfere with crystal formation.

Before you start making a crystalline candy, you need to understand sugar solutions and learn more about the solubility of sugar.

DEMONSTRATION: SOLUBILITY OF SUGAR
This demonstration shows two solutions for observation. Here are some terms to know:

**Common terms**

\[ \text{Sugar + Water} = \text{Solution} \]

**Food Science terms**

\[ \text{Solute + Solvent} = \text{Solution} \]

**VARIABLE 1**

**Ingredients**

- ½ cup water
- ¼ cup sugar

**Directions**

1. Place two ice cubes into a glass 1-cup measuring cup. Fill with cool water to the ½ cup measuring line, allow time for ice to melt a little.
2. Add ¼ cup sugar (solute) to the water (solvent) and stir to make a solution.
3. Observe and make notations in Sugar Solubility Observation Log.
VARIABLE 2

Ingredients

½ cup water
¼ cup sugar

SAFETY NOTE: Facilitator is in charge of boiling water. If water is heated in a microwave, be cautious of super heating—remove immediately upon boiling, then wait 1 minute before adding sugar. (Immediately adding sugar may cause the mixture to bubble violently.) Facilitator adds sugar. Learners stir after addition of sugar.

Directions

1. Place ½ cup boiling water into a glass 1-cup measuring cup.
2. Add ¼ cup sugar (solute) to the water (solvent) and stir to make a solution.
3. Observe and make notations in Sugar Solubility Observation Log.

SUGAR SOLUBILITY OBSERVATION LOG

<table>
<thead>
<tr>
<th>Variable 1</th>
<th>Variable 2</th>
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<tbody>
<tr>
<td>Cold water sugar solution</td>
<td>Hot water sugar solution</td>
</tr>
</tbody>
</table>
What is a solution? Use the scientific terms to describe a solution.
_________________________________________________________________________________

What did you observe when comparing the solubility of sugar in cold and hot water?
_________________________________________________________________________________
_________________________________________________________________________________

What do you think would happen if you continued to heat the sugar and water solution?
_________________________________________________________________________________
_________________________________________________________________________________

EXPERIMENT—SUGAR CRYSTALLIZATION
Make fondant to observe crystallization.

Ingredients
2 cups granulated sugar
¾ cup water
2 tablespoons light corn syrup

Directions for Learners
1. Set a large baking sheet or thick, heat-resistant plate on wire rack. Set aside.
2. Combine sugar, water, and light corn syrup in a medium saucepan. Stir until dissolved.
3. Place candy thermometer on side of saucepan. Make sure the bulb is covered by the solution and not touching the bottom or side of the pan.
Facilitator or Adult Takes Over
4. Using medium-high heat, stir constantly to boiling point.
5. WITHOUT stirring, heat to end-point cooking temperature of 237º F/114º C. This is called the soft ball stage. Carefully read thermometer at eye level for accuracy.
6. While heating, if crystals form on the side of pan, use a heat-resistant, damp pastry brush to dissolve the crystals. If these crystals are not removed, they might act as seed crystals and start the crystallization process too soon. Be sure not to let the brush touch the boiling sugar solution; doing so may also start the crystallization process too soon.
7. Carefully pour the mixture onto a baking sheet/large heat-resistant plate to cool. Use a heat-resistant rubber spatula to quickly scrape out saucepan. Do not stir or disturb.
8. Let cool until mixture is warm, but not hot. After 2–3 minutes, test carefully with finger.

Learners Take Over
9. Dampen a heat resistant rubber spatula or wooden spoon. Push the mixture into the middle of the baking sheet/plate. “Cream” or work the fondant in a figure-8 pattern. Continually scrape the fondant into the center, draw a figure-8, then scrape it together again. Mix for 5–10 minutes. The mixture changes from clear to opaque and creamy, then very stiff, crumbly, and difficult to stir.
10. Moisten clean hands and knead the fondant until the mixture is soft and smooth with no lumps. (Kneading technique is described in Activity 1.1 if a reminder is needed.)
11. Place on plate for tasting. Cut a small piece for each learner to sample. Pay attention to the “mouth-feel” of the crystalized sugar.
12. Record observations.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

FONDANT OBSERVATION LOG

<table>
<thead>
<tr>
<th>APPEARANCE</th>
<th>TEXTURE WHEN TOUCHING</th>
<th>TEXTURE IN MOUTH (MOUTH-FEEL)</th>
<th>TASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooled Fondant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DEMONSTRATION: CARAMELIZATION OF DRY SUGAR

Facilitator will do this demonstration. Learners will observe and record in the Observation Log below.

Some non-crystalline candies begin with caramelization. When sugar is heated dry, without water, it caramelizes rather than crystalizes. Nut brittles and caramels are examples of candy formulations using caramelization. Nut brittle recipes include the addition of baking soda. Baking soda (alkaline) reacts with the acid from caramelization, producing carbon dioxide (CO$_2$). The reactions produce acid, caramel color and flavor, and the characteristic “brittleness” of nut brittles. The carbon dioxide bubbles are trapped in the molten sugar, producing a porous end product. Without the carbon dioxide bubbles, the end product would be very dense and hard. Toffee, nut brittles, lollipops, and caramels are examples of non-crystalline candies; these types of candies are also called “amorphous.” Amorphous means the candies lack a crystalline structure. Most amorphous candies are poured to cool and are considered to have no definite shape or form until they are cooled. Recipes for non-crystalline candies contain ingredients and cooking techniques that prevent sugar crystallization. Exposure to high temperatures prevents the sugar from crystalizing during the cooling process; it hardens before crystals have time to form.
## DRY SUGAR CARAMELIZATION OBSERVATION LOG

<table>
<thead>
<tr>
<th>COLOR</th>
<th>APPEARANCE</th>
<th>TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry sugar cooked to clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sugar cooked to light brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sugar cooked to light brown with addition of baking soda</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Why does baking soda produce CO₂ in caramelized sugar?

_________________________________________________________________________________
_________________________________________________________________________________
SHARE
1. How is solution made for fondant?

_______________________________________________________________________________

2. How do you increase the saturation of the solutes (sugar, corn syrup) while making fondant?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

REFLECT
1. Based on your observation from sugar solutions and temperatures, what do you think happened from a food scientist's point of view?

_______________________________________________________________________________
_______________________________________________________________________________

2. Why is end-point cooking temperature of fondant important?

_______________________________________________________________________________

3. What do you think happens as the thick sugar solution for fondant cools on the baking sheet/plate?

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

4. What is the major difference between crystalline and non-crystallize candy?

_______________________________________________________________________________
ACTIVITY 4.3: Chemistry is Sweet (cont.)

5. Give an example of crystalline and non-crystalline candies?
_______________________________________________________________________________
_______________________________________________________________________________

TERMS & CONCEPT DISCOVERY

Terms: Crystallization, caramelization, sucrose, solution, solvent, solute, saturated, supersaturated, corn syrup, glucose, fructose, crystalline candy, non-crystalline candy, amorphous

GENERALIZE

1. List the basic steps of crystallization.
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

APPLY

1. Thinking of the texture of fondant, how do you think it might be used in manufacturing other types of confections?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Unit 4: Be a Food Scientist!
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THE SCIENCE OF SWEET IS COMPLEX
To understand sugar crystallization, one must understand the science of sugar and solutions.
1. Make a solution: Dissolve sugar and corn syrup in water.

Common terms ..................... Sugar + Water = Solution
Food Science terms ............. Solute + Solvent = Solution

Sugar dissolves, it is soluble in water. How much sugar is soluble (dissolves) depends on the temperature of the solution—the higher the temperature, the more sugar can dissolve. Once the saturation point is reached, the sugar will no longer dissolve. Increasing the temperature allows more sugar to be held in solution before reaching the saturation point. Later, in a demonstration, you will compare the amount of sugar at the saturation point using cold water to the amount of sugar held in solution in boiling water. Boiling water holds more sugar in solution.

BE A FOOD SCIENTIST
CRYSTALLIZATION AND CARAMELIZATION

Crystalline Candy Starts with a Sugar Solution
The most basic recipe for crystalline candies includes sugar, water, and corn syrup. This combination of ingredients makes fondant, a creamy off-white candy. The corn syrup (which is primarily glucose) controls crystallization of sucrose and keeps the crystal size small rather than large. Small crystal size feels good on the tongue. Besides fondant, fudge is another example of crystalline candy. You may have tasted properly made fudge that is smooth on the tongue due to small crystal size—but when made improperly, it feels grainy because of large sugar crystals.

The basic steps to make all crystalline candy are similar:
1. Start by making a solution.
2. Heat the mixture.
3. Cool and stir.

The procedures look deceptively simple. However, the detailed science of sugar, solutions, and super-saturation behind crystalline candy is complex.
2. **Heat the mixture:** Solution is saturated.
   As the solution continues to heat, the boiling point increases. The temperature continues to rise as the solution becomes even more concentrated or saturated. Once the end-point temperature is reached, the mixture is cooled. For fondant, the end-point cooking temperature is 237º F (114º C). The appropriate end-point temperature is critical to the quality of crystalline candy. End-point temperature determines the concentration/saturation of the solution.

3. **Cool for super-saturation and stir as sugar crystals re-form.**
   When the endpoint temperature is reached, the mixture is poured onto a baking sheet or plate and allowed to cool. A saturated sugar and water solution contains all the sugar it can hold. A super-saturated solution has more sugar than it can hold. As the mixture cools, the sugar begins to re-crystallize, to fall out of solution. As it cools, the super-saturated solution changes from a thick liquid to a soft, creamy solid called a fondant.

This is where some of the “art” of crystallization comes into play. Small crystals are desirable and sometimes it takes practice to keep crystals from getting large. The size of crystals that form depends on:
- The amount of small crystals (seed crystals) that start initially and collect other crystals.
- The rate at which crystals form (determined by temperature and stirring).

In crystalline candy, formation of small, numerous crystals after super-saturation is desirable. Other ingredients such as corn syrup, cream of tartar (acid), creams, and chocolate are included to delay and interfere with crystallization to prevent the formation of large crystals. It’s a balancing act to produce a high quality product!

**HOW IS FONDANT USED?**
Fondant can be colored, flavored, and used as the soft, creamy filling inside of chocolate candy. Or it can be used to coat nuts or fruit. It can even be rolled out and used to cover wedding cakes, thus giving the smooth, seamless frosting seen on these types of cakes.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

Sugar and Dry Heat Make Non-Crystalline Candy

Some non-crystalline candies are made with caramelization. When dry sugar is heated, it forms a clear liquid at 320º F (160º C). With continued heating, the molten sugar begins to turn brown at 338º F (170º C). This reaction is called caramelization. It is a complex reaction in which the structure of sucrose is changed by the heat. The reaction produces acid and the characteristic caramel color and flavor. Exposure to high temperatures prevents the sugar from crystalizing during the cooling process; it hardens before crystals have time to form.

Nut brittles and caramels are examples of candy formulations using caramelization. Nut brittle recipes include the addition of baking soda. Baking soda (alkaline) reacts with the acid from caramelization, producing carbon dioxide (CO₂). The carbon dioxide bubbles are trapped in the molten sugar, producing a porous end product. Without the carbon dioxide bubbles, the end product would be very dense and hard. Toffee, nut brittles, lollipops, and caramels are examples of non-crystalline candies; these types of candies are also called “amorphous.” The word “amorphous” refers to the fact that the sugar has no shape since it has not crystalized.
Recipes for non-crystalline candies contain ingredients and cooking techniques that prevent sugar crystallization. Additionally, there are many “interfering ingredients” added to amorphous candy recipes that help prevent crystallization. These include cream, evaporated milk, and butter. Marshmallows are an interesting non-crystalline candy using softened, plain gelatin to inhibit crystal formation.

### WHAT IS SUGAR?
The green leaves of sugar beets and sugar cane absorb energy from the sun. With the addition of carbon dioxide and water, the plants produce sugars, starch, and fiber. Sugar beets are 16–18% sucrose. Sugar cane is 14% sucrose. Sucrose is usually referred to as table sugar or white sugar. Sucrose is a disaccharide (“di” means two). Sucrose is a combination of two monosaccharaides (“mono” means one). The monosaccharaides fructose and glucose come together to form sucrose. Sucrose is composed of carbon, hydrogen and oxygen.

Sugar goes by many names—sucrose, demara, muscovado, turbinado, brown, and powdered. Sugar is made from sugar beets and sugar cane. After harvesting, these plants are processed in refineries into many types of sugar. To learn more about extracting sugar from sugar beets and sugar cane go to www.4-H.org/curriculum/foodsci.

### FOOD SCIENCE AND CRYSTALLIZATION IN FOODS—WHAT’S THE LINK?
There are different types of crystallization in food science. Ice cream is an example of ice crystallization. While ice crystallization occurs as a result of freezing rather than hot, super-saturated sugar solutions, crystalline candies and ice cream share similar quality concerns. In both, having small crystal size ensures a quality product that feels good on your tongue and tastes good. Ingredients such as fat—often in the form of cream (milk fat)—help keep crystal size small in ice cream as well as in candies by interfering with crystal development.
IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD PACKAGING

A food packaging engineer develops packaging to control air and water transfer and prevent chemical reactions between package and food using glass, metal, and plastic laminate. They also work on packages with seal-ability. A packaging specialist works with food production teams, sales, and marketing. Not only do they want the package to appeal to consumers, like you, but the packaging must meet food safety standards as well. Today, many consumers want packaging that is eco-friendly. The next time you visit a supermarket, look at the wide array of food packaging on the shelves.

LEARN MORE!

VIRTUAL FUN
Take virtual factory tours to see how jelly beans, candy canes, fudge, and other candies are manufactured. Find recipes for making peanut or almond brittle, and discover the story of chocolate with videos and links maintained at:

www.4-H.org/curriculum/foodsci
“I Pledge my **Head** to clearer thinking,
my **Heart** to greater loyalty,
my **Hands** to larger service,
and my **Health** to better living,
for my club, my community, my country,
and my world.”
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Unit 1 is just one part of exploring “What’s on Your Plate?” Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
INTRODUCTION

FOOD SCIENCE FACILITATOR GUIDE
Welcome to the Food Science Facilitator Guide! This guide is intended to help you lead an effective learning process for youth as they discover the science of what’s on their plate!

This 4-H curriculum uses an inquiry-based learning method designed to help young people first ask questions, then seek answers through hands-on activities and finally to reflect on what they’ve learned.

We encourage you to preview the activities, watch the short tutorial videos, and then carefully read through each activity. The pages from the Youth Science Journal are inserted so you have all the content of the curriculum as well as questions, answers, and tips to help you lead these activities. The activities are easily carried out in a home kitchen “laboratory” using inexpensive supplies available at grocery stores. If it’s been some time since your last science class, keep smiling—the curriculum and tutorial videos contain everything you need to know!

The activities are written for youth grades 6–9 but may be adapted for younger or older learners. You can limit or expand the amount of information you share or simplify the terms if needed. Explain the concepts to youth in terms they are able to understand depending on their age and level of experience. For younger learners, you might only focus on the physical reactions they can see. Chemical reactions that food scientists explore can be introduced to older or more advanced learners. Paraphrasing instructions and concepts in your own words will help activities and discussions flow more naturally.

For the best learning experience, please follow the instructions and do each part of the activity. Each of the activities within the units should be done in the order presented. The units may be done in any order, however the concepts are more complex in Units 3 and 4. For learners to have positive outcomes, pay close attention to the details and directions of the activities.

It’s easy to get caught up in the hands-on activities and forget to reserve time for the reflection and application questions. These questions are essential though for locking in the learning and assessing if learners grasped the concepts you have been teaching. Many times you’ll “see the light bulb come on” when you ask them to explain what they’ve done and what they’ve learned.

Keep in mind that some youth will prefer to process their thoughts internally and write down their responses. Others will be eager to share verbally. Structuring the time for individual reflection and writing first and then encourage sharing will allow both types of learning to thrive.
Your work with youth is a genuine opportunity to encourage them to consider careers in science, engineering, and technology. Food science and food technology are examples of STE using applied basic sciences. The work you’re doing with these young people may help someone discover a career path in food science, find a passion for creating meals that amaze, or simply help them be aware of healthy food preparation. You’ll never know how far your influence will reach.

Enjoy exploring “What’s on Your Plate?”

**4-H Mission Mandate Outcomes—Science and Healthy Living**
- Improved science skills and knowledge among youth.
- Youth apply science learning to contexts outside 4-H.
- Increased science literacy in general population.
- Increased knowledge, attitudes, skills, and aspirations to promote optimal physical, social, and emotional health habits.

**Life Skills**
- Cooperation
- Critical Thinking
- Communication
- Contributions to Group Effort
- Keeping Records
- Planning/Organizing

In preparing to do activities, follow these steps for the best success:
- Skim the Facilitator Guide.
- View the short video tutorial. It shows techniques and explains the science to make it easier for you to conduct the activity.
- Carefully read both the Facilitator Guide and the Youth Science Journal portion of the Facilitator Guide.

Note that the Youth Science Journal contains most of the science explanations in the Be a Food Scientist section. This information appears after the experiments and discussion portions. This enables the learners to use inquiry first, then confirm their findings later. It is not expected that learners will read this section during the activity; it may be useful if they want to delve deeper, remember, or share the concepts with others.

There are a number of additional materials, including videos, handouts, glossary terms, podcasts, resources, and links to other websites at www.4-H.org/curriculum/foodsci. Links to webpages often change, so rather than printing them here, they will be kept up-to-date on the 4-H webpage dedicated to this curriculum. These materials will hopefully enrich you, and your learners’ understanding of the content.

**Unit 1: The Secrets of Baking**

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NOTES
Have you ever noticed the similarity of ingredients for pancakes, pie crusts, biscuits, cookies, cakes, quick breads, and yeast breads? Their “basics” include flour, along with some type of liquid, salt, and a leavening agent. This activity explores a protein in flour called gluten. Gluten provides the structure for foods made with wheat flour—it’s the secret ingredient!

Ask each learner to bring a medium-sized bowl, a wooden spoon, and a kitchen towel.

**MATERIALS LIST**

**Supplies:**
- Medium-size bowl for each learner.
- 1 cup dry measuring cup
- 1 cup liquid measuring cup
- Spoons or scoops for flour
- Plastic knife for leveling flour
- Measuring spoons
- Wooden spoon for each learner
- Cutting board, plastic mat, or table top for each learner to knead dough
- Towels—one for each workspace
- Sanitizing solution
- Hand soap
- Paper towels
- 1 piece large paper for writing out chemical reaction; tape for posting on wall
- 4 small paper plates
- Marking pen
- Pencils

**Food:**
- Flour: Bread flour, all-purpose flour, cake flour, and whole wheat flour
- One cup of one type of flour per learner (NOT each type of flour for each learner)
- Cool water supply; sink is necessary
- Bread: 3 types for sampling, such as: 100% whole wheat, multi-grain, sourdough, gluten-free, etc.
- Wheat kernels, also called wheat berries. (Optional to show learners what wheat looks like. Usually available in a natural food store bulk bins.)

**Printed Materials:**
- Order Youth Science Journal, one for each learner

**SKILL LEVEL:**
Beginner

**LEARNER OUTCOMES**
- Knows how to observe, describe, and apply scientific principles of gluten development.
- Understands and identifies how gluten development is controlled and used favorably in baked goods.

**SUCCESS INDICATORS**
- Able to follow written directions, measure, and prepare formulations.
- Identifies protein components of gluten.

**SUGGESTED GROUP SIZE**
8 - 12 youth

**TIME NEEDED:**
Minimum of 60 minutes, preferably 90 minutes if group is 12 or larger.

**SPACE**
Any setting with a work table is fine. At least one sink is mandatory. Each learner will need a workspace such as table, counter, or sink. Put towel at each workspace.
DURING THIS ACTIVITY, YOU WILL:

• Explore the science of proteins found in flour and experience gluten development.
• Coordinate learners as each of them develops gluten from different types of flour.
  » Add water to flour, mix, knead
  » Wash starch out of flour, leaving behind gluten
  » Compare amounts of gluten in different types of flour
• Lead discussions with learners while comparing gluten made from four types of flour.
• Support and encourage learners so they understand and describe gluten development and how it is controlled and used favorably in bakery products.
• Sample different types of bread.

GETTING READY

Prior to the Activity

• View the tutorial video, other videos, glossary, and print resources for this activity. Available at: www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The Be a Food Scientist section of explains the science behind the experiments.
• Gather all equipment, supplies, and materials.
• Write out on large paper and post in room:
  Gliadin + Glutenin (Proteins in Flour) + Water + Mixing/Kneading = Gluten (Protein)
• Prepare bread samples ahead of time—one-inch squares are sufficient for tasting.
ACTIVITY 1.1: Flour's Secret Ingredient: Great Globs of Gluten (cont.)

THE SECRET INGREDIENT IN FLOUR IS GLUTEN
Gluten, the “secret” ingredient that provides the structure in baked goods, “develops” when mixing flour with water. During stirring and kneading, two proteins in wheat flour join together to form gluten. The structure, which you and the learners will be able to touch and feel during this activity, allows bakery products to rise.

GETTING TO THE GLUTEN—STEP 1
In order to see and feel this protein that is the basis of all wheat flour products, learners make dough by adding water to flours that have different amounts of protein. They knead the dough to “develop” the gluten.

SEPARATE THE GLUTEN FROM THE STARCH—STEP 2
Flour also contains starch. Proteins provide structure while starch fills the gaps between protein strands. Learners will work the dough in a medium bowl filled with water. This process washes away the starch, effectively separating the starch from the gluten. Only gluten remains between protein strands allowing learners to compare the amount of gluten found in the different flours.

BEGINNING the ACTIVITY Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What are some examples of foods made with flour that you like to eat?
2. Have you ever made any foods using flour? Which ones? How did they turn out?
3. What do you think might be in flour products that make them rise or stay flat, such as bread vs. tortillas?
EXPERIMENT 1—MAKING GLUTEN

Each learner chooses either whole wheat, all-purpose, bread, or cake flour. (Make sure at least one person does each type of flour so that all four can be compared.) Measure one cup of flour with a dry measuring cup, using proper measuring technique. Place in bowl.

Refer to the Youth Science Journal, “Be a Food Scientist—Getting to Know the Secret Ingredient.” As learners knead the mixture, explain that learners are seeing and feeling the gradual development of a special protein called gluten as it becomes elastic and stretchy. This is the physical reaction described in the Making Gluten section.

As learners continue to knead, explain the chemical reaction. The proteins that make up gluten absorb twice their weight in water. As they are kneaded, the protein molecules generally align in one direction. Strands of gluten then join together, get longer, and are able to stretch.

Post the chemical reaction for learners to see:

\[
\text{Gliadin} \quad \text{(Proteins in flour)} + \quad \text{Glutenin} \quad \text{+} \quad \text{Water} \quad \text{+} \quad \text{Mixing/Kneading (Protein)} = \quad \text{Gluten}
\]
EXPERIMENT 2—SEPARATING GLUTEN FROM STARCH
During the rinsing activity, starch separates from protein (gluten) and rinses away, leaving only the gluten. Gluten is strong and firm, yet springs back when touched.

See the physical and chemical reactions in the Youth Science Journal section Separating the Gluten from the Starch.

The amount of total protein differs in flours. Bread flour contains a large amount of protein, which captures the gases that rise through it; therefore, the gluten expands and makes a chewy texture in the baked product. Cake flour only contains a little protein, thus cakes are tender. Whole wheat flour contains a large amount of protein but also has tiny particles of bran. The bran particles cut the gluten strands as they form during mixing, thus reducing the amount of gluten produced from whole wheat flour. Therefore, since bread flour contains a large amount of protein, but does not contain bran to hinder gluten development, it produces the most gluten. All-purpose flour is a close second to bread flour in the amount of gluten it contains.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

Below are answers (bolded in blue) you might expect from the learners. When possible, help them understand the concepts in their own words before you explain. Use this as a guide to ensure learners understand the science behind their observations. Become familiar with the background information provided before doing this discussion.

ACTIVITY 1.1

Flour’s Secret Ingredient: Great Globs of Gluten

1. What is the main ingredient in these breads?  _Flour, water, and yeast_

2. Feel and taste bread samples. Which has the most tender texture?  ___________________________

3. Which has the most flavor?  ___________________________

4. Which one do you prefer?  ___________________________

5. Why do you think the breads have different tastes and textures?  _Different flours, different recipes_

6. What component in flour allows it to “rise” and become bread?  (Tip: Find out the answer by following the clues and doing the activities, then come back and answer this question.)  _Gluten_

Unit 1: The Secrets of Baking

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Full size page can be found in the Youth Science Journal on page 3.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

WHAT WILL WE DO?
Discover the secret ingredient in flour that forms the basis of all the flour products you like to eat—from pancakes to muffins, pizza crust to bread, one special ingredient holds the key to success. You get to discover this “secret” ingredient, a certain kind of protein, by adding water to flour, mixing, and kneading it. Then you’ll wash away starch from your mixture to leave behind the “secret” ingredient common to all foods made with wheat flour.

What is this protein and how does it work? Follow the clues and do the activity to find out!

WHAT DO WE NEED TO KNOW?
A special protein provides the structure in baked goods. It “develops” when mixing flour with water. During stirring and kneading, two proteins in wheat flour join together to form it. You will be able to see it and feel it during this activity.

CLUE #1
A kernel of wheat has three parts.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips regarding food safety.

Components of Wheat
A wheat kernel is made up of these components:
- The bran contains fiber.
- The endosperm contains mostly starch (carbohydrate) and protein.
- The germ contains vitamins, minerals, and a tiny amount of fat.

WHAT’S ON YOUR PLATE? Exploring Food Science
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ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

CLUE #2

The major components of wheat flour are starch (carbohydrate) and protein. There is very little fat in a wheat kernel—just a bit in the germ which is removed when making white flour. Generally, the higher the protein content of flour, the more structure and “body” in the final food product. In some products, such as pasta or pizza crust, a firm product is desired. In cakes or pie crusts, a tender product is preferred. While there are many things that influence baked goods, the protein content of flour is one of the most important. Look at the chart. Compare the percentage of protein in the different types of flour and note their different uses.

<table>
<thead>
<tr>
<th>TYPE OF FLOUR</th>
<th>PERCENT PROTEIN</th>
<th>COMMON USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cake flour</td>
<td>6.8—8.0</td>
<td>Cakes</td>
</tr>
<tr>
<td>Pastry flour</td>
<td>7.0—9.5</td>
<td>Tender pastries</td>
</tr>
<tr>
<td>All-purpose flour</td>
<td>9.5—11.5</td>
<td>Bread, muffins, cookies, cakes, pancakes, pizza dough, biscuits, etc.</td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td>11.0—14.0</td>
<td>Bread, muffins, cookies, denser cakes, pizza dough, biscuits, etc.</td>
</tr>
<tr>
<td>Bread flour</td>
<td>11.5—13.5</td>
<td>Bread</td>
</tr>
<tr>
<td>Durum flour</td>
<td>12.0—13.5</td>
<td>Pasta</td>
</tr>
<tr>
<td>Gluten flour</td>
<td>40.0—45.0</td>
<td>Bagels, chewy pizza crust, or added to other flours, such as rye or whole wheat, to improve rising and texture</td>
</tr>
</tbody>
</table>

Full size page can be found in the Youth Science Journal on page 5.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

CLUE #3
Do the following three steps to reveal flour’s secret ingredient!

STEP 1
Take a small amount of each flour and rub it between your thumb and forefinger. Is it soft, smooth, rough, grainy? Is one coarser than another, heavier, whiter, darker? Describe your observations in the chart.

Flour Observation Chart

<table>
<thead>
<tr>
<th>TEXTURE OF FLOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
</tr>
<tr>
<td>Not as fine as cake flour</td>
</tr>
<tr>
<td>Cake flour</td>
</tr>
<tr>
<td>Very fine, feels almost silky</td>
</tr>
<tr>
<td>Bread flour</td>
</tr>
<tr>
<td>Difficult to feel much difference between all-purpose and bread flour</td>
</tr>
<tr>
<td>Whole wheat flour</td>
</tr>
<tr>
<td>Coarse; feel small, sharp particles</td>
</tr>
</tbody>
</table>

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Full size page can be found in the Youth Science Journal on page 6.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

STEP 2
1. Each learner chooses either all-purpose flour, whole wheat flour, bread flour, or cake flour.
2. Measure one cup of chosen flour into medium bowl, using proper measuring technique.
3. Add about 2 tablespoons of water and stir with a heavy or wooden spoon. Add more water gradually to make a stiff dough—add just a tablespoon or two at a time.
4. Use hands to form the dough into a ball. You may need to put a little flour on your hands so the dough doesn’t stick. Use as little additional flour as possible.
5. Mix and knead dough for 10–15 minutes until texture is very smooth and surface is silky.

MEASURING DRY INGREDIENTS
To properly measure dry ingredients, spoon ingredient, such as flour, into measuring cup. Do not pack or tap the cup. Fill to slightly overflowing, then slide the back of a table knife across the top of the measuring cup to level the flour, as in the picture. Discard excess flour.

NEED HELP KNEADING?
To knead dough, press, fold, and stretch it repeatedly on a flat surface. Using the heels of your hands, push down on the dough, stretching it away from you. Fold it in half. Give the dough a quarter turn and repeat.

As learners begin to knead, discuss the physical reaction. As the dough looks and feels smooth, explain that they are seeing and feeling the gradual development of gluten, a protein in flour that is necessary for many baked products. The dough feels more soft, pliable, and stretchy—this is called elasticity.

As learners continue to knead, discuss the chemical reaction (a food scientist’s point of view!). Explain that when water is added to flour, it allows the proteins gliadin and glutenin to combine. Write the reaction where learners can see it.

Full size page can be found in the Youth Science Journal on page 7.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

As youth begin this activity, explain that in addition to protein, flour is also comprised of starch. Proteins provide structure while starch fills the gaps between protein strands. During the rinsing activity, starch separates from protein (gluten) and rinses away, leaving only the gluten. Gluten is strong and firm, yet springs back when touched.

### Dough Texture Observation Chart

Share information with other learners to complete this chart.

<table>
<thead>
<tr>
<th>Flour Type</th>
<th>WHAT DID THE DOUGH FEEL LIKE BEFORE KNEADING?</th>
<th>WHAT DID THE DOUGH FEEL LIKE AFTER 10-15 MINUTES OF KNEADING?</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
<td>Sticky, breaks apart into small pieces very easily</td>
<td>Smooth, soft, stretchy, elastic (Contains gluten)</td>
</tr>
<tr>
<td>Bread flour</td>
<td>Sticky, breaks apart into small pieces very easily</td>
<td>Smooth, soft, stretchy, elastic (Contains gluten)</td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td>Sticky, breaks apart into small pieces very easily</td>
<td>Smooth, soft, stretchy, elastic (Contains gluten)</td>
</tr>
<tr>
<td>Cake flour</td>
<td>Sticky, breaks apart into small pieces very easily</td>
<td>Smooth, soft, stretchy, elastic (Contains gluten)</td>
</tr>
</tbody>
</table>

### STEP 3

Rinse the dough in cool water to remove the starch, leaving behind the protein called gluten.

1. Pull and squeeze the dough while it is in the water. When water becomes very white, pour it out and add clean water. Repeat as many times as necessary for water to remain clear.
2. When water is clear or nearly clear, the process is complete—the starch is gone.
3. Observe and note differences in gluten from the different flours.

What color is the dough before rinsing in cold water?

**Light, almost white, except whole wheat**

What color is the gluten after the starch has been rinsed away?

**Tan, off white**

Explain that the amount of total protein differs in flours. Bread flour contains a large amount of protein, which captures the gases that rise through it; therefore the gluten expands and makes a chewy texture in the baked product. Cake flour only contains a little protein, thus cakes are tender. Whole wheat flour contains a large amount of protein, but also has tiny particles of bran. The bran particles cut the gluten strands as they form during mixing, thus reducing the amount of gluten produced from whole wheat flour. Therefore, since bread flour contains a large amount of protein but does not contain bran to hinder gluten development, it produces the most gluten. All-purpose flour is a close second to bread flour in the amount of gluten it contains. Flour with the least amount of protein should leave behind the smallest amount of gluten. Flour with the most protein should have the most gluten.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

Why did the color change after rinsing?

**Rinsed out starch, which is white**

Place gluten on small paper plates labeled “Whole Wheat Flour,” “Cake Flour,” “All-Purpose Flour,” and “Bread Flour.” Observe visual differences. Press and stretch each type. Record your observations in the chart below.

**Gluten Observation Chart**

Share information with other learners to complete this chart.

<table>
<thead>
<tr>
<th>TEXTURE OF GLUTEN</th>
<th>APPEARANCE OF GLUTEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-purpose flour</td>
<td>Rubbery</td>
</tr>
<tr>
<td>Bread flour</td>
<td>Rubbery</td>
</tr>
<tr>
<td>Whole wheat flour</td>
<td>Rubbery</td>
</tr>
<tr>
<td>Cake flour</td>
<td>Not as rubbery as other flours</td>
</tr>
</tbody>
</table>

Smaller than original size, tan appearance, able to see gluten strands

Smaller than original size, tan appearance, able to see gluten strands. Larger than all-purpose flour

Smaller than original, tan, particle of bran more visible, able to see gluten, about same size as all-purpose flour

Much smaller than original. The smallest of all of the gluten samples, able to see gluten

Compare and rank how much gluten was produced by each type of flour.

- **Bread**
- **All-Purpose**
- **Whole Wheat**
- **Cake**

**MOST**

- Bread
- Whole Wheat

**LEAST**

- Dense, hearty bread?

Based on the amount of gluten produced, which flour do you think a food scientist would use to make light and airy bread? _______ **Bread** _______. Dense, hearty bread? _______ **Whole Wheat** _______.

Unit 1: The Secrets of Baking

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ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

Below are answers you might expect from the learners. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Explain concepts as needed. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

1. What are the two ingredients you mixed together?
   
   Water and flour

2. How did the dough look and what did it feel like when you first mixed it together?
   
   Dough is sticky, crumbly, and initially breaks apart.

3. How did the dough look and feel as you continued to mix it and to knead it?
   
   During mixing, pulling, and stretching, the dough becomes more elastic and smooth.

4. What did you observe as you rinsed the dough in cool water?
   
   The dough releases something (starch) and the water turns white.
   While rinsing the dough, some of it seems to fall apart and disappear. The amount of dough becomes smaller.

5. When the water eventually turned clear, what did the gluten look like? Were some amounts of gluten bigger than others? Which were smaller? Which were larger?
   
   Full of holes and strands of gluten. The bread and all-purpose flour produced the largest amount of gluten, followed by whole wheat, and cake flour, the smallest.

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ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

EXPLORE
Explore the Science of Gluten Development

1. Which of the two ingredients you mixed together most likely provides structure to foods such as bread?
Flour

2. What happens when flour and water are mixed together and kneaded?
A stiff dough forms. Water allows the proteins in flour to mix. Kneading changes the texture and gradually becomes more elastic.

3. What might be happening to the flour that makes it more elastic?
Water is being evenly distributed as the flour absorbs it. Structure of the flour molecules might be changing.

Write the chemical reaction here:

\[
\text{Glutenin} + \text{Glutin} + \text{Water} + \text{Mixing} \rightarrow \text{Gluten}
\]

4. How did the gluten feel and look while you were rinsing?
It felt like the dough was breaking apart and getting smaller.
It got rubbery.
It changed color from white to tan.

5. Why are the gluten amounts different sizes after rinsing even though everyone started with the same amount of flour?
The flours contain different amounts of protein. Bread and whole wheat flour both contain large amounts of protein, but the bran in the whole wheat flour cuts the strands of gluten, thus producing gluten that is more similar to all-purpose flour.

Explain that flour is comprised of protein and starch. Proteins provide structure. Normally, starch fills the gaps between protein strands. During rinsing, starch separates from protein (gluten) and rinses away, leaving only the gluten. Gluten is strong and firm, yet springs back when touched.

Explain that the amount of protein differs in flours. The tiny particles of bran left in whole wheat flour after processing actually cut the gluten strands as they form during mixing, thus reducing the formation of gluten. Therefore, since bread flour does not contain bran to hinder gluten development, it produces the most gluten.

Full size page can be found in the Youth Science Journal on page 11.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

GENERALIZE

1. What are the major components of wheat flour? (See Clue #1)
   Protein and starch
   
   [Space for answers]

2. What is in protein that provides structure?
   Gluten
   
   [Space for answers]

3. How does gluten develop?
   Add water to flour then mix and knead it.
   
   [Space for answers]

4. What happens to dough the longer it is kneaded?
   Gets more stretchy and elastic
   
   [Space for answers]

Terms: Gluten, flour, bread flour, all-purpose flour, cake flour, elasticity, gluten development, leavening agents, baking powder, knead

At this point in the activity, ensure that the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.

Full size page can be found in the Youth Science Journal on page 12.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

APPLY

1. Why is flour important in products like cakes, cookies, and bread?
   *Gluten provides the structure for bakery products made from flour.*

2. If you are going to make a firm product such as pizza crust, which is the best flour to use?
   (Refer to Clue #2 if needed.)
   *All-purpose or bread flour*

   If you are going to make a cake, which is the best flour for a soft, tender cake?
   *Cake flour*

   What is different about these two flours?
   *Amount of protein*

3. Judging from what you have learned about the components of flour and looking at the amount of gluten produced by each type of flour, which flour would be best to have at home to make a wide variety of baked goods?
   *All-purpose*

BE A FOOD SCIENTIST

GETTING TO KNOW THE SECRET INGREDIENT!

While there are several types of protein found in wheat flour, the two most important for gluten formation are gliadin and glutenin. When these two proteins are mixed with water and stirred or kneaded, they form gluten. Gluten provides structure to baked foods such as yeast bread, quick breads, biscuits, cakes, muffins, pancakes, pizza crust, pie crusts, cookies, waffles, pop-overs, bagels, pastries, and cream puffs.
ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

MAKING GLUTEN

What You SEE & What You FEEL

The Physical Reaction
As the dough was kneaded, it looked and felt smooth. Eventually it felt soft, pliable and stretchy—this is called elasticity. You physically saw and felt the gradual development of gluten!

What Happens from a FOOD SCIENTIST’S Point of View

The Chemical Reaction
When water is added to flour, it allows the gliadin and glutenin proteins in the flour to combine, producing gluten. The higher the protein content of the flour, the more water is needed to make a dough. This is because the proteins that make up gluten absorb about twice their weight in water.

The repeated compressing and stretching of the dough (kneading) aligns the protein molecules so that most of them run in the same direction. Certain molecular bonds are broken and new ones are made. This allows the gluten molecules to stretch and get longer, increasing the strength of the gluten. When this happens, the dough can be easily molded into a shape and springs back from light pressure.

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ACTIVITY 1.1: Flour’s Secret Ingredient: Great Globs of Gluten (cont.)

SEPARATING THE GLUTEN FROM THE STARCH

What You **SEE**

**The Physical Reaction**

When dough is placed in water, the starch washes away, turning the water opaque or white. When the water become clear, the starch was gone and only the gluten, gluten, remained. The amount of dough was smaller than the original amount. It felt rubbery. The color was less white than in the beginning, it was more tan. At this point, stretching the dough allowed you to see the gluten fibers.

What You **FEEL**

**The Physical Reaction**

When dough is placed in water, the starch washes away, turning the water opaque or white. When the water become clear, the starch was gone and only the gluten, gluten, remained. The amount of dough was smaller than the original amount. It felt rubbery. The color was less white than in the beginning, it was more tan. At this point, stretching the dough allowed you to see the gluten fibers.

**The Chemical Reaction**

The water frees up the starch molecules so that they wash away. Only the gluten remains.

What Happens from a **FOOD SCIENTIST’S Point of View**

The water frees up the starch molecules so that they wash away. Only the gluten remains.

INGREDIENTS THAT AFFECT GLUTEN DEVELOPMENT

Ingredients in flour or added to flour affect how gluten develops. In this activity, you saw how protein content and bran affected gluten development.

- **Protein Content of Flour:** The percent of protein in flour affects gluten development—the higher the protein content, the greater the gluten development. Durum flour has a high protein content, so it is good for making firm products such as pasta or pizza dough. Cake flour is low in protein, giving cake a tender texture.

- **Bran:** Whole wheat flour contains bran. The tiny particles of bran are sharp and cut the gluten strands during mixing and kneading. Thus, there is less gluten development in whole wheat products, so the product may be more dense than if made with flour that does not contain bran. Recipes often mix whole wheat and all-purpose flour to get better gluten development and make a less-dense product.

- **Fats and Oils:** Strands of gluten are coated by the fats and oils in a recipe so they “slide” by one another, making less of a connection. Therefore, fats and oils lessen gluten’s ability to form a strong structure; this creates a more tender product.
ALL ABOUT FLOUR

Wheat flour is milled into a variety of products used for home and commercial baking. Some of the products you may recognize in the grocery store are whole wheat flour, bread flour, all-purposed flour, and cake flour—all made from wheat. There may be a few types of wheat flour you have not heard of such as durum flour, gluten flour, and pastry flour—these are used commercially for specific uses.

Wheat from Farm to Table

• Wheat is a member of the grass family that produces a dry, one-seeded fruit commonly called a kernel.
• Wheat is a cereal grain, which by definition is any plant of the grass family yielding an edible grain, such as wheat, rye, oats, rice, or corn.
• Wheat is grown in 42 states in the U.S. Kansas and North Dakota are the largest wheat producers.
• Six classes of wheat include thousands of varieties; the six classes are: Hard Red Winter, Hard Red Spring, Soft Red Winter, Durum, Hard White, and Soft White.
• Large machines called combines harvest wheat at the rate of 1,000 bushels of wheat per hour.
• One bushel of wheat makes 42 pounds of white flour or 60 pounds of whole wheat flour.
• One bushel of wheat yields about 42 pounds of pasta.

Leavening Agents Lend a Hand to Gluten

Common leavening agents include baking soda, baking powder, yeast, and steam formed from liquids during baking. These leavening agents make flour products rise by forming gas (carbon dioxide) that expands the gluten and then gets trapped in its structure. The gluten strands form a “net” that stretches during baking. Then, when leavening agents form carbon dioxide and/or steam, the gasses are trapped in the “net” of gluten strands. This elastic net lets the dough rise yet still hold its shape. As the product cooks, the “net” structure becomes firm, giving the product its final structure.

FOOD SCIENCE, NUTRITION, AND GRAINS—WHAT’S THE LINK?

Some people have problems with gluten. If people are gluten intolerant, that means they cannot properly digest gluten and must avoid it because it will damage the intestines, leaving them malnourished. Other people may be “gluten sensitive,” which means their body’s immune system reacts to the protein and causes a reaction. Symptoms of gluten sensitivity may include bloating, abdominal discomfort or pain, constipation, and diarrhea.
Gluten is found in wheat, barley, rye, and triticale (a cross between wheat and rye). Many foods typically made with these flours are now available without gluten thanks to food scientists. How is this possible? Food scientists use flours made from grains that don’t have gluten, along with special processing techniques. For instance, they may add eggs to help bread rise. A product called Expandex (modified tapioca starch) helps provide texture similar to that of gluten-containing flours.

Food scientists also play a role in developing whole grain products. U.S. Dietary Guidelines recommend that everyone choose whole grains for about half of the grain foods they eat each day. What makes whole grains special? A whole grain contains all edible parts of the grain—the bran, the germ and the endosperm. The bran and germ contain many vitamins, minerals, phytonutrients, and fiber. These nutrients are stripped away and lost in the process of making “white” flour. Since the endosperm contains mostly starch, protein, and only a few nutrients, U.S. law requires that certain nutrients be added back to the processed flour: the mineral iron and the B-vitamins thiamin, riboflavin, niacin, and folate. The mineral calcium may also be added but is not required. This is called enriched flour, but it still does not contain all of the nutrients that were removed from the whole wheat flour.

To find whole grain foods, check the ingredient label. The first ingredient of a whole grain bread or cereal should include the word “whole” in front of the name of the grain, such as “whole wheat.” Or it might contain the name of the grain in its whole form, such as “brown rice.” Some labels will state the number of grams of whole grain, while others might carry the whole grain “stamp.” Everyone ages 9 and older should aim for 3 to 5 servings of whole grains each day.
ACTIVITY 1.2
Baking the Best Bread: Leavening Agents in Action

There are three, distinctly different ways to “leaven” quick breads, yeast breads, and cakes. That’s one reason there are so many recipe variations for baked goods that share common ingredients. This activity concentrates on leavening agents. For best use, this activity best follows 1.1 which explored gluten formation. Learners will investigate leavening agents and how they interact with gluten to provide structure in baked goods. Illustrating yeast leavening, learners make soft pretzels.

MATERIALS LIST

Supplies:
• 6 re-sealable plastic sandwich bags
• 1 re-sealable food-grade gallon size plastic bag
• Measuring spoons
• 1 cup liquid measuring cup
• Dry measuring cups
• Spoons or scoops for flour
• Table knife for proper measuring technique
• Baking sheet
• Cooling rack
• Permanent marker with small point (for writing on plastic bags)
• Insta-read thermometer
• Pastry brush
• Pot holders
• Paper towels
• Paper plates
• Sanitizing solution
• Hand soap
• Pencils

Food:
• Samples of unleavened bread for taste-testing (optional): tortilla, chapatti, lefse, matzo
• Sample of one type leavened bread, cut into 1 inch squares

For Experiments:
• Active dry yeast—four packages, or if using bulk yeast, 3 tablespoons. For larger group, bulk yeast may be less expensive than small packages.
• 5 teaspoons sugar
• 2 tablespoons flour
• 1 tablespoon baking powder
• 1 teaspoon baking soda
• 1 teaspoon cream of tartar

For Making Soft Pretzels in a Bag
• The amount of ingredients below makes 6–8 pretzels (one pretzel for each learner).
• 1 cup all-purpose flour
• 1 cup whole wheat flour
• 1 tablespoon quick-rising yeast
• 1 teaspoon sugar
• ½ teaspoon salt
• 1 tablespoon vegetable oil
• Warm water (110–115˚F)
• Coating spray
• Coarse salt, optional

Printed Materials
• Order Youth Science Journal, one for each learner
• Three or more cookbooks with yeast bread recipes (can get from library)

There are three, distinctly different ways to “leaven” quick breads, yeast breads, and cakes. That’s one reason there are so many recipe variations for baked goods that share common ingredients. This activity concentrates on leavening agents. For best use, this activity best follows 1.1 which explored gluten formation. Learners will investigate leavening agents and how they interact with gluten to provide structure in baked goods. Illustrating yeast leavening, learners make soft pretzels.

SKILL LEVEL:
Intermediate

LEARNER OUTCOMES:
• Understands and applies Scientific Method of Inquiry.
• Understands the function of yeast as a leavening agent in recipes.
• Knows how to compare and contrast types of leavening agents in recipes.

SUCCESS INDICATORS:
• Identifies ingredients in recipe formulations that produce CO₂.
• Describes the principles of leavening with CO₂.
• Able to observe, describe, and apply scientific principles of leavening agents.

SUGGESTED GROUP SIZE:
8–12 youth

TIME NEEDED:
Minimum of 60–75 minutes

SPACE:
Kitchen with sink, hot and cold water. Oven if making pretzels.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

DURING THIS ACTIVITY, YOU WILL:
• Make soft pretzels in a bag
• Sample and compare unleavened bread with leavened bread
• Facilitate and encourage learners to observe, describe, compare, contrast, and apply scientific principles of leavening agents by experimenting with various leavening agents placed in re-sealable bags and observing the production of carbon dioxide.

INTRODUCTION—LEAVENING AGENTS IN ACTION
Learners use the Scientific Method of Inquiry to explore carbon dioxide-producing leavening agents and see yeast work in a soft dough recipe formulation. Starting with experiments showing carbon dioxide (CO₂) production, learners make observations, pose questions, interpret data, and suggest answers then make soft pretzels.

If your group did not complete Activity 1.1, please review the background information for details on leavening agents and gluten formation in flour.

Details about the three major types of leavening agents can be found in the What do we need to know? section of the Youth Science Journal.

GETTING READY
Organizing the Activity

Prior to the activity:
• View the tutorial video, other videos, glossary and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The What do we need to know? and Be a Food Scientist sections explain the science behind the experiments.
• Gather all equipment, supplies, and materials.

KEEP LEARNERS SAFE

• Facilitator: Monitor build-up of carbon dioxide in baggies to avoid bursting.
• FOOD SAFETY: Before each activity: Clean kitchen surfaces, cutting boards, etc. Learners and facilitators wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
• OVEN: Use caution when working with oven. An adult should be in charge. Have pot holders available.
• Tie back long hair.
• Roll up long sleeves.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

Here are some questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

BEGINNING the ACTIVITY Ask Lead-In Questions

1. What kind of bread do you eat most often?
2. Have you ever made bread? Have you ever smelled bread baking?
3. Do you know the name of the ingredient that makes bread rise? (yeast)
4. What do you think is the difference between a tortilla and bread? (tortilla has no leavening)

Open the Youth Science Journal
As learners look at the pictures and read the statement, “Yeast Makes Bread Rise,” urge them to ask questions about the bread making process.
EXPERIMENT 1—WHICH INGREDIENTS PRODUCE THE MOST CO₂?
Divide into teams of 2-3 participants each. Each team is assigned one variable of the experiment. Measure the water temperature accurately. See the Youth Science Journal for experiment instructions. As learners make observations about the amount of CO₂ produced in each bag, discuss the factors that affect CO₂ production. Discuss principles explained in the “Leavening Agents in Action” section and the “Factors Affecting Yeast” section.

While waiting for CO₂ production, learners can do the following experiment and/or two activities.

EXPERIMENT 2—SOFT PRETZELS IN A BAG
See the Youth Science Journal for recipe and experiment instructions. Each recipe makes 6–8 pretzels.

As dough is proofing, discuss what is happening inside the dough and ask learners:
• Which ingredients are contributing to the CO₂ production? (flour, yeast, sugar, warm water)
• How does CO₂ production affect the dough? (stretches/expands the gluten, makes the “net,” traps the gases)

After pretzels are cooked, ask learners why the dough eventually stopped rising (oven temperature increased the temperature of the dough, killing the yeast similar to the high temperature of the water that killed the yeast in Variable #3). When the yeast died, the CO₂ production stopped.

ACTIVITY 1—RECIPE RESEARCH
Using cookbooks, learners find three recipes for yeast bread (not quick bread) and make a note of the ingredients in the table in Youth Science Journal.

ACTIVITY 2—TASTE UNLEAVENED BREADS AND COMPARE WITH LEAVENED BREAD
Flatbreads, which can be unleavened breads, occur in many cultures around the world. If available, learners taste one or more unleavened breads such as tortillas from Mexico, chapatti from India, matzo from the Jewish tradition, or Norwegian lefse. Learners compare unleavened breads to leavened breads, noting the differences in tastes and textures.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

Below are answers (bolded in blue) you might expect from the learners. When possible, help them understand the concepts in their own words before you explain. Use this as a guide to ensure learners understand the science behind their observations. Become familiar with the background information provided before doing this discussion. Rating numbers and learners’ opinions will vary.

ACTIVITY 1.2
Baking the Best Bread: Leavening Agents in Action

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .” Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .
• How yeast helps make bread?
• What yeast produces that contributes to the rising of the bread?
• What that process is called and what yeast needs to do it?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

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Full size page can be found in the Youth Science Journal on page 18.

Unit 1: The Secrets of Baking
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What will we do?
Did you know there are three distinctly different ways to “leaven” quick breads, yeast breads, and cakes? That’s just one of reasons there are so many recipe variations for baked goods that share common ingredients. You will investigate leavening agents and how they interact with gluten to provide structure in baked goods. You get to observe, describe, compare, contrast, and apply scientific principles of leavening agents and make your own soft pretzels!

What do we need to know?
Leavening Agents in Action
There are three major types of leavening agents. Often recipes include one or more of these ingredients.

Biological ........ Yeast is a living organism that feeds off of the sugar and starch (flour) in a recipe. Through a process of fermentation, yeast produces carbon dioxide (CO₂) gas, which is trapped by the gluten structure during baking.

Chemical ........ Baking powder, or baking soda plus an acid (e.g. cream of tartar is considered an acidic ingredient). These produce carbon dioxide gas (CO₂), which is trapped by the gluten structure during baking. Most baking powders in the US are called “double acting.” They contain baking soda and acidic ingredients that release carbon dioxide when mixing the liquid and dry ingredients together, and again when the mixture is heated during baking.

These leavening agents are used in pancakes, muffins, and quick breads.

Physical ........ Air is trapped during the mixing of sugar and butter, as in cake preparation. This step is called creaming. The rough-edged sugar particles trap air in the fat. The air expands and rises, which stretches the gluten during baking. Foam forms when whipping egg whites for a meringue or soufflé. Foams will be explored in Activity 2.2. In addition, water as an ingredient in batters and dough changes to steam during baking which rises, stretches the dough and leavens the food product.

Be safe! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds before handling and mixing ingredients for soft pretzels. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips and handouts regarding food safety.

Unit 1: The Secrets of Baking
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ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

EXPERIMENT 1: WHICH INGREDIENTS PRODUCE THE MOST CO₂?
Divide into teams of 2—3 participants each. Each team is assigned one experiment. Measure the water temperature accurately.

Variable 1
Put ¼ cup water (110º F—measure temperature accurately!) and 1 package active dry yeast (2¼ teaspoons) into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 2
Put ¼ cup water (110º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), and 2½ teaspoons sugar into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 3
Put ¼ cup water (140º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), and 2½ teaspoons sugar into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 4
Put ¼ cup water (110º F—measure temperature accurately!), 1 package active dry yeast (2¼ teaspoons), 2 tablespoons flour into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 5
Put 1 tablespoon baking powder and ¼ cup room temperature water into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.

Variable 6
Put 2 teaspoons baking soda, 1 teaspoon cream of tartar, and ¼ cup room temperature water into a re-sealable sandwich-size plastic bag. Remove as much air as possible before sealing bag. Label bag with ingredients and start time. Make observations.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

CO₂ PRODUCTION OBSERVATION CHART

Record the amount of CO₂ production at the listed time intervals. Use a scale of 1–10:

1 = NO production of CO₂, bag is flat
5 = Quite a bit of CO₂ production, bag is about half full
10 = Large amount of CO₂ production, bag is tightly full (like a very full balloon)

<table>
<thead>
<tr>
<th>Variable 1</th>
<th>5 MINUTES</th>
<th>10 MINUTES</th>
<th>20 MINUTES</th>
<th>30 MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yeast and 110º F water</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Variable 2</td>
<td>3</td>
<td>4–5</td>
<td>7–8</td>
<td>9–10</td>
</tr>
<tr>
<td>Yeast, 110º F water, sugar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Yeast, 140º F water, sugar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 4</td>
<td>1</td>
<td>2–4</td>
<td>4–5</td>
<td>5–6</td>
</tr>
<tr>
<td>Yeast, 110º F water, flour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 5</td>
<td>2</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
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<tr>
<td>Baking powder and room temperature water</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable 6</td>
<td>5</td>
<td>9–10</td>
<td>9–10</td>
<td>9–10</td>
</tr>
<tr>
<td>Baking soda, cream of tartar, and room temperature water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While waiting for CO₂ production, do the experiment and/or two activities on the following pages.
EXPERIMENT 2—MAKE SOFT PRETZELS IN A BAG

**Ingredients**
- 1 cup all-purpose flour
- 1 cup whole wheat flour
- 1 tablespoon quick rising yeast
- 1 teaspoon sugar
- ½ teaspoon salt
- 1 tablespoon vegetable oil
- ¾ cup (water at 110–115º F)
- Coarse salt, optional

**Directions**
1. Put dry ingredients into a 1-gallon food-grade plastic re-sealable bag.
2. Close the bag and shake to mix.
3. Add the oil and water to the bag. Close again and manipulate with fingers to mix well.
4. Wash hands again using proper hand-washing technique.
5. One learner removes the dough from the bag and divides it into 6 to 8 equal pieces.
6. Each learner gets one piece of dough. Roll dough between hands to form a rope-like shape 12 inches long.
7. Form into a pretzel and place on a greased baking sheet. Let proof (rest) in a warm place for 10 minutes.
8. Using a pastry brush, brush lightly with water. Sprinkle with salt if desired.

What is happening inside the dough during proofing?
**Yeast produces CO2 and stretches the gluten. CO2 gets trapped in the gluten strands.**
**The dough rises.**

What would happen if you forgot to let the dough proof?
**The dough would not rise as much in the final product.**

Describe what is happening to the yeast and gluten as the pretzel bakes:
**Yeast continues to produce CO2 and expands the gluten “net.” The CO2 and steam from the water are trapped inside the “net.” As baking continues, the temperature inside the dough increases, killing the yeast, which stops CO2 production. The gluten becomes firm from baking.**
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

ACTIVITY 1—RECIPE RESEARCH
Using cookbooks, find three recipes for yeast bread (not quick bread). Put a check mark in the box if the recipe contains the listed ingredient. These ingredients are essential for producing a good loaf of yeast bread.

Did each bread recipe contain the essential ingredients? _______________________________________

Which ingredients are not essential? ______________________________________________________

<table>
<thead>
<tr>
<th>BREAD RECIPE 1</th>
<th>BREAD RECIPE 2</th>
<th>BREAD RECIPE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yeast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid—water or milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat—butter or oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ACTIVITY 2—TASTE UNLEAVENED BREADS
Flatbreads, which can be unleavened breads, occur in many cultures around the world. If available, taste some unleavened breads such as tortillas from Mexico, chapati from India, matzo from the Jewish tradition, or Norwegian lefse.

Compare unleavened breads to leavened breads. What are the differences you notice in tastes and textures?
_________________________________________________________________________________
_________________________________________________________________________________
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

Some answers you might expect from the learners are shown. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

SHARE
1. What did you do to find out which ingredients produce carbon dioxide?

Experiment 1
Learners describe their observations and what they did in the experiments.

Variable 1: Nothing happens. (No “food” for the yeast.)

Variable 2: Rapid CO₂ production. (Yeast feeds on sugar)

Variable 3: No CO₂ is produced. (Yeast is killed from hot water)

Variable 4: CO₂ is produced but less than in #2. (Flour has maltose that feeds the yeast, but no other sugar is present.)

Variable 5: Slow, moderate CO₂ production. (Baking powder produces some CO₂)

Variable 6: Rapid and complete CO₂ production. (Baking soda plus an acid produces quite a bit of CO₂)

Experiment 2
Yeast in action—yeast produced CO₂ in pretzel dough.

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REFLECT

1. What is CO₂?

   Carbon dioxide is a gas produced by yeast during fermentation.

2. What does CO₂ do in bread? What does it do to the gluten?

   Carbon dioxide causes bread to rise; it provides leavening. It stretches the net of gluten to make the dough expand and get lighter when baked.

3. What conditions and/or ingredients are necessary for CO₂ production from yeast?

   Yeast needs a warm but not hot temperature (110°F), and sugar from sucrose (table sugar) and/or flour (maltose). In Experiment 4, the high water temperature kills yeast.

   The dough would not rise as much in the final product.

4. What is CO₂ production from yeast called?

   This process is called fermentation. Yeast uses sugar and maltose in flour to produce carbon dioxide, ethyl alcohol, and flavor components.

5. Name a biological leavening agent you can use to make bread or soft pretzels.

   Yeast

6. What is a chemical leavening agent that you could use in a recipe for banana bread?

   Baking soda and acid(s) such as cream of tartar or baking powder.

7. What are the ingredients that are essential and found in all bread recipes?

   Flour, yeast, water or other liquid, and salt to control yeast growth. Sugar may be added for faster fermentation. Oil is added to shorten gluten strands, which makes product more tender.

8. What is the main difference in texture between leavened and unleavened breads?

   Unleavened are denser because there was no leavening action.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

At this point in the activity, make sure the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.

TERM Concept Discovery

GENERALIZE
1. To make bread successfully, what are the ideal ingredients and optimum temperature?

Flour, liquid at 110°–115° F, yeast, sugar, salt, fat/oil.

APPLY
Two friends call to ask if you can help with a recipe. They printed a recipe for soft pretzels from a website, but the printing is poor—only some of the letters of the ingredients are legible. They need help figuring out the ingredients. Fill in the missing letters to determine the names of the ingredients.

After you help them figure out the ingredients, they ask whether all those ingredients are essential. Is there anything that can be left out? What is your answer?

Then they ask you why each of the ingredients is needed. Write what you would tell them about the function each ingredient.

SOFT PRETZEL RECIPE INGREDIENTS

<table>
<thead>
<tr>
<th>COMPLETE THE INGREDIENT NAME</th>
<th>DESCRIBE THE INGREDIENT FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>All purpose flour</td>
<td>Gluten development for structure</td>
</tr>
<tr>
<td>Sugar</td>
<td>Leavening (fermentation with yeast), controls gluten development, adds flavor (sweetness)</td>
</tr>
<tr>
<td>Active dry yeast</td>
<td>Leavening, flavor</td>
</tr>
<tr>
<td>Oil</td>
<td>Flavor, controls rate of fermentation</td>
</tr>
<tr>
<td>Water</td>
<td>Necessary for gluten development, leavening (steam)</td>
</tr>
<tr>
<td>Milk</td>
<td>Liquid for gluten development, leavening (steam), nutrition</td>
</tr>
<tr>
<td>Oils</td>
<td>Controls gluten development, flavor</td>
</tr>
</tbody>
</table>

WHAT'S ON YOUR PLATE? Exploring Food Science

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**Fermentation**

Flour (starch) + yeast + water = CO₂ + ethyl alcohol + flavoring components

(Note: The ethyl alcohol evaporates during baking.)

**Factors Affecting Yeast**

- Water temperature is important. Too cold of a temperature, under 100°F, leads to slow fermentation, which means the bread will be very slow to rise. Too hot of a temperature, over 140°F, kills most yeast cells, making fermentation impossible. Water temperatures between 100°F and 115°F are just right.
- Sugar is needed for the yeast fermentation process. There are typically a couple of sources of sugar in a recipe:
  1. The maltose in flour is a naturally occurring sugar in wheat.
  2. Table sugar (sucrose) is often added to recipe formulations to enhance the rate of fermentation. Fermentation is slower without added sugar.
- Salt moderates yeast’s activity so fermentation occurs at a consistent rate. Salt also enhances flavor.
- Proofing (sometimes called rising) is the process of letting dough “rest” during which time the yeast continues to ferment, produce CO₂, and further raise the dough product. Proofing is best done in a warm place. To prevent a crust from forming on the surface of the dough, cover it with a clean, damp towel or plastic wrap lightly coated with cooking spray. Some recipes call for proofing one, two, or more times.

**Essential Elements for Baking the Best Bread**

To make a good loaf of bread, adequate leavening, good structure, and great flavor are essential. The typical ingredients in bread are flour, water and/or milk, yeast, sugar, salt, and a small amount of fat or oil. Here’s the science behind the recipe—how ingredients work together for a good loaf of bread.

Leavening is primarily due to carbon dioxide produced by yeast. Water also converts to steam during baking and contributes to leavening. Sugar and maltose in flour, plus salt, control the rate of fermentation.
ACTIVITY 1.2: Baking the Best Bread: Leavening Agents in Action (cont.)

Structure of bread comes from gluten development. As learned in Activity 1.1, gluten development requires flour, water, and manipulation (mixing and kneading). Leavening gases, CO₂, and steam are trapped by the gluten "net" and the product rises.

Flavor in bread comes from the end products of yeast fermentation, sugar, salt, and a browning reaction that occurs during baking.

FOOD SCIENCE, NUTRITION, AND CARBOHYDRATES—WHAT’S THE LINK?

Have you ever heard someone say, “I don’t do carbs . . .”? Perhaps you’ve seen “low-carb” tortillas or crackers or other foods that typically have a lot of carbohydrates in them. Food scientists are behind the scenes, making low carbohydrate foods that look and taste similar to the original foods, for those who want or need them.

What are carbohydrates? They are the starch, fiber, and naturally occurring sugars that make up many foods. Carbohydrates are abundant in fruits, vegetables, dairy products, beans, nuts, foods made from grains, and more. The only foods that do not contain carbohydrates are meat, fish, shellfish, poultry, and fats and oils.

Carbohydrates are essential to life—they provide the energy the body needs to do everything it does! It’s a good idea to focus on eating “complex carbohydrates.” Complex carbohydrates have starch and fiber along with vitamins and minerals.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD QUALITY SPECIALIST

A food quality specialist may have many roles in food processing and food safety. During food processing, they made sure that product quality standards are met during manufacturing. Quality includes things like shape, color, texture, flavor, and appearance of food products. Many quality assurance careers also involve product food safety.

LEARN MORE!

VIRTUAL FUN

For videos on commercial bread production, to see how yeast is made, and other online resources, visit the 4-H Food Science curriculum web site at:

www.4-H.org/curriculum/foodsci

WHAT’S ON YOUR PLATE? Exploring Food Science

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Full size page can be found in the Youth Science Journal on page 28.
NOTES
This activity focuses on the functions of ingredients found in batters for muffins, cakes, and quick breads. Batters and dough contain similar ingredients. The primary ingredients are flour (explored in 1.1), leavening agents (explored in 1.2) plus salt, fat and sugar. In this activity, you will make a variety of muffins to apply the principles of gluten development and leavening agents, investigate the function and relationship of ingredients in muffins, the effects of mixing, and explore the ratio of liquid and dry ingredients in recipe formulations. For explanations of the science and to see what you will be doing, watch the short tutorial video at www.4-H.org/curriculum/foodsci.

**MATERIALS LIST**

**Supplies:**
- Muffin tin with standard size muffin cups (either one tin with 12 cups or two tins with 6 cups each)
- Three medium mixing bowls
- 3 rubber spatulas
- Dry measuring cups
- Measuring spoons
- 1 cup liquid measuring cup
- Sieve or sifter for sifting
- Metal fork for mixing wet ingredients with egg
- Spoons or scoops for flour
- Table knife for proper measuring technique
- Cooling rack
- Cooking spray
- Small ruler—show 1/8”
- Potholders
- Waxed paper or paper towel
- Toothpicks for testing doneness
- Masking tape and marker for use on muffin tin
- Paper towels
- Paper plates
- Spoons or forks for sampling
- Sanitizing solution
- Hand soap
- Pencils
- Salt
- 1 cup milk plus amount needed for commercial muffin mix
- 1 egg plus amount needed for commercial muffin mix
- 1/4 cup oil plus amount needed for commercial muffin mix
- Vanilla extract
- 1 box banana muffin mix (Please use banana mix because it doesn’t contain large fruit pieces, which could interfere with texture comparisons. Use “regular,” not low-fat or light mix.)
- About 2 cups all-purpose flour
- Fresh baking powder
- 1/4 cup sugar

**Optional:** Make Better Baking Mix—Additional Supplies and Food
- 1 quart re-sealable plastic bags, 1 per learner
- 1 or 2 large bowls
- Food for Better Baking Mix: Makes 9 cups of baking mix. Make enough for each learner to take home 2 cups of mix.
- 4 cups of all-purpose flour
- 4 cups of quick rolled oats OR whole wheat flour
- If using old-fashioned oats, whirl the oats in a blender about 30 seconds to make smaller flakes.
- 1 1/3 cups nonfat dry milk powder
- 4 tablespoons baking powder
- 1 teaspoon salt

**Printed Materials:**
- Youth Science Journal, one for each learner
- If making Better Baking Mix, download the handout from www.4-H.org/curriculum/foodsci

**SKILL LEVEL:**
Advanced

**LEARNER OUTCOMES:**
- Understands, identifies, and explains function of leavening and other ingredients in muffins.
- Knows how to use principles of gluten development in recipe formulations.
- Knows how to compare and contrast ratio of ingredients in batters and dough.
- Understands and identifies how gluten development is controlled and used in baked goods.

**SUCCESS INDICATORS:**
- Define and describe function and ratio of leavening and other ingredients in batters.
- Able to follow written directions, measure, and prepare batters.
- Analyze and compare products prepared from commercial mix and recipes.
- Observe and describe how the amount of mixing and changing the ratio of ingredients in recipes affects end products.

**SUGGESTED GROUP SIZE:**
8–12 youth

**TIME NEEDED:**
Minimum of 65–75 minutes

**SPACE:**
A kitchen with an oven
Optional Activity: Make Better Baking Mix
This healthy baking mix can be used in a variety of products. While waiting for muffins to bake, learners make the mix, divide, and take home to make various baked goods.

GETTING READY
Organizing the Activity
Prior to the activity:
- View the tutorial video, other videos, glossary and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal. The What do we need to know? and Be a Food Scientist sections explain the science behind the experiments.
- Gather all equipment, supplies and materials.
- Optional: Download and provide copies of Better Baking Mix handout.

LET’S DO IT!
Learners explore muffin recipe formulations investigating ingredient ratios, functions of ingredients, and the effects of mixing. The more they learn and apply in this activity, the more creative they can be at home producing new, unique baked goods.

In Experiment 1, learners discover when a batter contains lower amounts of fat and sugar, there may be more gluten formation. Learners vary the number of stirring strokes while making muffins, comparing the final products. If the batter is even slightly over-mixed in a low-fat, low-sugar recipe, there will too much gluten formation. The over-mixed muffin will have a peaked, smooth top, with larger-than-normal air tunnels that point toward the peak. It will be tough and chewy.

In Experiment 2, learners increase the amount of fat and sugar. They also vary the strokes used to mix the batter. They will see that with a little more fat and sugar, over-mixing is less of a concern in the final product.

Experiment 3 uses a commercial muffin mix. Learners vary the number of strokes used to mix the batter. They will see that poor results from over-mixing are not likely—due to the high sugar and fat content in typical muffin mixes.

KEEP LEARNERS SAFE
- FOOD SAFETY: Before each activity: Clean kitchen surfaces, cutting boards, etc. Learners and facilitators wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
- After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.
- OVEN: Use caution when working with oven. An adult should be in charge. Have pot holders available.
- Tie back long hair.
- Roll up long sleeves.
DOING THE ACTIVITY

1. Before the activity, divide an egg. One-half beaten egg is required in Experiments 1 and 2. A typical large egg is about 3 tablespoons. Mix egg thoroughly with fork. Use 1½ tablespoons of beaten egg for each experiment.

2. Measure the flour. In food science labs and commercial bakeries, dry ingredients would be weighed using the metric system—in grams/kilograms and liquids measured using milliliters/liters. This ensures accuracy and reproducibility in a laboratory or food processing setting. Because you have a “kitchen laboratory,” measuring is accomplished using measuring cups and spoons. Please discuss with learners the differences in measuring between a laboratory setting and a kitchen. For best results, use proper dry measuring technique and follow the directions carefully.

3. Stress to learners the importance of controlling for muffin size by filling each muffin cup to within ⅛-inch of the top.


BEGINNING the ACTIVITY Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. Compare a pancake to a biscuit. Can you identify which is a dough and which is a batter?

1. What do you think the difference might be between recipes for a batter and a dough?
2. What is a main ingredient in foods made from batters or dough? Hint: Think structure
3. Do you recall what is in flour that forms the structure of baked goods?  
   Hint: Activity 1.1 was Great Globs of Gluten!

Open the Youth Science Journal

As learners look at the pictures and read the statement, “These food products have many similar ingredients.” Guide them to ask questions such as those listed in the Answer Key.
STATEMENT: THESE FOOD PRODUCTS HAVE MANY SIMILAR INGREDIENTS.
Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”
Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

• What makes these foods different from one another?
• What is the same in all these foods?
• What is different in all these foods?
• What gets mixed with flour to make these foods?
• How to prepare these foods so that they come out right?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.
My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

Answers you might expect from learners are (bolded in blue) When possible, help them understand the concepts using their own words before you explain. Use this as a guide to help learners understand the science behind their observations. Become familiar with the background information provided before the discussion. Rating numbers and learners’ opinions will vary.
WHAT WILL WE DO?
This activity brings together the things you discovered in the previous activities in this unit. You found out in 1.1 that gluten develops when flour and water are mixed, then stirred or kneaded. In activity 1.2, you investigated leavening agents such as yeast, baking soda, and baking powder, and how they interact with gluten. Now you explore how different ingredients and mixing influence gluten development and texture of the final product, as well as see leavening agents in action as you make muffins using several variables.

WHAT DO WE NEED TO KNOW?
Amount of Sugar, Fat, and Mixing Alters the Final Product
The variables in this activity explore how the amount of mixing or stirring a batter may affect the end product, especially if the recipe is low in sugar and fat. Remember that manipulation of dough (as in kneading or stirring) develops the gluten in flour. The more the gluten is developed, the stronger it is, resulting in a firmer product which may seem tough or rubbery.

The addition of increased amounts of sugar and fat interfere with gluten formation. So the more fat and sugar that are in the muffin recipe, the more likely it is to be tender, even if over-mixed.

MUFFIN MANIA
Make muffins using a variety of ingredients and techniques to find out how to make magnificent muffins.

Prepare a muffin tin (one with 12 muffin cups) by coating each cup lightly with cooking spray and mark according to variations (see below). There will be 12 muffins. The control for size will be filling each muffin cup to within 1/8 inch of the top.

To mark the muffin cups for each variable, use small pieces of masking tape with permanent marker: one each of 1A, 1B, 1C, 2A, 2B, 2C, and two each of 3A, 3B, and 3C. Label small paper plates with each variable number.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. In addition, after handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg. Visit www.FightBac.org for tips and handouts regarding food safety.
EXPERIMENT 1

**Ingredients**
1 cup all-purpose flour
1 tablespoon sugar
1½ teaspoons baking powder
½ teaspoon salt
½ cup milk
½ teaspoon vanilla extract
½ egg, well beaten (½ egg = 1½ tablespoons)
1 tablespoon oil

**Directions:**
1. Preheat oven to 425°F.
2. Before measuring, sift flour, using a sifter or by shaking it through a sieve.
3. Measure flour by lightly spooning it into measuring cup. Do not pack or tamp down. Place flour in a medium bowl.
4. Add the rest of the dry ingredients to the flour. Mix gently.
5. Sift dry ingredients together onto waxed paper or paper towel and return to bowl.
6. Mix together milk, vanilla, egg, and oil with fork, making sure egg is thoroughly mixed.
7. Add liquid mixture to dry ingredients. Mix as instructed below for each variable then place in appropriately labeled muffin cups.

**VARIABLE 1 A**
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

**VARIABLE 1 B**
1. Using a rubber spatula, stir an ADDITIONAL 12 strokes.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

**VARIABLE 1 C**
1. Using a rubber spatula, stir an ADDITIONAL 35 strokes.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

**ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)**

Ask learners: What is different in each variable? (Amount of stirring.) Remind learners that stirring/kneading develops gluten (Activity 1.1). Explain fat and/or sugar in the recipe formulation inhibits gluten formation—so in low-fat, low-sugar recipes there will be excessive gluten formation with over-mixing. Too much stirring over-develops gluten, so the muffin will be tough, and have a peaked top with tunneling.

Full size page can be found in the Youth Science Journal on page 31.
EXPERIMENT 2

Ingredients
1 cup all-purpose flour
2 tablespoons sugar
1½ teaspoons baking powder
½ teaspoon salt
½ cup milk
½ teaspoon vanilla extract
½ egg, well beaten (½ egg = 1½ tablespoons)
2 tablespoons oil

Directions:
1. Preheat oven to 425º F.
2. Before measuring, sift flour, using a sifter or by shaking it through a sieve.
3. Measure flour by lightly spooning it into measuring cup. Do not pack or tamp down. Place flour in a
   medium bowl.
4. Add the rest of the dry ingredients to the flour. Mix gently.
5. Sift dry ingredients together onto waxed paper or paper towel and return to bowl.
6. Mix together milk, vanilla, egg, and oil with fork, making sure egg is thoroughly mixed.
7. Add liquid mixture to dry ingredients. Mix as instructed below for each variable then place in appropriately
   labeled muffin cups.

VARIABLE 2.A
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

VARIABLE 2.B
1. Using a rubber spatula, stir an ADDITIONAL 12 strokes.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

VARIABLE 2.C
1. Using a rubber spatula, stir an ADDITIONAL 35 strokes.
2. Fill one muffin cup within ⅛ inch of top—one only in tin.

Ask learners: How is this recipe different from the recipe in Experiment 1? (This recipe has twice as much fat and sugar as the recipe.) What is your hypothesis for how this might affect the baked muffins? (Flavor will be different—sweeter because there is more sugar. Fat
and sugar tenderizes product. Muffins will be more tender.) Explain
that both fat and sugar inhibit gluten formation. Have learners guess
(hypothesize) whether these over-mixed muffins will be different from those
in Experiment 1.
EXPERIMENT 3—COMMERCIAL MUFFIN MIX

Directions
Place muffin mix in a bowl and add additional ingredients as instructed on the package but do NOT stir. Mix as instructed below for each variable.
Place in appropriately labeled muffin cups.

VARIABLE 3.A
1. Using a rubber spatula, stir gently until just moistened; NO MORE than 18 strokes. Batter will be lumpy.
2. Fill two muffin cups within 1/8 inch of top. Make 2.

VARIABLE 3.B
1. Using a rubber spatula, stir an additional 12 strokes.
2. Fill two muffin cups within 1/8 inch of top. Make 2.

VARIABLE 3.C
1. Using a rubber spatula, stir an additional 35 strokes.
2. Fill two muffin cups within 1/8 inch of top. Make 2.

Place muffin tin in a 425°F oven and bake for 15–20 minutes or until a toothpick inserted into the middle of a couple of the muffins comes out clean.

COOLING INSTRUCTIONS FOR ALL MUFFINS
1. When done, place on cooling rack for 10 minutes.
2. Carefully remove muffins from tin; put on plate with same label as that of the muffin tin.
3. Cool an additional 5 minutes.
4. Cut each muffin in half.
5. Observe and taste; record observations.

Full size page can be found in the Youth Science Journal on page 33.
### ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

Encourage learners to look for small differences between the muffins. Also, the muffins are smaller than what most people expect. The size of each muffin may vary, especially if learners did not fill tin within $\frac{1}{8}$th of an inch from the top.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NUMBER OF STROKES</th>
<th>EXTERIOR APPEARANCE (Shape, volume, browning)</th>
<th>INTERIOR APPEARANCE/TEXTURE</th>
<th>TENDERNESS 1-5 (1 = coarse, tough or rubbery, 5 = fine and tender)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1.A</td>
<td>18</td>
<td>Small, pebbly surface</td>
<td>Good texture</td>
<td>4-5</td>
</tr>
<tr>
<td>Variable 1.B</td>
<td>30</td>
<td>Small, smooth surface</td>
<td>Larger air cells</td>
<td>3-4</td>
</tr>
<tr>
<td>Variable 1.C</td>
<td>65</td>
<td>Larger peaked top, smooth,</td>
<td>Large air cells, tunnels point toward peak</td>
<td>2-3</td>
</tr>
<tr>
<td>Variable 2.A</td>
<td>18</td>
<td>Small, pebbly surface</td>
<td>Good texture</td>
<td>5</td>
</tr>
<tr>
<td>Variable 2.B</td>
<td>30</td>
<td>Small, pebbly shiny surface</td>
<td>Larger air cells</td>
<td>4-5</td>
</tr>
<tr>
<td>Variable 2.C</td>
<td>65</td>
<td>Fewer changes than Variable 1.C</td>
<td>Tunnels, but fewer than Variable 1.C</td>
<td>3</td>
</tr>
<tr>
<td>Variable 3.A</td>
<td>18</td>
<td>Good volume, pebbly surface</td>
<td>Good texture</td>
<td>5</td>
</tr>
<tr>
<td>Variable 3.B</td>
<td>30</td>
<td>Good volume, pebbly surface</td>
<td>Good texture</td>
<td>4-5</td>
</tr>
<tr>
<td>Variable 3.C</td>
<td>65</td>
<td>Good volume, Smoother surface</td>
<td>Possible tunnels, larger air cells</td>
<td>4-5</td>
</tr>
</tbody>
</table>

Compare and contrast the recipe formulations in Experiments 1 and 2.

1. Which formulation had the most sugar and fat?

   **Experiment 2 and Experiment 3**
ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

2. How did the number of strokes affect the exterior appearance?
   The more strokes, the greater the possibility of having a smooth surface on the top. A pebbly, golden brown surface is the desirable “standard.” Recipes with less fat and sugar are most affected. Variable 2 will be less affected because the greater amount of fat and sugar inhibits gluten development. Variable 3, the commercial mix, is affected even less since the formulation has more fat and sugar. (It will be noticeable in the taste as well.)

3. How did the number of strokes affect the texture and tenderness?
   Same principles apply. With recipes lower in fat and sugar, the texture and tenderness will be adversely affected with increased stirring.

4. How did the amount of sugar and fat affect the exterior appearance?
   Higher amounts of sugar made the surface appear more shiny.

5. How did the amount of sugar and fat affect the texture and tenderness?
   Sugar and fat control the formation of gluten. With less sugar and fat, there is additional gluten development so tunnels appear inside the muffin, the surface peaks, and the end product is less tender. Sugar and fat are tenderizing ingredients in recipes.

6. After examining your results in the Muffin Observation Log, what are your conclusions about the optimum amount of sugar, fat, and mixing to produce a good muffin?
   It depends. If you use less sugar and fat, it will be healthier and taste less sweet, but you need to be very careful to guard against over-mixing. With more sugar and fat, there are more calories and the taste changes, but it’s easier to avoid over-mixing.
ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

SHARE
1. Generally speaking, what did you do in this experiment?

Made several variables of muffins to test how the amount of sugar, fat, and mixing influences gluten development and the final muffin texture and appearance.

REFLECT
1. What effects does stirring have on muffins that contain:
   a. Not much fat and sugar? Why?
   Fat and sugar inhibit gluten development. Over-mixing (too much stirring) produces excess gluten development and the product becomes tough, chewy, and has tunnels.

   b. Large amounts of fat and sugar? Why?
   Over-stirring has less effect because of decreased gluten formation.

2. Between the muffins from Experiment 1 and 2, which one did you like the best and why?
   Answers vary, but it is likely they will prefer variable 1.A or 2.A because they were mixed less.

3. Judging from your results, is it possible to over-mix muffins made from a commercial mix? Why?
   Not very likely, because commercial mixes usually contain quite a bit of fat and sugar, which are tenderizing agents.

WHAT’S ON YOUR PLATE? Exploring Food Science
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ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

Understanding terms and concepts are important—either discovered by learners or introduced during your facilitation. The goal is to have learners develop an understanding of the concepts through their exploration and define the terms using their words and experiences.

GENERALIZE
1. In your opinion, what is the most important factor in making a good muffin?
   ____________________________________________________________________________

2. In your opinion, what is the second most important factor in making a good muffin?
   ____________________________________________________________________________

APPLY
1. Imagine you are helping to judge muffins at a 4-H event. The first muffins have peaked tops and tunnels inside. The 4-H member who made them is present and very excited about his muffins. What do you tell him in a way that won’t dampen his enthusiasm but that will motivate him to try again and get a better result?
   ____________________________________________________________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

2. If you wanted to make up a new recipe for moist cookies using three cups of flour, about how much liquid would you need? _____________
   What would the liquid to dry ratio be? ____________
   What type of batter or dough would this be? ____________

Unit 1: The Secrets of Baking
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ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

BE A FOOD SCIENTIST

BATTERS THAT MATTER
Your family may have many recipes in cookbooks or saved electronically. If you take a close look at a few recipes for baked goods (cakes, muffins, drop cookies, quick breads), you’ll discover they have more in common than you might think at first glance. As you understand recipe formulation, ingredients, ratio of ingredients, and preparation methods as a science and understand the basic principles, there will be more opportunities to be creative with recipes, building on your food science knowledge. That’s what many food scientists and technologists do as part of their careers: product development.

1. Ratio and Function of Ingredients
The ratio of liquid ingredients to flour is one of the important factors that determine whether a recipe produces a pancake, a cake, a cookie, bread, or a pie crust. A ratio shows the relative proportions of two or more amounts. Ratios are often shown using a colon “:” to separate amounts. For instance, if there is 1 cup of water and 3 cups of flour, the ratio would be written as 1:3.

The ratios in the chart below read “about” because formulations may vary slightly. For instance, a drop batter may have one-half to three-quarters of a cup liquid to dry ingredients and still be considered a drop batter.

<table>
<thead>
<tr>
<th>RATIO Liquid Ingredients : Flour</th>
<th>TYPE OF BATTER OR DOUGH</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>About 1:1</td>
<td>Pour batters</td>
<td>Pancakes, popovers</td>
</tr>
<tr>
<td>About 1:2</td>
<td>Drop batters</td>
<td>Muffins, quick breads, cakes</td>
</tr>
<tr>
<td>About 1:3</td>
<td>Soft dough</td>
<td>Biscuits, moist cookies, yeast bread</td>
</tr>
<tr>
<td>About 1:4</td>
<td>Stiff dough</td>
<td>Pie crusts, noodles/pasta, cookies</td>
</tr>
</tbody>
</table>

WHAT’S ON YOUR PLATE? Exploring Food Science

Full size page can be found in the Youth Science Journal on page 38.
2. What do the ingredients do?

Batters and soft dough have different liquid to flour ratios but contain many similar ingredients, many of which have similar functions in the product.

<table>
<thead>
<tr>
<th>INGREDIENT</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>Structural “net” of gluten.</td>
</tr>
<tr>
<td>Liquid (Water, milk, cream, fruit juice, beverages, and flavorings)</td>
<td>Necessary for gluten development.</td>
</tr>
<tr>
<td></td>
<td>Produces steam for leavening.</td>
</tr>
<tr>
<td></td>
<td>Dissolves sugar, salt and baking powder.</td>
</tr>
<tr>
<td></td>
<td>The ratio of liquid to flour determines type of batter or dough.</td>
</tr>
<tr>
<td>Leavening Agents</td>
<td>Steam (from liquid)</td>
</tr>
<tr>
<td></td>
<td>CO(_2) from baking powder or baking soda with an acid (e.g. cream of tartar, fruit juice, or buttermilk).</td>
</tr>
<tr>
<td></td>
<td>CO(_2) from yeast.</td>
</tr>
<tr>
<td></td>
<td>Air incorporated during mixing.</td>
</tr>
<tr>
<td>Fat or Oil</td>
<td>Fat inhibits gluten formation by coating flour particles and shortening gluten strands.</td>
</tr>
<tr>
<td>Sugar</td>
<td>Sweetness and flavor.</td>
</tr>
<tr>
<td></td>
<td>Ties up water in formulations so there is less gluten development.</td>
</tr>
<tr>
<td></td>
<td>Tenderizing agent (due to less gluten development).</td>
</tr>
<tr>
<td></td>
<td>Aids in browning of batters and dough.</td>
</tr>
<tr>
<td></td>
<td>Stabilizer in egg white foams.</td>
</tr>
<tr>
<td>Salt</td>
<td>Flavor</td>
</tr>
</tbody>
</table>

When you understand recipe formulation ratios and the function of ingredients, there are endless variations for batters and dough. That’s one of the reasons there are so many cookbooks and online recipes—people like new foods and it’s easy to create a recipe once ratios and functions of ingredients are understood.
ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

Use amounts from Experiment #2 recipe formulation. Write in the amount of liquid and dry ingredients. In your own words, describe the function of the ingredients in the recipe.

<table>
<thead>
<tr>
<th>LIQUID INGREDIENTS AMOUNT</th>
<th>DRY INGREDIENTS AMOUNT</th>
<th>INGREDIENT</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cup</td>
<td>1 cup</td>
<td>Flour</td>
<td>Structure, gluten development</td>
</tr>
<tr>
<td>1 ½ tsp.</td>
<td>Baking powder</td>
<td>1 ½ tsp.</td>
<td>Leavening</td>
</tr>
<tr>
<td>½ tsp.</td>
<td>Salt</td>
<td>½ tsp.</td>
<td>Flavoring</td>
</tr>
<tr>
<td>2 Tbs.</td>
<td>Sugar</td>
<td>2 Tbs.</td>
<td>Tenderizing (controls gluten development while stirring), flavor</td>
</tr>
<tr>
<td>½ cup</td>
<td>Milk</td>
<td>½ tsp.</td>
<td>Steam for leavening, liquid necessary for gluten development, nutritional value, dissolves sugar and salt</td>
</tr>
<tr>
<td>½ tsp.</td>
<td>Vanilla</td>
<td>1 ½ Tbs.</td>
<td>Flavoring</td>
</tr>
<tr>
<td>1 ½ Tbs.</td>
<td>Egg</td>
<td>2 Tbs.</td>
<td>Structure, nutritional value, emulsifying agent allowing oil and liquids to mix</td>
</tr>
<tr>
<td>2 Tbs.</td>
<td>Oil</td>
<td></td>
<td>Tenderizing (controls gluten development while stirring).</td>
</tr>
</tbody>
</table>

WHAT'S ON YOUR PLATE? Exploring Food Science

Full size page can be found in the Youth Science Journal on page 40.
MEASURING MATH—CALCULATE RATIO

Are muffins made with a batter or a dough? Find out by using the recipe from Experiment 2 to do the calculations below.

Hints: 1 cup = 16 tablespoons 1 tablespoon = 3 teaspoons

Calculate amount of milk: ___________ tablespoons

Calculate amount of flour: ___________ tablespoons

Write the ratio of these two primary ingredients: ___________ : ___________

Using the chart on page 38, determine the type of batter or dough you made. ___________

3. Dry Mixes

Muffin mixes, cakes, brownies, corn bread, biscuits, and pancakes are just a few examples of dry mixes available at the grocery store. While they can be a timesaver, you can make your own mixes at home to save money and take advantage of what you know about function and ratio of ingredients. In addition, you can often make them healthier by including whole grains, slightly reducing fat and/or sugar, and using healthier types of fat.

FOOD SCIENCE, NUTRITION, AND MUFFINS—WHAT’S THE LINK?

Food scientists can use their knowledge to make foods healthier. To make a reduced-fat muffin, ingredients and manufacturing methods need to be altered so that the muffin has less fat but still has good taste and texture. For instance, a food company may want a large-size muffin to have only a certain amount of calories, so food scientists must adjust the ingredients to meet the calorie requirement.

What size were the muffins you made in these experiments? Traditionally, a muffin is about 2 1/4 inches across, 1.5 inches high, and weighs 1.5 to 2 ounces. Many muffins are larger than that—about 4 inches across and weighing in at 5.5 to 6.5 ounces. The larger muffins can have nearly as many calories as a small meal! Yet many people eat the large muffin as a quick snack—which can lead to too many calories.

Over the years, the serving sizes for many foods have become larger. Being smart about portion size is important for energy balance. Energy balance is when the amount of calories consumed in food and beverages is the same amount as the calories expended by the body in metabolism and physical activity. When energy, or calories, is balanced, body weight stays the same. If a person consumes more calories than they expend, weight gain occurs. The opposite is also true—using up more calories than consumed will result in weight loss. Consuming appropriate portion sizes is important to energy balance.
### ACTIVITY 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

#### Activity 1.3: Batters that Matter: Ingredients and Mixing Methods (cont.)

<table>
<thead>
<tr>
<th></th>
<th>Daily Intake for Teens</th>
<th>Typical Muffin Mix—1.5 Ounce Muffin</th>
<th>Typical Bakery Muffin—6 Ounce Muffin</th>
<th>Muffin as Prepared from Boxed Mix Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>2000 (recommended average)</td>
<td>250</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td>Total Fat (g)</td>
<td>60 (daily maximum)</td>
<td>13</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Saturated Fat (g)</td>
<td>16 (daily maximum)</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>30 (daily maximum)</td>
<td>15</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Calories and fat recommendations from 2010 U.S. Dietary Guidelines for Americans. Sugar recommendation from American Heart Association because Dietary Guidelines do not have a specific sugar recommendation.

Using the chart above, compare the recommended intake of nutrients with a typical bakery muffin. Answer these questions:

1. A bakery muffin uses up ___% of my total recommended caloric intake for one day.*
2. A bakery muffin uses up ___% of my maximum total fat intake for one day.
3. A bakery muffin uses up ___% of my maximum saturated fat intake for one day.
4. A bakery muffin uses up ___% of my maximum sugar intake for one day.

(*Hint: To calculate percentage, divide the amount in the bakery muffin by the recommended amount then multiply by 100. For example, to calculate percent calories, 670 ÷ 2000 = .335 x 100 = 33.5%)

Optional:

1. Fill in the final column of the chart using the “As Prepared” information from the Nutrition Facts label on the muffin mix box. Calculate the above percentages again using those amounts.
2. Also calculate the above percentages using the 1.5 ounce muffin in the chart. Which muffin would be best to have as a snack, not a meal?

---

**WHAT’S ON YOUR PLATE? Exploring Food Science**

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IN FOOD SCIENCE AND FOOD TECHNOLOGY—
CEREAL CHEMIST

Grains are a type of grass. Botanically, grasses are called cereals. “Cereal” doesn’t always mean the crunchy stuff you pour milk over in the morning! The term “cereal” can refer to grains in general. Some food scientists specialize in cereals. Cereal chemists often work in food processing or food manufacturing facilities that produce fresh and frozen baked goods, snack foods containing cereal grains, prepared grain mixes (such as a baking mix or muffin mix), pet foods, and animal feed. A food scientist specializing in cereals also has career opportunities in research, university teaching, sales, and with government agencies.

LEARN MORE!

VIRTUAL FUN
For videos on commercial muffin production and several other online resources including the Better Baking Mix from Washington State University and many associated recipes and tips, visit the 4-H Food Science curriculum web site at:

www.4-H.org/curriculum/foodsci

Unit 1: The Secrets of Baking
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UNIT 1 REFERENCES


Fleischmann’s Bread World: http://www.breadworld.com/default.aspx


Soft Pretzel Recipe:
http://www.spokane-county.wsu.edu/Food_Sense/Recipes/Current/Pretzels%20in%20a%20Bag%20Recipe.pdf


Washington Grains: http://www.wawg.org/all-about-wheat

“I Pledge my **Head** to clearer thinking,
my **Heart** to greater loyalty,
my **Hands** to larger service,
and my **Health** to better living,
for my club, my community, my country,
and my world.”
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Unit 2 The Power of Protein Chemistry is just one part of exploring “What’s on Your Plate?” be sure to check out the other units in this curriculum series for more fun, experiments you can eat!
INTRODUCTION

FOOD SCIENCE FACILITATOR GUIDE

Welcome to the Food Science Facilitator Guide! This guide is intended to help you lead an effective learning process for youth as they discover the science of what’s on their plate!

This 4-H curriculum uses an inquiry-based learning method designed to help young people first ask questions, then seek answers through hands-on activities, and finally to reflect on what they’ve learned.

We encourage you to preview the activities, watch the short tutorial videos, and then carefully read through each activity. The pages from the Youth Science Journal are inserted so you have all the content of the curriculum as well as questions, answers, and tips to help you lead these activities. The activities are easily carried out in a home kitchen “laboratory” using inexpensive supplies available at grocery stores. If it’s been some time since your last science class, keep smiling—the curriculum and tutorial videos contain everything you need to know!

The activities are written for youth grades 6–9, but may be adapted for younger or older learners. You can limit or expand the amount of information you share or simplify the terms if needed. Explain the concepts to youth in terms they are able to understand depending on their age and level of experience. For younger learners, you might only focus on the physical reactions they can see. Chemical reactions that food scientists explore can be introduced to older or more advanced learners. Paraphrasing instructions and concepts in your own words will help activities and discussions flow more naturally.

For the best learning experience, please follow the instructions and do each part of the activity. Each of the activities within the units should be done in the order presented. The units may be done in any order, however the concepts are more complex in Units 3 and 4. For learners to have positive outcomes, pay close attention to the details and directions of the activities.

It’s easy to get caught up in the hands-on activities and forget to reserve time for the reflection and application questions. These questions are essential though for locking in the learning and assessing if participants grasped the concepts you have been teaching. Many times you’ll “see the light bulb come on” when you ask them to explain what they’ve done and what they’ve learned.

Keep in mind that some youth will prefer to process their thoughts internally and write down their responses. Others will be eager to share verbally. Structuring the time for individual reflection and writing first and then encourage sharing will allow both types of learning to thrive.
Your work with youth is a genuine opportunity to encourage them to consider careers in science, engineering, and technology (STE education). Food science and food technology are examples of STE using applied basic sciences. The work you’re doing with these young people may help someone discover a career path in food science, find a passion for creating meals that amaze, or simply help them be aware of healthy food preparation. You’ll never know how far your influence will reach.

Enjoy exploring “What’s on Your Plate?”

**4-H Mission Mandate Outcomes—Science and Healthy Living**
- Improved science skills and knowledge among youth.
- Youth apply science learning to contexts outside 4-H.
- Increased science literacy in general population.
- Increased knowledge, attitudes, skills, and aspirations to promote optimal physical, social, and emotional health habits.

**Life Skills**
- Cooperation
- Critical Thinking
- Communication
- Contributions to Group Effort
- Keeping Records
- Planning/Organizing

In preparing to do activities, follow these steps for the best success:
- Skim the Facilitator Guide.
- View the short video tutorial. It shows techniques and explains the science to make it easier for you to conduct the activity.
- Carefully read both the Facilitator Guide and the Youth Science Journal portion of the Facilitator Guide.

Note that the Youth Science Journal contains most of the science explanations in the Be a Food Scientist section. This information appears after the experiments and discussion portions. This enables the learners to use inquiry first, then confirm their findings later. It is not expected that learners will read this section during the activity; it may be useful if they want to delve deeper, remember, or share the concepts with others.

There are a number of additional materials, including videos, handouts, glossary terms, podcasts, resources, and links to other websites at www.4-H.org/curriculum/foodsci. Links to webpages often change, so rather than printing them here, they will be kept up-to-date on the 4-H webpage dedicated to this curriculum. These materials will enrich you and your learners’ understanding of the content.

**KEEP LEARNERS SAFE**

Each activity includes safety tips. Some of these change for each activity so please be sure to read them.

Food safety and preventing foodborne illness is important. Make a sanitizing solution and use it before every activity. Here’s how:
- Use regular, non-scented bleach. Mix 1/8 teaspoon bleach with 2 cups cool water in a spray bottle.
- Wash surfaces with soap and water. Spray sanitizing solution onto hard, non-porous surfaces and let air dry. Or let set for two minutes and dry with clean paper towel.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

MATERIALS LIST

Supplies:
- Stove top with multiple burners, hot plates and/or electric skillets.
- 1 small non-stick fry pan with lid (for modified poached egg)
- 1 medium non-stick fry pan (for scrambled eggs)
- 1 small saucepan with lid (for hard-boiled egg)
- 1 small saucepan (for custard)
- 1 Insta-read thermometer
- 2 turners/spatulas suitable for non-stick surfaces
- 2 heat-resistant or wooden spoons
- 2 wire whisks (or 2 groups can share one whisk)
- 1 tablespoon measuring spoon
- 1 1-cup measuring cup
- 4 small bowls (1 for mixing scrambled eggs, 2 for separating 5 eggs, and 1 for cooked custard)
- 1 metal cooking spoon, small
- 1 small bowl/custard cup (for overcooked custard)
- 1 medium to large bowl (for ice water bath)
- Paper plates—white or a solid color
- Plastic forks or spoons for tasting
- Plastic wrap
- Sanitizing solution
- Hand soap
- Paper towels
- Potholders
- Egg carton with nutrition label
- Pencils
- Watch or clock with second hand for timing

Food:
- 10 fresh eggs—refrigerate until ready to use
- 1 ¾ cups (1% or 2%) milk (divided)
- 1/2 teaspoon vanilla
- 1/4 cup sugar
- Cooking spray
- Water source
- Ice

Printed Materials:
- Order Youth Science Journal, one for each learner

When cooking scrambled eggs, have you ever wondered why the liquid mixture becomes solid? Or, wonder why so many recipes contain eggs? Eggs have many special, functional properties that make them unique in the study of food science. This activity shows how heat affects the proteins in eggs.

SKILL LEVEL:
Beginner

LEARNER OUTCOMES
- Knows how to observe, describe, and apply scientific principles of heat and protein denaturation and coagulation in eggs.
- Knows how to use protein coagulation in recipe formulation.
- Understands the characteristics of egg components.
- Understands food safety principles and practices applied to eggs.

SUCCESS INDICATORS
- Identifies components of eggs.
- Defines and describes denaturation, coagulation, and over-coagulation as well as the effect of heat on egg protein.
- Able to follow written directions, measure and prepare recipes illustrating egg protein coagulation and over-coagulation.
- Understands and explains egg nutrition label information and health benefits of eggs.
- Defines and describes food safety principles and practices applied to eggs.

SUGGESTED GROUP SIZE
- 8–12 youth

TIME NEEDED:
- 60 minutes

SPACE
- Kitchen with multiple cooking surfaces is preferred. Electric skillets and hot plates may also be utilized. Any setting with a work table is fine; water and soap for hand washing.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

DURING THIS ACTIVITY, YOU WILL:
• Demonstrate how to crack and separate an egg.
• Identify the parts of an egg.
• Facilitate learner experiments: cooking and overcooking scrambled eggs, preparing hard-boiled eggs, modified poached eggs, and stirred egg custard.
• Support and encourage learners as they “see,” understand, and apply the science behind protein coagulation.

KEEP LEARNERS SAFE
• CAUTION: EGGS AND FOODBORNE ILLNESS
Some eggs contain the bacteria called Salmonella enteritidis (SE), which cause foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.
• FOOD SAFETY: Before each activity: Clean and sanitize kitchen surfaces, cutting boards, etc. Learners and facilitators wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
• COOKING: Use caution when working with hot foods and equipment; an adult needs to oversee all heat-related aspects of the experiments. Keep pan handles turned in, away from the edge of the stove or hotplate. Have pot holders available. Use medium and low heats, not high. Learners need to roll up long sleeves and/or use rubber bands to secure them.
• TASTING: When taste testing use the two-spoon method:
  » Sampling spoon (or fork): Use to remove small amount of food from cooking pan. Place onto tasting spoon (or small bowl or plate) WITHOUT touching tasting spoon, bowl, or plate.
  » Tasting spoon: Use to place food into mouth. Never let the sampling spoon touch the tasting spoon. If it does, wash or replace sampling spoon.
• Tie back long hair.

GETTING READY
Organizing the Activity
Prior to the Activity
• View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The What do we need to know? and Be a Food Scientist sections explain the science behind the experiments.
• Gather all equipment, supplies, and materials.
• Divide learners into four teams. One team will do one activity then share information.
• Print out instructions from Youth Science Journal for each experiment and place at each work station.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

BEGINNING the ACTIVITY Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What are your favorite ways to eat eggs?
2. Can you identify any parts of an egg?
3. Can you think of recipes containing eggs or egg whites or egg yolks? Why do you think eggs might be included in the recipes you just mentioned?
4. Can you describe what happens when you heat an egg?
5. Why do you think it does that? (Refers to question #4.)

Open the Youth Science Journal

As learners look at the pictures and read the statement “Cooking Changes Eggs From A Liquid To A Solid,” guide them to ask questions such as those listed in the Answer Key found on page 9.

FACILITATOR DEMONSTRATION: HOW TO CRACK AN EGG

Step 1. Hold the egg in one hand.
Step 2. Gently crack the egg on the edge of a measuring cup or bowl.
Step 3. Using the tips of your two thumbs, slowly open the shell so learners can observe your actions and gently drop the egg onto a plate.
Step 4. Remove any shell pieces with a spoon.

Note: Set aside and use for the “modified poached egg” experiment.

HOW TO CRACK AN EGG

Tap firmly on hard surface. Insert thumbs into crack and pull apart. Still not sure? Check out the video at www.4-H.org/curriculum/foodsci
FACILITATOR DEMONSTRATION: IDENTIFY PARTS OF EGG WITH LEARNERS
Using the egg you cracked in the first demonstration, identify egg components as shown in illustration.

QUICK TOUR OF AN EGG

- Shell and membranes protect the contents of the eggs.
- Chalaza helps suspend the yolk in the center of the egg. It looks like a twisted rope. When you see a noticeable chalaza, the egg is very fresh.
- Albumen is also called the egg white. It is 93% water and 10% protein. It contains forty different proteins. The albumen in fresh eggs is very viscous (thick) and keeps the yolk centered. In older eggs, the albumen thins and cannot keep the yolk in the middle.
- Yolk contains other ingredients such as proteins, fat, fat soluble vitamins, carbohydrates, lipoproteins, and cholesterol. Lipoproteins, proteins, and cholesterol can serve as emulsifying agents.
EGG FRESHNESS
Once learners have identified the components of the egg, observe the egg carefully to see if the freshness of the egg can be determined using the following information.

**FRESH EGG:** Yolk is rounded and centered in the middle of the albumen (egg white). The albumen (egg white) may look thicker near the yolk and thin near its edges. Fresh eggs are best used for poached, fried, and scrambled eggs.

**OLDER EGG:** Yolk appears more flattened; albumen (egg white) is thin and may run around the edges. If you fry an older egg, the yolk may not be centered and the albumen (egg white) will run in the pan. The chalaza may be smaller or not there. Older eggs work best for hard-boiling—they are typically easier to peel than fresh eggs.

**SPECIAL NOTE:** When eggs are stored for long time periods, quality changes, such as albumen thinning, may occur. If eggs are stored at temperatures above 40° F, changes in quality and food safety may occur quickly. Depending on the climate in which you live, bringing eggs home from the supermarket may change the quality and be a hazardous food safety practice. Think about the summer temperature differences between places such as Arizona and Maine. If in doubt, bring a cooler to the supermarket for carrying perishable items on the drive home.
FACILITATOR DEMONSTRATION: SEPARATING WHITES FROM YOLKS
Some recipes, such as the custard recipe in Experiment Four, require the separation of whites and yolks. Show learners how to separate egg whites from yolks using the technique illustrated in the Youth Science Journal or in the videos provided at www.4-H.org/curriculum/foodsci.

EXPERIMENTS
Follow the experiment instructions as given in the Youth Science Journal. See pictures below for results to expect. Review the What do we need to know? and Be a Food Scientist sections of the Youth Science Journal to help explain the science of the experiments.

Experiment 1—Scrambled Eggs
Use the right heat for the eggs you eat! Overcooked egg on left has been exposed to too much heat. The appropriately cooked egg on right is less dry, and retains some air, making it lighter and retains some moisture allowing it to hold together. Note: How you like your eggs is a personal preference.

Experiment 2—Hard-Boiled Eggs
Learners will observe and touch hard-boiled egg. Note: Newer, fresh eggs do not peel as easily as on older egg.

Experiment 3—Modified Poached Egg
After gently spooning the boiling water over the egg yolk, watch for color changes in the surface of the yolk.

Experiment 4—Stirred Custard
Left: Properly cooked custard cooling in ice water bath. Right: Overcooked, curdled custard.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

STATEMENT: COOKING CHANGES EGGS FROM LIQUID TO SOLID.

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

- What makes eggs change from liquid to solid when cooked?
- How does heat cook things such as eggs?
- What happens if too much heat is applied to an egg (i.e., overcooking)?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .
EGGS AND FOODBORNE ILLNESS
Some eggs contain the bacteria called Salmonella enteritidis (SE), which causes foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE, so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.

WHAT WILL WE DO?
When cooking scrambled eggs, have you ever wondered why the liquid mixture becomes solid? Or wondered why so many recipes contain eggs? Eggs have many special, functional properties that make them unique in the study of food science. This activity shows how heat affects the proteins in eggs. You'll cook eggs several different ways. You'll become an egg expert!

WHAT DO WE NEED TO KNOW?
First, identify the parts of an egg.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips regarding food safety.
Getting to Know a Good Egg
Eggs contain protein. Heat used in cooking changes an egg’s protein from liquid form to solid. This is called coagulation. When used in recipes, the coagulated protein helps give structure to the food product.

Utensils
These are some of the utensils used in this activity. From top to bottom: wooden spoon, wire whisk, and three “spatulas.” Each type of spatula has a very different use: straight spatula (cake spatula), silicone rubber spatula, grill spatula. The silicone spatula is used in this activity. Silicone can withstand cooking temperatures.

ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

HOW TO CRACK AN EGG
Tap firmly on hard surface. Insert thumbs into crack and pull apart. Still not sure? Check out the video at www.4-H.org/curriculum/foodsci.

Full size page can be found in the Youth Science Journal on page 5.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

EXPERIMENT 1—SCRAMBLED EGGS

Ingredients
- 3 eggs
- \(\frac{1}{4}\) cup 1% or 2% milk
- Cooking spray

Directions
1. Crack three eggs into a bowl
2. With a wire whisk, rapidly whisk the eggs for 45-60 seconds. Whisking adds air and makes scrambled eggs fluffy.
3. Add milk and whisk to mix.
4. Lightly spray a medium, non-stick skillet with cooking spray; place on low to medium heat.
5. Pour whisked eggs and milk into skillet. Using a utensil that won’t scratch the skillet, such as a plastic, heat-resistant spoon or spatula, stir occasionally during cooking. Scrape the egg from the bottom of the pan and stir gently. Break up large pieces. Eggs are done as soon as they have become solid and no liquid remains.
6. Carefully remove skillet from heat.
7. Place half of the scrambled eggs on paper plate for taste-testing. Label: Cooked to Solid. Taste and record your observations.
8. Place the skillet back on the heat. Continue to cook the remaining eggs for an additional 7 minutes.
10. Place remaining scrambled eggs on paper plate for taste-testing. Label: Overcooked.
11. Using proper technique, taste and record your observations.

SCRAMBLED EGG OBSERVATIONS

<table>
<thead>
<tr>
<th>COLOR</th>
<th>TASTE</th>
<th>TEXTURE (Moist? Dry? Fluffy? Flat?)</th>
<th>RATE TOUGHNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked to Solid</td>
<td>Light yellow</td>
<td>Mild</td>
<td>Moist and fluffy</td>
</tr>
<tr>
<td>Overcooked</td>
<td>Darker yellow, some brown pieces</td>
<td>Mild</td>
<td>Dry, flat</td>
</tr>
</tbody>
</table>

As the scrambled eggs cook, ask learners to describe what is happening and why they think it is happening. Based on the descriptions given by the learners, introduce relevant concepts and terms, i.e. the chemical reaction of denaturation and coagulation.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat (cont.)

EXPERIMENT 2—HARD BOILED EGGS

Ingredients
One egg
Water

Directions
1. Place egg in saucepan. Add cold water to cover egg by 1 inch. Heat over high heat just to boiling. Remove from burner. Cover pan.
2. Let egg stand in hot water to cook:
   - Medium eggs: 9 minutes
   - Large eggs: 12 minutes
   - Extra-large eggs: 15 minutes
3. Cool completely under cold running water or in bowl of ice water; remove shell, cut in half, place on a paper plate for observation.

HARD BOILED EGG OBSERVATION
Touch the hardboiled egg. Describe the consistency of the hardboiled egg (liquid or solid? Soft or firm?).

To peel a hardboiled egg, tap each end to crack it, then gently roll. Slip thumb beneath the shell and thin membrane to slide off the shell.

Water is just starting to boil—so turn off the heat, cover, and let stand.

Cool hard-boiled egg in ice water.

Full size page can be found in the Youth Science Journal on page 7.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

MODIFIED POACHED EGG

Ingredients
1 egg
4 tablespoons water
Cooking spray
Clock or watch with second hand for timing

Directions
1. Lightly spray a small, non-stick skillet with cooking spray; place on medium-low heat.
2. Carefully crack one egg into the skillet, being careful not to break the yolk. Note time and begin to make
observations as indicated in chart below.
3. As soon as the egg begins to cook, add 4 tablespoons water.
4. When water boils, reduce heat to low, cover for 3 minutes, then carefully spoon water over white and yolk.
   Do this continually as cooking progresses. Observe changes.
5. Cook until white and yolk have both coagulated.
7. Using a non-stick grill spatula, place egg on paper plate. Note observations in log.

MODIFIED POACHED EGG OBSERVATIONS
Describe the appearance of the white and yolk at these time intervals.

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Egg White</th>
<th>Egg Yolk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MINUTE</td>
<td>Liquid, clear</td>
<td>Liquid, yellow</td>
</tr>
<tr>
<td>2 MINUTES</td>
<td>Clear liquid in some spots, opaque in other spots</td>
<td>Liquid, yellow, maybe a little bit of white on top</td>
</tr>
<tr>
<td>3 MINUTES</td>
<td>Mostly opaque (cloudy white—not clear, not white), getting solid.</td>
<td>Semi-liquid looking, deeper yellow color, more white forming on top</td>
</tr>
<tr>
<td>5 MINUTES</td>
<td>Solid and white</td>
<td>Yolk is darker yellow, looks firm and has white film on top</td>
</tr>
</tbody>
</table>

As the clear egg white begins to cook, ask the learners what is happening to it. Use the terms denaturation and coagulation to explain. Ask learners why the yolk is still liquid even though some of the white is getting solid. (Yolk needs a higher temperature to cook.) As learners spoon the hot water over the egg yolk, ask them what they think is happening to the yolk. (Hot water on top of the yolk is helping it to cook from the top down. Heat from the burner is cooking it from the bottom up.)
EXPERIMENT 4—STIRRED CUSTARD

To make custard, eggs need to be separated. Here’s how to do it:

**Separating Whites from Yolks**
Some recipes, such as the custard recipe in Experiment Four, require the separation of whites and yolks.

**Ingredients**
5 egg yolks, beaten  
1 1/2 cups 1% or 2% milk  
1/4 cup sugar  
1 1/2 teaspoons vanilla

**Directions**
1. Separate eggs using the technique demonstrated by the facilitator or as shown in the video. Cover egg whites and refrigerate for another use.
2. Put egg yolks in small bowl and beat lightly with wire whisk or fork.
3. Use a rubber spatula to scrape beaten yolks into a heavy, small size saucepan. Use a heat-resistant or wooden spoon to stir together egg yolks, milk, and sugar.
4. Place mixture in saucepan over low heat. Cook and stir continuously over low to medium-low heat just until mixture coats a clean metal spoon; check frequently by dipping a metal spoon into mixture (see picture). Use an instant-read thermometer to monitor cooking temperature. Final temperature will be above 165 degrees and below 170 degrees. Remove pan from heat immediately. Record temperature. Stir in vanilla.
5. Pour all except about half a cup of custard into medium mixing bowl.
6. Some learners need to continue cooking the half cup of custard over low heat until the custard curdles. Record temperature. Pour into a small custard cup for observation and tasting.

**ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)**

There are two variables for the stirred custard: Cooked and over-cooked. It is easy to over-cook stirred custard, so make sure to use low heat and cool immediately. Unlike baked custard, stirred custard will thicken to the consistency of thin syrup. Overheating stirred custard leads to over-coagulation of protein. When this occurs, egg protein “clumps” and the liquid separates; this is called syneresis. It’s still safe to taste, it just looks unappetizing.
7. At the same time, other learners quickly cool the custard in the mixing bowl by placing bowl into a larger bowl filled with ice and water. Be sure cooling water does not get into the custard. Cool for about 5 minutes, stirring frequently. Remove from ice water.
8. Using proper technique, sample the cooled custard. You may also sample the curdled custard if desired.
9. If any custard is left over, cover the surface with plastic wrap to prevent a skin from forming. Normally, custard should chill at least 2 hours without stirring. Custards are often served over fresh fruit or other desserts. Makes about 2 cups, total.

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ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

A reading between 165º F and 170º F

Pleasing consistent yellow color
Sweet, good
Smooth
5

A reading above 170º F

Slightly pale yellow liquid
Ok, but not as good
Clumps with thin liquid
1–5

CUSTARD OBSERVATIONS

<table>
<thead>
<tr>
<th>FINAL COOKING TEMPERATURE</th>
<th>COLOR</th>
<th>TASTE</th>
<th>TEXTURE</th>
<th>RATE TASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked to Doneness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A reading between 165º F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and 170º F</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overcooked</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A reading above 170º F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Flavor may be affected by appearance. More information about taste and flavor can be found in Unit 4.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)

**SHARE**

1. Briefly describe what you did in each experiment and your observations of what happened to the eggs during the cooking process.
   
   Learners describe what they did in each experiment and their observations of what happened to the eggs when heat was applied.

**REFLECT**

1. Describe what you saw happening in each of the experiments as the eggs cooked.

   In each experiment, the application of heat changed the egg from liquid to a solid.
   
   • Scrambled eggs that were cooked just until done were yellow color and fluffy.
     The overcooked scrambled eggs were brown and dry.
   
   • The hard-boiled egg’s yolk and white were both solid.
   
   • The modified poached egg’s albumin (white) coagulated before the yolk did (albumin changes to a solid (coagulates) at a lower temperature than the yolk).
   
   • In the custard, the egg yolks coagulated, thickening it. Overcooked stirred custard separates because of over-coagulation. The water is squeezed out of the protein, leaving clumps and a thin, pale yellow fluid. This is called syneresis.

2. Is this a physical or chemical reaction? **Both**

3. Describe the physical reaction.

   Egg white and yolk change from a liquid to a solid.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat

4. Describe the chemical reaction.

Protein molecules first denature (un-fold) then re-group to form a new structure. This process is called coagulation. When protein continues to heat, protein over-coagulates, toughens, and water separates from the protein. In the case of eggs, they get tough and dry. In custard, the protein curdles and liquid separates from the protein. This is called syneresis.

5. Determine the average taste rating from your group for the stirred custard.

(To determine average, add up all responses then divide by the number of responses.)

- Cooked to doneness average rating: _______________________________
- Overcooked average rating: _____________________________________

Note: Flavor perception may be affected by the appearance.

GENERALIZE

1. What happens to the proteins in eggs when heat is applied and they are cooked?

They turn from liquid to solid. This means the proteins are uncoiling, which is called denaturing. Then they re-form in a different way, which is coagulation.

2. What happens when eggs proteins are overcooked?

They over-coagulate and become dry and tough (as in scrambled eggs). In stirred custard, the overcooked proteins curdle—clumps of egg protein form and the water separates from the protein, which is called syneresis.

Terms: Protein denaturation, coagulation, yolk, egg white (albumen), chalazae, syneresis, functional properties of eggs
APPLY
If you were teaching someone how to cook scrambled eggs, what tips would you give them? Explain the reasons for your tips using some of the scientific terms learned in this activity.

- Use low to medium-low heat to control coagulation rate. Keeps eggs from overcooking.
- Cook just until done, don’t overcook. When protein coagulates, it becomes solid. Overcooking eggs makes them tough and dry.
- Remove from heat as soon as they are done—this prevents over-coagulation of the protein.
- Some people may prefer the texture and flavor of overcooked eggs.

BE A FOOD SCIENTIST
EGGS ARE EXCEPTIONAL!
Few foods are as versatile as the egg. Eggs’ properties lend themselves to a variety of functions, which make them vital to the successful outcome of many recipes and types of foods. Here’s an overview of the many functions that make eggs exceptional in food science.

- Eggs provide structure: when heat changes the eggs’ protein from liquid to solid, it leads to coagulation, giving structure to a product. You observed coagulation in this activity.
- Eggs act as emulsifying agents, binding liquid and oil in baked goods or in salad dressings such as mayonnaise. An emulsifying agent helps to keep oil and water ingredients from separating. Recipes that include oil and a liquid generally have egg, specifically egg yolk because the yolk contains the emulsifying agents.
- Eggs provide leavening when the whites are whipped to incorporate air and create a foam, such as in soufflés and meringues. (This is a different example of coagulation that is explored in Activity 2.2.)
- Eggs control crystallization in certain candy products.
- Eggs provide color, texture, and nutrition in foods.
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)

What You **SEE** & What You **FEEL**

**The Physical Reaction**
The scrambled egg changes from liquid to solid during application of heat.

**What Happens from a **FOOD** **SCIENTIST’S** Point of View**

**The Chemical Reaction**
There are more than 40 types of protein in eggs. Each of the egg proteins has a specific structure as a result of strong bonds or connections. With heat, the proteins change their structure. The white (albumen) and yolk denature and coagulate at different temperatures. When cooking a modified poached egg, you noticed the white changed to a solid first.

Protein in its natural state

Unfolded, denatured protein

Coagulated protein
Effect of Heat on Proteins
Heat used in cooking changes an egg’s proteins from liquid form to solid.

All proteins, whether in meat, eggs, milk, or other foods, are made up of amino acids. Amino acids are molecules that are strung together in long chains that fold into distinct structures due to chemical bonding. (See Process of Coagulation graphic.) When proteins are heated, as in cooking, changes occur in a two-step process:

The first step is **denaturation**. The proteins begin to unwind and unfold. Denaturation is the unfolding process.

The next step is **coagulation**. With continued heating, the denatured protein chains make new bonds and connections with other protein chains to form a solid gel as seen during the heating of scrambled eggs, poached eggs, and baked/stirred custard. Coagulation is the gelling process. Overcooking with high heat, or heating too long, over-coagulates the protein, making it tough and dry. Egg proteins are 75% water. Over-coagulation (called syneresis) squeezes the water out of the proteins. In the case of scrambled eggs, the water evaporates, making the final product dry and tough. In the case of overcooked stirred custard, clumps (curds) are formed and liquid separates from the protein. Overcooked boiled eggs may have a tough white and dry yolk.

**Key points to remember:**
- Heating eggs causes the protein to change from liquid to solid. This is a two-step process: first, heat denatures protein. Then the proteins reform in a different way, which is coagulation. The physical change (coagulation) occurs because of alterations in the protein molecules.
- With excess heat, protein can over-coagulate and become tough and dry. This is illustrated with the scrambled eggs experiment.
- Egg coagulation is also illustrated with the preparation of stirred custard. If custard is overheated and/or not cooled quickly, the custard will over-coagulate or curdle. When excessive coagulation causes the liquid to separate from the protein, it is called syneresis.

**FOOD SCIENCE AND EGGS—WHAT’S THE LINK?**
Eggs have many functions in recipes, so if a person does not want to eat eggs, how can a recipe be made successfully? Food scientists can develop recipes and foods that don’t use eggs. They may substitute other ingredients that have the same function that eggs did in that particular recipe or food. For instance, if an egg were used for leavening in muffins, changing the amount of baking powder and/or baking soda may give a similar result. Or a food might have eggs in it to give it structure or to help liquid ingredients mix together without separating. Food scientists then use other ingredients that can do the same thing as eggs to make foods such as salad dressings, dry baking mixes, puddings, and baked goods. Check out products in your pantry and see how many of them contain eggs.
Sometimes people want to avoid eating egg yolks because they contain cholesterol and saturated fat. Eating too much saturated fat and cholesterol can lead to clogged arteries, which in turn may lead to heart attacks and strokes.

The Dietary Guidelines for Americans state the following:

Moderate evidence shows a relationship between higher intake of cholesterol and higher risk of cardiovascular disease. Independent of other dietary factors, evidence suggests that one egg (i.e., egg yolk) per day does not result in increased blood cholesterol levels, nor does it increase the risk of cardiovascular disease in healthy people. Consuming less than 300 mg per day of cholesterol can help maintain normal blood cholesterol levels. Consuming less than 200 mg per day can further help individuals at high risk of cardiovascular disease.

Since the Dietary Guidelines for Americans suggest no more than 300 milligrams per day of cholesterol from the foods you eat, let’s see how much cholesterol is in an egg. Look at the Nutrition Facts Panel on the back or inside flap of an egg carton.

How much cholesterol is in one egg? _____________

Is that more or less than half of the daily recommended amount of cholesterol? ____________

If you want to eat more eggs than recommended, mix several egg whites with one whole egg to get a great serving of high-quality protein without too much cholesterol and saturated fat. Separate egg whites from yolks using the technique you learned in this activity.

What type of milk did you use to make the custard? You might want to consider switching to fat-free or 1% milk if you haven’t already done so. This one switch will greatly reduce the amount of saturated fat and cholesterol you eat every day, especially if you’re drinking the three cups of milk each day that the Dietary Guidelines recommend.

**Did You Know?**

- Sometimes hard-cooked eggs have a greenerish ring around the yolk. This occurs as a result of a reaction between sulfur in the egg white and iron in the yolk. It occurs more often when eggs have been cooked too long or at too high a temperature. The instructions in this experiment minimize the greenerish ring reaction by proper cooking and immediate cooling.
- Using eggs that are 7–10 days old are easier to peel. Peeling under cool, running water also helps to get the shell separated from the egg.
- If you live at altitudes above 10,000 feet, it is almost impossible to hard-cook eggs.

**ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat! (cont.)**
ACTIVITY 2.1: Eggs are Exceptional: The Right Heat for the Eggs You Eat!

COOKING UP FOOD SCIENCE AT HOME
Heart Healthy Scrambled Eggs

Ingredients
1 whole egg
3 tablespoons egg whites (use pasteurized liquid egg whites or dried egg whites)
2 tablespoons milk

Directions
1. With a wire whisk, rapidly whisk the egg and whites for 45–60 seconds. Whisking adds air and makes scrambled eggs fluffy.
2. Add milk and whisk to mix.
3. Lightly spray a small, non-stick skillet with cooking spray; place on medium to low heat.
4. Pour whisked mixture into skillet. Using a utensil that won’t scratch the skillet, such as a plastic heat-resistant spoon or spatula, stir occasionally during cooking. Scrape the egg from the bottom of the pan and stir gently. Break up large pieces. Eggs are done as soon as they have become solid and no liquid remains.
5. Carefully remove skillet from heat. Makes 1 serving.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—POULTRY INDUSTRY
Watch the process eggs undergo as they travel from farm to table! This series of videos also describes food science jobs and career development in the poultry industry. See how science, technology, engineering, and math are used in egg processing. Access the video at: www.4-H.org/curriculum/foodsci

LEARN MORE!
VIRTUAL FUN
Learn more with some great videos about egg production, the egg industry, cracking and separating eggs, and the science behind egg coagulation at: www.4-H.org/curriculum/foodsci

Full size page can be found in the Youth Science Journal on page 17.
NOTES
ACTIVITY 2.2
Make Sense of Soufflés: Eggstreme Egg Makeover

MATERIALS LIST

Supplies:
- 2 custard cups for each learner, if available. Otherwise, minimum of 2.
- 6 small to medium sized mixing bowls (ceramic or metal only, no plastic bowls)
- Small microwave-safe bowl
- 4 hand mixers
- 2 10-ounce ramekins
- 2 rubber spatulas
- Wire whisk
- Small spoon
- Measuring spoons
- 2 liquid measuring cups—1-cup and 2-cup
- Baking sheet
- Potholders
- Plastic forks or spoons for tasting
- Paper plates
- Hand soap
- Paper towels
- Sanitizing solution
- Pencils
- Timer
- Toothpicks to test for cooking completion

Food:
- Eggs: 6 for experiments, plus several extra eggs in case yolk gets into some of the egg whites being separated. If more than 6 learners, they each need one egg too.
- ½ cup semi-sweet chocolate chips (extra ½ cup in case chocolate is overheated)
- ¼ teaspoon cream of tartar
- ½ cup granulated sugar
- 1 tablespoon cream
- 1 teaspoon all-purpose flour
- ¼ teaspoon cinnamon
- ¼ teaspoon salt
- 2 teaspoons confectioners’ sugar
- Cooking spray

Printed Materials:
- Order Youth Science Journal, one for each learner

Making a soufflé? This may be a new experience for you. As you understand more about food science, the ingredients and recipe instructions for soufflés make sense. The science behind foods made with egg whites such as soufflés, meringues, and angel food cakes, focuses on egg protein coagulation. This activity examines the proteins found in egg white (albumen) and protein coagulation from mechanical action (beating). There are many proteins in albumen (egg white). Some proteins in albumen are coagulated during beating.

Ask some of the learners to bring bowls and hand mixers if they have them.

SKILL LEVEL:
Intermediate

LEARNER OUTCOMES
- Knows how to observe, describe, and apply scientific principles making egg white foams.
- Knows how to use principles of egg white foams in recipe formulation and food preparation.
- Understands and identifies how egg white protein coagulation is controlled and used favorably in recipe formulations.

SUCCESS INDICATORS
- Defines, describes, and prepares product showing the stages of egg white foams.
- Identifies ingredients and equipment that stabilize and prevent coagulation of egg white foams.
- Able to follow written directions and prepare stable egg white foam for a soufflé.

SUGGESTED GROUP SIZE
- 8–12 youth

TIME NEEDED:
Minimum of 70–90 minutes

SPACE
Kitchen with oven, microwave, and counter space is mandatory.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

DURING THIS ACTIVITY, YOU WILL:

• Demonstrate how to crack and separate an egg and how to “fold” an egg white mixture.
• Review parts of an egg, discuss egg white (albumen) and protein coagulation from mechanical action (beating) showing how egg whites serve as a leavening agent.
• Facilitate learner experiments: produce three stages of egg white foam, use various ingredients and equipment to stabilize or prevent egg white coagulation, and make a soufflé.
• Help learners understand the function of ingredients in the soufflé and why recipe directions are important to the outcome of the final product.
• Support and encourage learners to understand, learn, and apply the science of mechanical protein coagulation to other food products.

KEEP LEARNERS SAFE

• CAUTION: EGGS AND FOODBORNE ILLNESS: Some eggs contain the bacteria called Salmonella enteritidis (SE), which cause foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE, so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.
• FOOD SAFETY: Before each activity: Clean kitchen surfaces, cutting boards, etc. Learners and Facilitators wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
• EXPERIMENTING: Use caution when working with hot foods, especially the microwave-heated chocolate and equipment; an adult should be in charge. Have pot holders available. An adult should be in charge of using the oven and microwave oven. Foods like melted chocolate may be super-heated and cause burns.
• TASTING: When taste testing use the two-spoon method:
  » Sampling spoon (or fork): Use to remove small amount of food from cooking pan. Place onto tasting spoon (or small bowl or plate) WITHOUT touching tasting spoon, bowl, or plate.
  » Tasting spoon: Use to place food into mouth. Never let the sampling spoon touch the tasting spoon. If it does, wash or replace sampling spoon.
  » Do not taste raw eggs.
• Tie back long hair.
• Roll up long sleeves.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

GETTING READY

Prior to the Activity

• View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The What do we need to know? and Be a Food Scientist sections explain the science behind the experiments.
• Gather all equipment, supplies, and materials.
• Divide learners into teams. One team will do one activity, then share information.
• Print out instructions from Youth Science Journal for each experiment and place at each work station.

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. Have you, or someone you know, ever beaten egg whites? In what food were the beaten egg whites going to be used?
2. What happens when they are beaten or whipped for a while? (Become stiff.)
3. Can you name some foods that are made from egg white foams? (Soufflés, lemon meringue pie, angel food cake, puffy omelets)
4. Why do you think the egg whites have to be beaten stiff to use in these recipes? (Incorporates air, provides leavening)

Open the Youth Science Journal

As learners look at the pictures and read the statements, “Raw egg whites change from liquid to solid,” and “Egg white foams can be cooked to make a soufflé.” Guide them to ask questions such as those listed in the Answer Key.

Optional: Demonstration: How to Crack and Separate Eggs

In Activity 2.1, you demonstrated cracking and separating eggs. If necessary, repeat this demonstration with learners.

Unit 2: The Power of Protein Chemistry

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PREPARATION ACTIVITY
Each learner cracks and separates an egg—six of which can be saved for the experiments.

Important: DO NOT use any whites that contain yolk in these experiments unless instructed to do so.

Ideally, each learner has two custard cups. If not, you might have one learner at a time separate an egg, putting the white into one custard cup and the yolk into the second custard cup. In this way, any yolk that accidentally gets into a white will not ruin all the whites. If a white gets any yolk in it, set aside and refrigerate for another use.

To prepare for the experiments, after a learner has separated an egg, do the following:
• Pour one egg white and one egg yolk into a mixing bowl.
• Pour one egg yolk into a mixing bowl.
• Pour one egg white into each of 3 mixing bowls
• Pour two egg whites into a mixing bowl.
• Put extra yolks into a container to save and refrigerate for later use, or discard. If you use this method, you will only need six eggs plus two extra in case yolk goes into a white and has to be discarded. (Plus one for each additional learner if you have more than six learners, so that everyone can learn the skill.)

EXPERIMENT 1—STABILIZING EGG WHITE FOAMS
Divide learners into four groups. Use separated eggs from Preparation Activity. Follow experiment instructions in Youth Science Journal.

Use the terms introduced in the Be a Food Scientist section as learners work with the eggs. As learners beat egg whites, ask them to describe what is happening and why they think it is happening. Based on the descriptions given by the learners, introduce relevant concepts and terms, i.e. coagulation occurs because beating changes the structure of the proteins in the albumen, just like heat did when making scrambled eggs. Whole egg will not beat stiff because of the presence of the yolk, which contains fat. Fat inhibits foam production.

Explain the physical and chemical reactions: Beating traps air in the egg white. Continued beating denatures the protein in the egg white and causes it to re-form, which is coagulation. This coagulation occurs without heat. Sugar stabilizes the egg white foam for use in a product—it helps the foam to leaven the product.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

EXPERIMENT 2: EAT AN EGG WHITE FOAM—CHOCOLATE SOUFFLÉ!

Follow the experiment instructions in the Youth Science Journal.

WHAT IS “FOLDING”?  
Folding is more gentle than mixing or stirring. It is typically used with ingredients that have been whipped to incorporate air, such as egg whites or whipped cream. It is usually done with a broad plastic spatula or other flat utensil. To fold, move the spatula along the inside of the bowl, going down to the bottom of the bowl and twisting the wrist so that the spatula stays flat, and gently bring ingredients up from the bottom all in one movement. Then “fold” the mixture over on top of itself. Repeat a few times just until ingredients are combined, being careful to maintain as much of the air and fluffiness of the whipped item as possible. Optional: Demonstrate folding technique using the egg white foam with sugar from Experiment 1, Variable D.

Special Note: Most soufflés start with preparation of a white sauce. You will notice milk/cream, flour, and butter in the recipes. Egg whites provide structure and leavening. Our recipe for this activity illustrates the principles of egg white coagulation with a simple recipe.
STATEMENT: RAW EGG WHITES CHANGE FROM LIQUID TO SOLID.
BEATEN EGG WHITES CAN BE COOKED TO MAKE A SOUFFLÉ.

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder . . .” Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

- How raw egg whites change from liquid to a solid foam? Why do they do that?
- Why beating egg whites make them stiff? (Some learners may already know that beating produces stiff egg whites.)
- How egg whites are made into food?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .
EGGS AND FOODBORNE ILLNESS
Some eggs contain the bacteria called Salmonella enteritidis (SE) which cause foodborne illness (food poisoning). You cannot tell from looking or smelling whether an egg has SE, so all eggs need to be treated as if they do. Although SE is typically found in the yolk, SE in the white cannot be ruled out. Always cook eggs thoroughly. Never eat raw or undercooked eggs. After handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg.

WHAT WILL WE DO?
In this activity, you get to use some of the skills you practiced in Activity 2.1. You will crack and separate eggs, then find out how to beat egg whites to make a foam. You’ll make three stages of egg white foams, use various ingredients and equipment to stabilize egg white coagulation, and then make a chocolate soufflé!

WHAT DO WE NEED TO KNOW?
There’s more than one way to change egg whites from a liquid to a solid! In Activity 2.1, heat was used to coagulate egg protein in the yolk and white. In this activity, you will use an electric mixer to beat the egg whites. Beating is a mechanical action; it is another way to coagulate egg protein.

There are many proteins in albumen (egg white). Some of the proteins coagulate during beating. The science behind foods made with egg whites, such as soufflés, meringues, and angel food cakes, focuses on egg white protein coagulation. As you learn the food science in this activity, the ingredients and recipe instructions for soufflés will make sense.

To coagulate egg protein with beating, you start with a foam. As beating begins, air is trapped in large bubbles. With continued beating, the proteins in albumen change structure. Coagulation starts as the proteins “coat” the air bubbles.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds before handling and mixing ingredients for soufflés. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips and handouts regarding food safety.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

PREPARATION ACTIVITY
Using the technique demonstrated by the facilitator, crack an egg and separate the egg white from the egg yolk by carefully pouring the yolk back and forth between the egg shell halves while letting the white drop into the bowl.

EXPERIMENT 1—STABILIZING EGG WHITE FOAMS
Divide into groups; one group per variable. Share results to fill in Observation Log.

Variation A: Whole egg
Use an egg white and yolk from Preparation Activity.
1. Place one egg white and one yolk into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. At the end of 7 minutes, stop beating.
5. Describe appearance of mixture in Observation Log.

Variation B: Plain Egg White
Use an egg white from Preparation Activity.
1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.

HOW TO BEAT EGG WHITES
Place beaters of hand mixer in bowl so that the beaters touch the bottom of the bowl. Start on low speed. Move beaters slowly around the bottom of the bowl and/or turn the bowl continuously. As egg white begins to foam, put on medium speed. Continue moving beaters and turning bowl. Keep beaters low in the bowl so that product does not fly off the beaters into the room.
3. After one minute, change speed to medium.
4. Beat to stiff peak stage. Be careful not to overbeat. The change from soft peak to stiff peak occurs rapidly. Stop beaters about every 30 seconds. When beaters have stopped completely, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage. If foam forms a peak and stays standing, it is stiff peak stage.
5. Record time that stiff peak stage is achieved.
6. Describe appearance of foam in Observation Log.

**Variation C: Egg White with Acid—Cream of Tartar**

Use an egg white from Preparation Activity.
1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. Beat to foamy stage, then add 1/8 tsp. cream of tartar.
5. Beat to stiff peak stage. Be careful not to overbeat. Stop beaters about every 30 seconds. When beaters have stopped completely, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage. If foam forms a peak and stays standing, it is stiff peak stage.
6. Record time that stiff peak stage is achieved.
7. Describe appearance of foam in Observation Log.

**Variation D: Egg White with Sugar**

Use an egg white from Preparation Activity.
1. Put one egg white into a small mixing bowl.
2. Record time in Observation Log and begin beating on low for one minute.
3. After one minute, change speed to medium.
4. Beat to soft peak stage. Be careful not to overbeat—stop beaters about every 30 seconds. When beaters have stopped, use them to lift some egg white foam. If it forms a peak and falls over on itself, it is soft peak stage.
5. Add 2 teaspoons sugar. Beat for about 20 seconds. Repeat two times until a total of 6 teaspoons of sugar have been added.
6. Continue beating until stiff peak stage is reached. With beaters stopped, lift some egg white foam. If foam forms a peak and it stays standing, it is stiff peak stage.
7. Record time that stiff peak stage is achieved.
8. Describe appearance of foam in Observation Log.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

EGG WHITE FOAM OBSERVATION LOG

<table>
<thead>
<tr>
<th>BEGINNING TIME</th>
<th>ENDING TIME</th>
<th>DESCRIBE THE APPEARANCE OF THE EGG WHITE FOAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation A:</td>
<td></td>
<td>Foamy with air bubbles. Mixture is not stiff.</td>
</tr>
<tr>
<td>Whole egg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variation B:</td>
<td></td>
<td>Looks stable (but if incorporated into another mixture, it will lose volume easily).</td>
</tr>
<tr>
<td>Plain egg white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variation C:</td>
<td></td>
<td>Foam is fine-textured and stable.</td>
</tr>
<tr>
<td>Egg white with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>acid (cream of tartar)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variation D:</td>
<td></td>
<td>Foam is fine-textured and stable.</td>
</tr>
<tr>
<td>Egg white with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sugar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPERIMENT 2: EAT AN EGG WHITE FOAM—CHOCOLATE SOUFFLÉ!
This experiment helps you put the principles you learned in Experiment 1 into action by making a delicious dessert using an egg white foam.

WHAT IS “FOLDING”?
Folding is more gentle than mixing or stirring. It is typically used with ingredients that have been whipped to incorporate air, such as egg whites or whipped cream. It is usually done with a broad plastic spatula or other flat utensil. To fold, move the spatula along the inside of the bowl, going down to the bottom of the bowl and twisting the wrist so that the spatula stays flat, and gently bring ingredients up from the bottom all in one movement. Then “fold” the mixture on top of itself. Repeat a few times just until combined, being careful to maintain as much of the air and fluffiness of the whipped item as possible.
**ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)**

**Ingredients**

<table>
<thead>
<tr>
<th>CHOCOLATE SOUFFLÉ</th>
<th>FUNCTION OF INGREDIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooking spray</td>
<td>Egg white foam stability, flavor</td>
</tr>
<tr>
<td>3 tablespoons granulated sugar</td>
<td></td>
</tr>
<tr>
<td>½ cup semi-sweet chocolate chips</td>
<td>Flavor</td>
</tr>
<tr>
<td>2 large eggs, separated</td>
<td>Structure, steam leavening</td>
</tr>
<tr>
<td>1 tablespoon heavy cream</td>
<td>Flavor</td>
</tr>
<tr>
<td>1 teaspoon all-purpose flour</td>
<td>Structure</td>
</tr>
<tr>
<td>¼ teaspoon ground cinnamon</td>
<td>Flavor</td>
</tr>
<tr>
<td>¼ teaspoon salt</td>
<td>Flavor</td>
</tr>
<tr>
<td>2 teaspoons confectioner’s sugar</td>
<td>Flavor and visual appeal</td>
</tr>
</tbody>
</table>

**Directions**

Learners divide into four groups—when not active, observe the group actively doing the preparation.

**Group One:**
1. Preheat oven to 375º F. Position oven rack in center of oven.
2. Determine the holding capacity of your ramekin or oven-safe bowl. Use a 2-cup liquid measuring cup showing ounces. Place water in a ramekin and measure. It should hold about 10 ounces. Dry ramekin.
3. Spray two ramekins lightly with cooking spray. Sprinkle interior sides and bottom of ramekins with 1½ teaspoons granulated sugar.
4. Use eggs from Preparation Activity or
   - Separate two eggs; discard one of the yolks.
   - Place one yolk in a mixing bowl.
   - Place the two egg whites in a different mixing bowl (give to Group Three).
5. Using a wire whisk, whisk together the cream and one egg yolk in mixing bowl (give to Group Two).

**Group Two:**
1. Melt chocolate in a small microwave-safe bowl. Stir every 15 seconds. Watch carefully. Overheated chocolate is crumbly and not useable. Should it overheat, discard and start over with more chocolate.
2. Drizzle melted chocolate into egg yolk mixture (given to you by Group One) slowly while constantly whisking. Whisk until smooth.
3. Add cinnamon and flour and whisk again until smooth.

**Unit 2: The Power of Protein Chemistry**

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Full size page can be found in the Youth Science Journal on page 23.
Group Three:
1. Get the two egg whites from Group One. Add salt. Using a hand mixer, beat to soft peak stage.
2. Add remaining sugar in three parts (2 teaspoons at a time, then beat for a short time. Repeat twice). Beat until stiff peak stage.
3. Pour about half of chocolate mixture into egg whites.
4. Gently fold chocolate mixture into egg whites just until combined.
5. Add remaining chocolate mixture and gently fold just until combined.

Group Four:
1. Divide mixture equally between two 10-ounce ramekins. Place ramekins on baking sheet.
2. Carefully place baking sheet into oven and bake 18–22 minutes.
3. Check at 18 minutes with a clean toothpick. When toothpick inserted into center comes out clean, soufflé is done; remove from oven.
4. Dust soufflé lightly with confectioner’s sugar. (“Dust” by placing a small amount of sugar in a spoon. Hold spoon over soufflé. With one hand, tap the hand holding the spoon so that sugar falls gently off the edge of the spoon.)
5. Serve immediately. Spoon out a small amount onto paper plates so that everyone can sample the soufflé.

• Soufflés are usually served immediately in the dish in which they were baked because they stay puffy for only a short amount of time. As the soufflé cools, it will fall slightly. It is not as pretty, but still delicious!

Describe the appearance of the soufflé when it comes out of the oven:
________________________________________________________

Describe the texture of the inside of the soufflé: Very light and airy

Describe the texture of the soufflé in your mouth: Warm and soft

This soufflé was a dessert. Most soufflés start with a white sauce of milk/cream, flour, and butter. A savory soufflé using such things as cheese and finely chopped or pureed vegetables can make a main dish. Now that you have “Made Sense” of soufflés, find and try a new recipe for one at home!
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

Below are answers you might expect from the learners. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

**SHARE**
Briefly describe what you did in each experiment and your observations of the egg white foams.

Learners describe their observations and what they did in the experiments.

**REFLECT**

1. What did you do that changed egg whites from liquid to solid without heat?
   - They were beaten for a few minutes.

2. Why does this change occur?
   - The proteins in egg whites undergo changes. The changed proteins surround the air bubbles when beating (coagulate).

3. What is in egg white foam that makes products rise?
   - Air

4. What helps keep egg whites stable so that they can hold air?
   - Sugar or acid, such as cream of tartar, and proper amount of beating.

   Bowl with a round bottom, small beaters, room temperature of egg whites.

5. What are the best times to add stabilizing agents in order to maximize stability?
   - Add cream of tartar at the beginning of beating.
   - Add sugar gradually, in small amounts, after reaching soft peak stage.

6. What is the major function of egg white foam in a soufflé?
   - Traps air and steam to stretch the structure and make it rise.

7. What are the functions of ingredients in the chocolate soufflé?
   - Learners may look back at the list of function of ingredients, or answer from memory.
ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

At this point in the activity, ensure that the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.

**TERM & Concept Discovery**

Terms: Egg albumen, egg white foam, protein coagulation, stabilizing ingredient, cream of tartar, sugar, leavening agent, wire whisk, fold, soufflé

**GENERALIZE**

1. As egg whites are beaten, what changes do you see?
   - They get more solid, more firm, changing from soft peak stage then to stiff peak stage.

2. What ingredients can stabilize egg white foams?
   - Sugar or cream of tartar (acid).

**APPLY**

Imagine you are at a friend’s house and feel like having angel food cake. You decide to make one, but your friend doesn’t know how. You find a recipe online. What are several preparation tips you can tell your friend to make sure the cake is good?

- Separate eggs carefully, no yolks allowed!
- Add cream of tartar and/or sugar exactly as instructed.
- Beat slowly then at medium speed, checking frequently to see when stiff peak stage is reached.
- Fold in other ingredients, using proper folding technique to preserve trapped air.

**BE A FOOD SCIENTIST**

**BEAT THE EGGS!**

Egg white foams are included in many recipes. For example, meringue on the top of a pie, angel food cake, puffy omelets, and soufflés are made of egg white foam. The foam adds volume to the food products by trapping air during beating. In order to keep the air trapped, the egg white foam must be stable. Creating stable foam is a two-step process.

Full size page can be found in the Youth Science Journal on page 26.
First, as air is incorporated during beating, specific proteins in egg whites (albumen) coagulate and undergo structural changes. The proteins then re-align and create a new structure, a protein film. The protein film surrounds and traps air bubbles created by beating.

Added ingredients such as sugar and acid (e.g. cream of tartar) stabilize the foam, helping maintain the trapped air bubbles. The trapped air helps to leaven the product, making it light and fluffy. At the same time, such stabilizers help to prevent the breakdown of the foam. In addition, the liquid in egg white foam changes into steam during cooking. As the water portion of the egg white becomes steam, it expands and rises in the trapped air, stretching the other ingredients that help form the structure. The heat of cooking further coagulates the protein, thus making the structure of the food more firm.

FOUR STAGES OF EGG WHITE FOAM

There are four stages of egg white foam formation. You will experiment with the first three of these stages. In the first stage, as beating begins, air is trapped in large bubbles. With continued beating, the proteins found in albumen changes structure. Coagulation starts as the proteins “coat” the air bubbles.

Stage One: Air is incorporated and trapped in large bubbles. Mixture is foamy, bubbles are large. It is referred to as foamy.

Stage Two: Air cells in the foam become finer. If you stop beating at this stage and pull up the beaters, the peak of the foam flops over. This is called the soft peak stage. The photo on the left shows early soft peak stage. The photo on the right still shows soft peaks, although they are not as soft as the previous photo. Note how they have fallen over.

Stage Three: Continued beating makes the air bubbles smaller, so the foam becomes very fine. When you pull up the beaters, the egg white foam holds a peak. This is called the stiff peak stage.

Stage Four (Not Shown): Continued beating without extra ingredients to stabilize the egg white foam may result in the foam breaking apart and appearing dry and chunky. Liquid egg white begins to separate from the foam; this is called syneresis. When this happens, the foam can no longer provide leavening action.
RECIPE INGREDIENTS THAT INFLUENCE EGG WHITE FOAMS

- **Fat**: The fat present in egg yolks will stop or greatly delay foam from forming. Therefore, one must be very careful when separating egg whites from egg yolk. Even a small amount of fat from the yolk, if mixed with egg whites, will decrease the final volume.

- **Acid**: Acid stabilizes the egg white foam so other ingredients can be added in a recipe without decreasing the final size of the product. The most common acid added to egg white foam is cream of tartar. Typically it is added at the beginning of beating. When added to egg white, the foam is more stable, but it will take longer to achieve stage three—stiff peaks. The stabilized foam provides good leavening action in the final product.

- **Sugar**: Like cream of tartar, sugar stabilizes egg white foams while slowing formation of the foam. Sugar stabilizes the foam to hold incorporated air. Generally, sugar is added after the foam has reached the soft peak stage. Sugar is added gradually to minimize time needed to obtain stiff peak. It also protects the foam from being whipped to the dry stage, thus preserving its ability to provide leavening.

EQUIPMENT INFLUENCES EGG WHITE FOAMS—BEATERS, BOWLS, AND MORE

These things are often mentioned in recipe directions for soufflés, angel food cakes, and similar foods. At other times, these details are not mentioned but are still important in how the food comes out, so it’s good to be aware of them.

**Beaters, Bowls, and Temperature**

- **Beaters**: The finer, or thinner, the wires are in a whisk or beater, the finer the texture of the egg white foam. However, with a wire whisk or typical electric hand mixer, the foam becomes finer the longer it is whipped. A stand mixer with a wire whisk attachment produces egg white foams very quickly; care must be taken not to overbeat.

- **Bowls**: Bowls with small rounded/flat bottoms allow the beater to pick up more egg white. Thus, the foam forms more quickly. Don’t use plastic bowls because fat residue from previous uses can stick on the surface even after washing. The tiniest amount of fat interferes with foam formation. Fat coats the proteins, preventing the structural changes that make it coagulate.

- **Temperature**: Whites whip more quickly at room temperature than if cold from the refrigerator. It’s best to set out eggs to be whipped for about 20–30 minutes before beating. Remember for food safety purposes that perishable foods such as eggs should not be left at room temperature for more than two hours.
Key points to remember:
- Cream of tartar or sugar stabilizes foams for a properly leavened product.
- The stage of the foam and the timing when ingredients are added to a foam are important for the final product.
- Use the correct equipment and eggs at the right temperature to make a stable, fine foam.

ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

What You SEE & What You FEEL

The Physical Reaction in Egg White Foams

LIQUID → FOAMY → SOFT PEAK → STIFF PEAK → DRY PEAK

What Happens from a FOOD SCIENTIST’S Point of View

EGG WHITE FOAMS

LIQUID → AIR TRAPPED → PROTEIN STRUCTURAL CHANGES → REACTION CONTINUES → OVER-COAGULATION

ADDITION OF SUGAR OR CREAM OF TARTAR → DELAYS OR PREVENTS OVER-COAGULATION

ACTIVITY 2.2: Make Sense of Soufflés: Eggstreme Egg Makeover (cont.)

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FOOD SCIENCE, NUTRITION, AND EGG PROTEIN—WHAT’S THE LINK?

Food scientists can use the protein from eggs to make special foods such as protein powders or high protein snack bars.

The protein in eggs is very high quality. It is one of the most easily digested and perfectly balanced proteins for humans. Compared to other proteins, only those in milk are as good as the protein in eggs. A typical large egg contains 7 grams of protein. To compare, the Recommended Dietary Allowance for protein is as follows:

- Children ages 9—13........ 34 grams of protein
- Girls ages 14—18........ 46 grams of protein
- Boys ages 14—18........ 52 grams of protein

Now that you know eggs are a good source of protein, you may want to eat more of them without getting all the saturated fat and cholesterol that come along with the yolk. Besides separating eggs and discarding most of the yolks, you can purchase pasteurized liquid egg whites. They come in a small carton in the refrigerated section at the grocery store. They are usually sold alongside the whole eggs. Look for ones with egg whites only.

In addition, many grocery stores carry dried egg whites. These come in handy if you run out of eggs, or if you just want egg whites for a recipe. Pasteurized egg white powder is pure albumen that has been dried. They are mixed with water to use them.

LEARN MORE!

VIRTUAL FUN

For videos on working with eggs, recipes, and additional resources about the use of eggs in the food industry, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
Do you think cheese-making might be a complicated and mystifying process? It’s not! Making a fresh cheese, like queso fresco, is actually simple. In this activity, you discover how milk turns into cheese. The focus is the coagulation of a protein (casein) found in milk. Coagulation, the formation of cheese curds, occurs because of acidic ingredients such as buttermilk and vinegar, an enzyme called rennet, and heat. Once coagulated, the curds (solids) are separated from the whey (liquid).

**SKILL LEVEL:**
Advanced

**LEARNER OUTCOMES**
- Knows how to observe, describe, and apply scientific principles for making fresh cheese.
- Knows how to use principles of acid and enzyme coagulation of milk protein (casein) in cheese manufacturing.
- Understands cheese-ripening concept and identifies types of commercial cheese products.
- Applies food safety principles for cheese and protein foods.

**SUCCESS INDICATORS**
- Identifies the protein in milk that is affected by acid and rennet.
- Defines and describes physical and chemical coagulation of milk protein.
- Able to follow written directions, measure, and prepare recipe illustrating milk protein coagulation.
- Understands the functional properties of acid and rennet in cheese.

**SUGGESTED GROUP SIZE**
- This is designed as a group activity for 8–12 youth.

**TIME NEEDED:**
Minimum of 90 minutes

**SPACE**
Kitchen is necessary.
Making *queso fresco* is simple!
Fewer than a half dozen ingredients are needed! Here’s a quick overview:

- Start with pasteurized whole milk; add buttermilk and vinegar.
- Heat to 90°F.
- Add rennet enzyme, then let set until curd forms.
- Curd is cut into pieces. Liquid whey is released.
- Heat to 115°F to boost release of whey.
- Strain through cheesecloth. Drain off whey. Remaining curds are the soft cheese.
- Add salt, mix, and hand-form cheese.

### KEEP LEARNERS SAFE

- **EXTRA SAFETY MEASURES ARE NECESSARY FOR CHEESE!**
  Begin with clean equipment and new cheesecloth. All equipment used in making the cheese, including the cheesecloth, must be sanitized using a water-bleach solution of ½ tablespoon unscented bleach added to ½ gallon (8 cups) of cool water. Everything must be soaked in the solution for two minutes and air dried (not rinsed). This procedure needs to be done by the facilitator prior to the start of the activity.

- **FOOD SAFETY:** Clean and sanitize kitchen surfaces, cutting boards, and all work surfaces. Learners and facilitators should wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.

- **EXPERIMENTING:** Use caution when working with hot foods and equipment; an adult should be in charge and directing the group activity. Keep pan handles turned in, away from the edge of the stove or hotplate. Have pot holders available. Follow recipe and directions carefully. Learners working with the hot liquids need to roll up long sleeves and/or use rubber bands to secure them.

- **TASTING:** Samples are cut with a plastic knife and placed on paper plate for individual sampling.
- Tie back long hair.
- Roll up sleeves

Homemade *queso fresco* is easy to make and delicious when warmed in tortillas!
GETTING READY

Prior to the Activity

- View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal. The What do we need to know? and Be a Food Scientist sections explain the science behind the experiments.
- Download the video showing how cheese is made at the Washington State University Creamery. This 8-minute video can be shown on a laptop or tablet during cheese cooling time. Available at www.4-H.org/curriculum/foodsci.
- Gather all equipment, supplies, and materials.
- Clean and sanitize cheese-making equipment as instructed in the “Personal Safety” section.
- Select cheeses to sample—if possible, choose some that are in various ripening stages.

ORGANIZING THE ACTIVITY

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. Do you like cream cheese, or mozzarella on pizza, or feta or ricotta cheese?
2. How are these cheeses different from cheddar cheese? (They are soft, fresh, un-aged cheeses, like the one we are making today.)

DURING THE ACTIVITY, YOU WILL:

- Work alongside learners making queso fresco.
- Review protein coagulation due to heat (scrambled eggs), mechanical action (egg white foams), and now discuss how the milk protein, casein, is coagulated with the aid of acid in buttermilk and vinegar, the enzyme rennet, and heat during fresh cheese production.
- Taste and compare un-ripened and ripened cheeses and their manufacturing processes.
- If possible, show the video of commercial cheese manufacturing.
Open the Youth Science Journal
As learners look at the pictures and read the statement, “Milk can separate into solids and liquid. The solids make cheese.” Guide them to ask questions such as those listed in the answer key.

THE EXPERIMENT—MAKING QUESO FRESCO
Follow the experiment instructions as given in the Youth Science Journal. See pictures below for procedure and results to expect. Review the What do we need to know? and Be a Food Scientist sections of the Youth Science Journal to understand and help you explain the science of the experiments.

1. Take the temperature of the milk without letting the thermometer touch the sides or bottom of the pan. Pictured is an Insta-Read type of thermometer.

2. Later in the process, cut curds into ½-inch cubes. Pour through cheesecloth.

3. Mix salt into curds.

4. After salting and setting, gently twist the cheesecloth to squeeze out remaining whey.

5. Scrape queso fresco out of cheesecloth and onto a plate.

6. Press and form queso fresco into a ball or rectangle.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

Below are answers (bolded in blue) you might expect from the learners. When possible, help them understand the concepts in their own words before you explain. Use this as a guide to ensure learners understand the science behind their observations. Become familiar with the background information provided before doing this discussion. Rating numbers and learners’ opinions will vary.

STATEMENT: MILK CAN SEPARATE INTO SOLIDS AND LIQUID. THE SOLIDS MAKE CHEESE.

Ask as many questions as you can about these pictures and this statement. Start your first question with “I wonder…”

Don’t stop to discuss, answer, or judge any questions. Write them here, then share with your group.

I wonder . . .

• How milk turns into cheese?
• How curdes and whey form?
• What makes milk coagulate?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. In addition, after handling raw eggs, always wash hands with soap and warm water. Wash and sanitize any surfaces that come into contact with raw egg. Visit www.FightBac.org for tips and handouts regarding food safety.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

WHAT WILL WE DO?

In this activity, you get to make cheese. You’ll find out how milk turns into cheese. Do you think cheesemaking might be a complicated and mystifying process? It’s not! Making a soft, “fresh” cheese, such as queso fresco, is actually simple. Here’s a quick overview:

- Start with pasteurized whole milk. Add buttermilk and vinegar.
- Heat to 90°F.
- Add rennet enzyme, then let set until curd forms.
- Cut curd into pieces. Liquid whey is released.
- Heat to 115°F to boost release of whey.
- Strain through cheesecloth. Drain off whey. Remaining curds are the soft cheese.
- Add salt, mix, and hand-form cheese.

WHAT DO WE NEED TO KNOW?

Milk proteins are a combination of 80% casein and 20% whey. To make cheese, the protein in milk needs to be thickened, or coagulated. The casein coagulates when acid (vinegar and buttermilk) and rennet (an enzyme) are added. During coagulation, casein becomes a solid, called cheese curd. The coagulated protein curds are the base of almost all cheeses.

The whey protein in milk is not changed by acids or rennet, so it stays liquid. It is drained away after the casein coagulates, leaving behind the cheese curds.

MAKE QUESO FRESCO CHEESE!

This is a popular cheese in Mexico; queso fresco means “fresh cheese” in Spanish. It is a crumbly, mild-tasting cheese used as an ingredient or topping in Mexican cooking.

It’s easy to make and you’ll learn more about the unique powers of protein.

Ingredients

- 1 tablet Junket rennet
- ½ cup cold water
- 2 quarts, plus 1 cup pasteurized whole milk
- 1 quart buttermilk
- 2 tablespoons plus 1 teaspoon white vinegar
- 1½ teaspoons salt

EXTRA FOOD SAFETY FOR CHEESE!

Begin with clean equipment and new cheesecloth. All equipment used in making the cheese, including the cheese cloth must be sanitized using a water-bleach solution of ½ tablespoon unscented bleach added to ½ gallon of cool water. Everything must be soaked in the solution for two minutes and air dried.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

Ask learners why they think the milk is getting thicker. (Milk contains protein. Acid makes protein coagulate. Explain casein and whey proteins found in milk. See the “What do we need to know” and “Be a Food Scientist” sections in the Youth Science Journal for details.)

Directions
1. Place one tablet Junket rennet into ½ cup cool water. Stir until dissolved. Set aside.
2. Pour pasteurized milk into large saucepan. Stir gently. Note texture and record in Observation Log.
4. Add 2 tablespoons plus 1 teaspoon white vinegar to the milk mixture and mix well. Stir gently. Note texture and record in Observation Log.
5. Using low heat, heat milk mixture to 90º F. Use a thermometer to check temperature; don’t let it touch the sides or bottom of the pan. Remove pan from heat.
6. Add dissolved rennet to mixture and stir gently for 2 minutes. Note texture and record in Observation Log.
7. Let mixture stand in cool place for 30–40 minutes until curd is firm. Note cooling start time.
8. After curd is firm, cut curd into ½-inch cubes and let stand for 5 minutes. Whey will separate. Write observations in Observation Log.
9. Heat curds and whey to 115º F. Stir once or twice to ensure that the curds on the bottom do not overcook. Remove from heat. Let stand for 5 minutes. Write observations in Observation Log.
10. Place a colander in the sink. Line it with double-layered cheesecloth. Pour mixture through cheesecloth and allow to drain for 5 minutes. Write observations in Observation Log.
11. Pull up the edges of the cheesecloth, and form curd into a ball, gently twisting the cheesecloth to squeeze out the whey.
13. Add salt to curds. Mix with table knife or fork and let stand for 5 minutes.

While Cheese is Cooling
• Discuss the difference between fresh cheese and aged, or ripened cheese.
• Taste several cheeses, if available.
• Tell the group the names of some of your favorite cheeses.
• View downloaded video on cheese-making.
• Have most or all of the “Talk it Over” discussion.

Cheese ripening is a process that gives cheese a distinctive flavor. Ripening agents are used, which are typically microorganisms such as bacteria, mold, or yeast. Humidity and the environment where the cheese is stored are carefully controlled because they also influence the final flavor, as does the amount of time a cheese ages. Cheese typically ages anywhere from several weeks to a couple of years. All these factors play a role in the final taste and texture of the cheese. Queso fresco is a “fresh” cheese because it is not aged.
14. Gather edges of cheesecloth. Hold over sink or bowl, gently twist cheesecloth to squeeze out remaining whey. Open up the cheesecloth. Write observations in Observation log.

15. Scrape the cheese onto a plate. Hand-form the cheese into flat circle or rectangle. After cheese is drained, it may be sampled immediately. Divide remaining cheese into equal portions, put into re-sealable plastic baggies to take home. Refrigerate promptly!

16. If tortillas are available, place some queso fresco on one-half of tortilla, then fold over. Heat briefly in microwave or skillet. Cut into pieces to sample.

Pour mixture into colander lined with a double layer of cheesecloth.

Gently twist the cheesecloth to squeeze out the whey.
### ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

#### QUESO FRESCO OBSERVATION LOG

<table>
<thead>
<tr>
<th>STAGE OF CHEESE</th>
<th>DESCRIBE THE APPEARANCE AND CONSISTENCY</th>
<th>SEPARATION OF SOLIDS AND LIQUIDS (Use 1–5 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain milk.</td>
<td>Thin, fluid.</td>
<td>1</td>
</tr>
<tr>
<td>Milk with buttermilk.</td>
<td>Fluid, a little thicker than plain milk.</td>
<td>1</td>
</tr>
<tr>
<td>Milk with buttermilk and vinegar.</td>
<td>Fluid, slightly thicker than buttermilk.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Doesn’t slosh as easily.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very tiny clumps visible on spoon.</td>
</tr>
<tr>
<td>After rennet was added to mixture.</td>
<td>Thicker, looks like clotted milk.</td>
<td>3</td>
</tr>
</tbody>
</table>

Note time cheese is placed in cool area to set ____________

Note time at which curds have formed ________________

Full size page can be found in the Youth Science Journal on page 35.
### ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

<table>
<thead>
<tr>
<th>STAGE OF CHEESE</th>
<th>DESCRIBE THE APPEARANCE AND CONSISTENCY</th>
<th>SEPARATION OF SOLIDS AND LIQUIDS (Use 1–5 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture after curd is cut and it stands for 5 minutes.</td>
<td>More whey is present.</td>
<td>5</td>
</tr>
<tr>
<td>Mixture after it is heated to 115º F and stands for 5 minutes.</td>
<td>Even more whey is around sides of curd.</td>
<td>5</td>
</tr>
<tr>
<td>Mixture after it is poured into cheesecloth.</td>
<td>Looks like white, moist residue, a solid. Soft and breaks apart easily into crumbles.</td>
<td>NA–Whey has been removed</td>
</tr>
<tr>
<td>Mixture after cheesecloth is twisted and opened.</td>
<td>Thick, but not hard, lots of small crumbles.</td>
<td>NA–Whey has been removed</td>
</tr>
<tr>
<td>After mixture is salted and squeezed again.</td>
<td>Firmer, but not hard, some crumbles are larger now.</td>
<td>NA–Whey has been removed</td>
</tr>
</tbody>
</table>

### MEASURING MATH

To make queso fresco, you need to be sure to use a pan that is large enough to hold all of the ingredients. First, calculate the total number of cups of liquid in the recipe. Then, measure that amount of water into the saucepan you are considering. Does it fit with at least an inch of space at the top? If so, then it is large enough.
Below are answers you might expect from the learners. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

Talk It Over

SHARE
Briefly describe what you did to make cheese and your observations of the mixture.

Learners describe their observations and what they did in the experiment.

REFLECT
1. What is in milk that turns into cheese?
   The protein casein

2. Why do the milk curds separate from the liquid? What is happening to the casein?
   Acid from buttermilk and vinegar, plus rennet (an enzyme) make the protein casein denature and coagulate.

3. How is this similar to what occurred to make an egg white foam?
   It is a different example of coagulation.

4. What is whey? What happens to whey during the cheesemaking process?
   Whey is another type of protein in milk. The whey is not affected by acids or the enzyme rennet. It separates from the cheese curd; it remains a liquid.

TERM & Concept Discovery

Terms: Rennet, buttermilk, vinegar, curd, whey, queso fresco, casein, enzyme, cheesecloth, sanitation
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

GENERALIZE
In cheesemaking, what ingredients make casein coagulate?
Acids (buttermilk, vinegar) and rennet

APPLY
How would you use queso fresco at home?
Crumble on top of pinto beans, tacos, or a salad. Put in a corn tortilla and put in microwave for 20 seconds for a quick quesadilla. Spread on a cracker or fresh vegetables.

FOOD SAFETY AND QUESO FRESCO
In many Hispanic communities, queso fresco is made with unpasteurized milk, sometimes resulting in many cases of foodborne illness (food poisoning). This is because the milk they used was not pasteurized (pasteurization kills germs). Food science students at Washington State University did a project working with Hispanic communities to develop a queso fresco made with pasteurized milk. After working with Hispanic cooks and many experiments, a new recipe was developed that people liked. As people in the Hispanic community started making the recipe using pasteurized milk, the rate of foodborne illness in those areas rapidly decreased. People no longer got sick from the cheese!

BE A FOOD SCIENTIST

MILK BECOMES CHEESE
Queso fresco is an unripened or fresh cheese, which means it is ready to eat right away. It does not need to age like ripened cheese. Other examples of fresh or unripened cheese include cream cheese, feta (usually made from goat milk), mascarpone, paneer, mozzarella, and ricotta. Examples of ripened or aged cheese include cheddar, Swiss cheese, Provolone, blue cheese, and parmesan. Ripened cheeses are aged from a few months to years. As a result, they have stronger flavors than unripened cheese.
COAGULATING THE CASEIN

**Acids**
To make queso fresco, coagulation of casein begins by adding lactic acid bacteria or acid to milk to get the coagulation process started:
- Lactic acid bacteria in buttermilk helps ferment lactose (the natural sugar in milk) to lactic acid and provides flavor to queso fresco.
- Acid in vinegar promotes the coagulation process since buttermilk alone does not contain enough acid to cause coagulation.

Acid changes the structure of casein. It goes from a liquid to clumps of solid curds and begins to separate from the liquid whey. When the pH of milk reaches an acidic 4.7, the reaction begins. This reaction can be observed during the cheesemaking process. This is an example of protein coagulation.

**Rennet**
To help the coagulation process, rennet is added to the acidified milk. Rennet is comprised of digestive enzymes.

There are several types of rennet:
- Rennet from animal sources (typically extracted from the lining of a calf’s stomach).
- Rennet from food-grade mold used for vegetarian cheesemaking.
- Rennet from genetically modified organisms—bacteria that have been implanted with the gene that makes a rennet which is chemically the same as that from the calf’s stomach.

Animal rennet is favored by traditional cheesemakers, but the other types of rennet make fine cheese as well. Rennet comes in liquid or tablet form. For the purposes of making queso fresco, a rennet tablet will do. A popular and relatively easy to find rennet is called Junket rennet. The tablet is dissolved in water before being added to the milk mixture. Rennet’s coagulation of casein is a complicated reaction—something that might be studied by food science students in college.

**WHAT IS BUTTERMILK?**
Cultured buttermilk is manufactured by adding lactic acid-producing bacteria to 1% or 2% pasteurized milk. The bacteria used for buttermilk are called Lactococcus lactis. As a result of the acid made by the bacteria, buttermilk is thicker than milk and tastes sour. It is thicker because the acid has partially coagulated the casein.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

What You **SEE** & What You **FEEL**

**The Physical Reaction**
Buttermilk, vinegar, and rennet are added to milk, making it thicken; liquid separates from solids.

- Milk—a liquid
- Add vinegar and buttermilk—mixture thickens
- Add rennet—additional thickening
- Tiny curds or clumps form solids, separating from the liquid

**What Happens from a **FOOD SCIENTIST’S** Point of View**

**The Chemical Reaction**
Acids and rennet are added to milk to coagulate the proteins, resulting in curds and whey.

- Protein in milk—including casein
- Add acids to casein—coagulation begins
- Add rennet—additional coagulation
- Curds and whey form. Curds are solids, whey is liquid

Full size page can be found in the Youth Science Journal on page 40.
WHAT ABOUT THE WHEY?
Once curds are formed from casein, the liquid whey is drained, squeezed, and pressed from the mixture. Whey contains water, protein, lactose (naturally occurring milk sugar), vitamins, and minerals. It has many uses:

- Make ricotta cheese
- Enhance nutritional value of beverages
- Enhance the color and crust of commercially produced baked goods
- Protein supplement in numerous foods or as “protein powder”
- Additive to animal feed

FOOD SCIENCE, NUTRITION AND CHEESE - WHAT’S THE LINK?
Food science principals are used to make cheeses. Different kinds of milk (e.g. cow milk or goat milk), plus different acid ingredients and long or short aging times result in different textures and flavors.

Since cheese is a dairy food, it contains many of the same nutrients as milk— but in concentrated form. For instance, one-third cup of grated cheese counts as one cup of milk. Cheese is high in protein and calcium.

Cheese made from whole milk contains the same amount of saturated fat and cholesterol found in whole milk. Therefore, regular cheeses should be eaten in moderation. To meet the needs of people who want to eat less saturated fat, food scientists develop cheeses that taste good and have less fat. These cheeses are typically made with 2% milk, thus reducing calories, saturated fat, and cholesterol, while retaining much of the cheese flavor, texture, and melting characteristics. They are sold right alongside the regular cheeses. Look for labels that say “Made from 2% milk” or “Reduced-fat cheese.”

Sometimes cheese can be eaten by people even though they are lactose intolerant. Lactose intolerance is the inability to digest lactose, the sugar naturally found in milk. Rennet causes coagulation of the casein portion of milk, so most of the lactose is drained off in the whey. Additionally, if the cheese is aged (cheddar, Asiago, parmesan), lactose is nearly absent, because during the aging process it has been fermented to lactic acid.

However, if a person is allergic to cow’s milk, they will be allergic to cheese as well. Allergic reactions are the body’s reaction to a certain protein, and cheese still contains casein, the protein in milk. Goat cheese, which contains proteins of slightly different structure than cow milk protein, may not cause an allergic reaction.

To meet the needs of these people who cannot eat cheese, food scientists develop “cheese” that is not made from milk. They combine non-dairy ingredients that create a food that looks and tastes somewhat like cheese, although it may not have the melting quality of true cheese.
ACTIVITY 2.3: Separating the Curds from the Whey (cont.)

IN FOOD SCIENCE AND FOOD TECHNOLOGY—DAIRY INDUSTRY
There are many opportunities for interesting careers with a degree in Dairy Science. You might be a milk inspector, dairy herd manager, milk plant field representative, or work on formulating nutritious animal feed. Dairy scientists may also work in cheese science and technology and in ice cream manufacturing.

LEARN MORE!
For videos showing the cheesemaking process, recipes, and additional resources on cheese, visit the 4-H Food Science curriculum website at: www.4-H.org/curriculum/foodsci
ACKNOWLEDGMENTS

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UNIT 2 REFERENCES


American Egg Board: www.incredibleegg.org

Discovery Channel: www.discoverychannel.com

Fankhauser, D.B. PhD. Professor of Biology and Chemistry, University of Cincinnati Clermont College, Batavia OH 45103
http://biology.clc.uc.edu/fankhauser/Cheese/Rennet/Rennet.html


FunctionalEgg.org Twelve videos focusing on a variety of the functional properties of egg products in baked, refrigerated and frozen products. www.FunctionalEgg.org

Hillers, V. PhD. Professor Emeritus. Washington State University. Queso Fresco project.


Washington State University http://www.foodsafety.wsu.edu/consumers/factsheet7.htm
"I Pledge my **Head** to clearer thinking,
my **Heart** to greater loyalty,
my **Hands** to larger service,
and my **Health** to better living,
for my club, my community, my country,
and my world."
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Unit 3 “The Inner Mysteries of Fruits and Vegetables” is just one part of exploring “What’s on Your Plate?” Be sure to check out the other units in this curriculum series for more fun, experiments you can eat!
FOOD SCIENCE FACILITATOR GUIDE

Welcome to the Food Science Facilitator Guide! This guide is intended to help you lead an effective learning process for youth as they discover the science of what’s on their plate!

This 4-H curriculum uses an inquiry-based learning method designed to help young people first ask questions, then seek answers through hands-on activities, and finally to reflect on what they’ve learned.

We encourage you to preview the activities, watch the short tutorial videos, and then carefully read through each activity. The pages from the Youth Science Journal are inserted so you have all the content of the curriculum as well as questions, answers, and tips to help you lead these activities. The activities are easily carried out in a home kitchen “laboratory” using inexpensive supplies available at grocery stores. If it’s been some time since your last science class, keep smiling—the curriculum and tutorial videos contain everything you need to know!

The activities are written for youth grades 6–9, but may be adapted for younger or older learners. You can limit or expand the amount of information you share or simplify the terms if needed. Explain the concepts to youth in terms they are able to understand depending on their age and level of experience. For younger learners, you might only focus on the physical reactions they can see. Chemical reactions that food scientists explore can be introduced to older or more advanced learners. Paraphrasing instructions and concepts in your own words will help activities and discussions flow more naturally.

For the best learning experience, please follow the instructions and do each part of the activity. Each of the activities within the units should be done in the order presented. The units may be done in any order, however the concepts are more complex in Units 3 and 4. For learners to have positive outcomes, pay close attention to the details and directions of the activities.

It’s easy to get caught up in the hands-on activities and forget to reserve time for the reflection and application questions. These questions are essential though for locking in the learning and assessing if learners grasped the concepts you have been teaching. Many times you’ll “see the light bulb come on” when you ask them to explain what they’ve done and what they’ve learned.

Keep in mind that some youth will prefer to process their thoughts internally and write down their responses. Others will be eager to share verbally. Structuring the time for individual reflection and writing first and then encourage sharing will allow both types of learning to thrive.
Your work with youth is a genuine opportunity to encourage them to consider careers in science, engineering, and technology. Food science and food technology are examples of using applied basic sciences. The work you’re doing with these young people may help someone discover a career path in food science, find a passion for creating meals that amaze, or simply help them be aware of healthy food preparation. You’ll never know how far your influence will reach.

Enjoy exploring What’s on Your Plate?

4-H Mission Mandate Outcomes—Science and Healthy Living
- Improved science skills and knowledge among youth.
- Youth apply science learning to contexts outside 4-H.
- Increased science literacy in general population.
- Increased knowledge, attitudes, skills, and aspirations to promote optimal physical, social, and emotional health habits.

Life Skills
- Cooperation
- Critical Thinking
- Communication
- Contributions to Group Effort
- Keeping Records
- Planning/Organizing

In preparing to do activities, follow these steps for the best success:
- Skim the Facilitator Guide.
- View the short video tutorial. It shows techniques and explains the science to make it easier for you to conduct the activity.
- Carefully read both the Facilitator Guide and the Youth Science Journal portion of the Facilitator Guide.

Note that the Youth Science Journal contains most of the science explanations in the Be a Food Scientist section. This information appears after the experiments and discussion portions. This enables the learners to use inquiry first, then confirm their findings later. It is not expected that learners will read this section during the activity; it may be useful if they want to delve deeper, remember, or share the concepts with others.

There are a number of additional materials, including videos, handouts, glossary terms, podcasts, resources, and links to other websites at www.4-H.org/curriculum/foodsci. Links to webpages often change, so rather than printing them here, they will be kept up-to-date on the 4-H webpage dedicated to this curriculum. These materials will enrich you and your learners’ understanding of the content.
MATERIALS LIST

Supplies:
• 1 cup liquid measuring cup
• Measuring spoons: 1 teaspoon
• Grater with shredder and fine grater (as shown)
• Small sieve/strainer
• 8 paper plates
• 5 paper or plastic cups to hold up to ½ cup liquid
• 8 plastic spoons for stirring solutions and dipping fruit
• Cutting board
• Paring knife for adult
• Plastic knives for youth
• Metal or wooden spoon to crush vitamin C
• Hand soap
• Paper towels
• 2 sheets of poster or large paper and tape
• Masking tape for labeling variables
• Marking pens
• Pencils

Food:
• 1 medium Red Delicious apple (This variety displays more browning than others.)
• 1 medium Russet/baking potato (This type of potato browns; waxy varieties do not.)
• 2 teaspoons sugar
• ½ cup lemon juice
• 250 to 500 milligram vitamin C tablet or capsule. (Whatever you have on hand is fine, but do not use a tablet that is “enteric coated” or it will not dissolve well in water.) While there are commercial products available, a ground tablet or the crystalline contents of a capsule work for this experiment.
• Water, if no sink is available, approximately 3 cups
• 4 ice cubes
• Three to four different varieties of apples for tasting

Printed Materials:
• Order Youth Science Journal, one for each learner

You have undoubtedly noticed that some fruits and vegetables turn brown after they are peeled, cut or bruised. Perhaps you have wondered why they do this and what you can do to stop it—besides splashing a little lemon juice on them. A process called enzymatic browning occurs when apples, pears, bananas, peaches, grapes, avocados, potatoes, sweet potatoes, lettuce, eggplant and mushrooms are cut. This activity focuses on preventing browning in some food processes and understanding how browning is used to make other products.

SKILL LEVEL:
Beginner

LEARNER OUTCOMES
• Knows how to observe and describe scientific principles of enzymatic browning.
• Knows how to use several methods to prevent or delay enzymatic browning in freshly cut produce.
• Understands and identifies how enzymatic browning is controlled and used favorably in food processing.

SUCCESS INDICATORS
• Identifies two or more fruits and vegetables prone to browning when cut.
• Defines and describes the principle of enzymatic browning.
• Prepares cut produce in ways that prevent or delay browning.
• Able to follow written directions, measure and prepare solutions.
• Identifies processed foods that use enzymatic browning to get a desirable color.

SUGGESTED GROUP SIZE
8–12 youth

TIME NEEDED:
Minimum of 45–60 minutes

SPACE
Any setting with a work table is fine; room with a sink is preferred but not mandatory.
DURING THIS ACTIVITY, YOU WILL:
• Understand and discuss plant cell structure components contributing to enzymatic browning.
• Facilitate learner experiments with apples and potatoes.
  » Cut and shred apples and a potato.
  » Treat these with simple variables (e.g. vitamin C) to study enzymatic browning.
• Write out and discuss the Physical and Chemical Reactions of Enzymatic Browning.
• Taste and compare a variety of apples with learners.
• Support and encourage learners to observe, understand, and apply the science behind the process of enzymatic browning in freshly cut produce.

KEEP LEARNERS SAFE
• FOOD SAFETY: Clean and sanitize kitchen surfaces, cutting boards, etc. Wash hands with soap and warm water for 20 seconds; dry with paper towel. Wash apples thoroughly before cutting. Do not leave cut apples at room temperature for more than two hours to prevent bacterial growth that may cause foodborne illness. Refrigerate leftovers after two hours. Visit www.FightBac.org for tips and handouts regarding food safety.
• TOOL SAFETY: Use caution when working with knives, peeler, and grater. An adult should be in charge and do the food preparation if children are young. Younger children should not use the peeler or grater—facilitator should do the grating. Learners should carefully use plastic knives. Before doing this activity, review important knife safety information posted at http://www.4-H.org/curriculum/foodsci.
• Tie back long hair.
• Roll up long sleeves.

ENZYMATIC BROWNING
Fruits and vegetables contain numerous substances inside their cells. Many of those substances are familiar, such as water, natural sugar (fructose), starch, phytonutrients (fahy-tuh-roo-tree-uhnts) fiber, vitamins, and minerals. Food scientists often work with familiar substances while exploring lesser-known substances and how they affect the appearance, flavor, and textures of food and food products. Individual cells also contain phenolic (fi-noh-lik) compounds and enzymes. Some phenolic compounds may be phytonutrients. These substances are important to the process of enzymatic (en-zahy-mat-ik) browning.
GETTING READY

Prior to the Activity

- View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal. The What Do We Need to Know? and Be a Food Scientist sections explain the science behind the experiments.
- Gather all equipment, supplies, and materials.
- Write out physical and chemical reactions on large paper. Have tape ready to post this where learners can see it AFTER the activity. If working with young students, discuss only the physical reactions.
- Crush or dissolve vitamin C tablet prior to the activity—place in small bowl and use back of a spoon to crush it. Or shave it with a paring knife on a cutting board then crush the shavings.

Organizing the Activity

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What are your favorite fruits?
2. Do you like eating them raw or cooked?
3. Do you like them best whole or sliced/cut up?
4. What makes cut fruit appealing to eat? (easy to eat, tastes good, looks fresh)
5. Have you ever seen apple slices or chopped lettuce that looks brown?
6. What other cut fruits or vegetables have you seen that have turned browned? (pears, peaches, mushrooms, etc.)

Open the Youth Science Journal

As learners look at the pictures and read the statement, “Some fruits and vegetables turn brown a while after cutting.” Guide them to ask questions such as those listed in the Answer Key.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce

BEGIN THE EXPERIMENTS WITH LEARNERS

Divide into small groups of 3 to 4 for experiments, each group making one or two solutions and preparing apple or potato samples. Follow the experiment directions in the Youth Science Journal.

While waiting for the browning reaction to occur, have learners taste a variety of apples. (See While Waiting... Taste a Variety of Apples section on page 8.)

After waiting 20 minutes, learners observe samples and record observations. The photos show the amount of browning you can expect to see.

**Apple Experiments**

Results will always vary depending on ripeness of fruit, temperature of the room, variety of apple, etc. So look for and point out trends in the treatment results. Generally, ascorbic acid will be the best treatment for fresh apples. Shredded apples and potatoes have accelerated browning because there is more cellular damage when compared to slices. Using the Be a Food Scientist Information in the Youth Science Journal, explain substances inside the cells (enzymes and phenolic compounds) interact with each other and with oxygen to create a brown compound called melanin. Melanin is a pigment.

**WHILE WAITING . . . TASTE A VARIETY OF APPLES**

Use the wait time to taste several different varieties of apples. Ask learners to compare sweetness, tartness, texture, and overall appeal. Which ones do they like best? Least? Explain that some food scientists work to cultivate or create new varieties of apples that have different colors, tastes, and textures. See additional information about apple varieties at http://www.4-H.org/curriculum/foodsci.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

Below are answers (bolded in blue) you might expect from the learners. When possible, help them understand the concepts in their own words before you explain. Use this as a guide to ensure learners understand the science behind their observations. Become familiar with the background information provided before doing this discussion. Rating numbers and learners’ opinions will vary.

SOME FRUITS AND VEGETABLES TURN BROWN AFTER CUTTING.

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”
Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .

• What causes fruits and vegetables to turn brown?
• How long does it take before they turn brown?
• How could I keep things from browning so that they look fresh longer?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

Full size page can be found in the Youth Science Journal on page 3.
WHAT WILL WE DO?
You have probably noticed that some fruits and vegetables turn brown after they are peeled, cut, or bruised. Perhaps you have wondered why they do this and what you can do to stop it.

You will divide into groups with some learners working with apples and others with potatoes. Each group will prepare apples or potatoes in different ways to see which ones brown the least and which ones brown the most. The goal is to find the method that prevents browning the best so you can prepare fruits and vegetables in ways that will keep them looking their best. Become the expert in your family!

WHAT DO WE NEED TO KNOW?
A process called enzymatic browning occurs when apples, pears, bananas, peaches, grapes, avocados, potatoes, sweet potatoes, lettuce, eggplant, and mushrooms are cut. The unsightly brown color is not very appealing. To understand why this happens, you first need to know more about plant cells, and a few terms.

Plant Cells
On the outside of the cell membrane is the cell wall. The cell wall provides strength and structure to fruits and vegetables. Different cells have different substances in them; some have certain enzymes and some have phenolic (feen-awl-ik) compounds. When a fruit or vegetable is cut, the cell wall and membrane are damaged, allowing the substances in the individual cells to leak out and mix with one another. Cutting also exposes cell contents to oxygen from the air. Exposing phenolic compounds and enzymes to oxygen leads to enzymatic (en-zahy-mat-ik) browning.

WHAT’S ON YOUR PLATE? Exploring Food Science
BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash produce thoroughly under cool, running water. Wash and sanitize area where produce will be prepared, as well as cutting board and knives. Visit www.FightBac.org for tips and handouts regarding food safety.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

**ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)**

**ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)**

Knife injuries are the leading on-the-job injury for people under 18. Please review knife safety with your learners! Younger children should not use the peeler or grater—facilitator should do the grating. Learners should carefully use plastic knives. Knife safety publications are available at http://www.4-H.org/curriculum/foodsci.

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**EXPERIMENT 1—APPLE SAMPLES**

1. Wash the apple, then cut it in half.
2. Slice half of the apple into five slices.
3. Shred other half of the apple using the largest holes on the grater.
4. Divide shredded apple into five equal portions.
5. Use one slice of apple and one shredded portion of apple to do each variable listed below.

**Variable 1: No Treatment—Control**

Place apple slice and portion of shredded apple on a paper plate labeled “No Treatment.”

**Variable 2: Lemon Juice**

Pour ¼ cup lemon juice into a cup; label using masking tape/pen, “Lemon Juice.” Using a spoon, put one apple slice into lemon juice for 20 seconds, turning and tilting the cup to make sure all surfaces are coated. Remove the apple slice. Place on a paper plate labeled “Lemon Juice.”

Gently submerge the spoonful of shredded apple into the solution for 20 seconds; use a spoon to hold shredded apple in place. Gently press on the shredded apple as it is taken out of the cup to remove excess solution. Place on “Lemon Juice” plate.

---

**Enzyme (en-zahy-m) . . . . . . Substance produced by cells such as those in fruits and vegetables that produce a certain chemical reaction. In this activity, enzymes allow phenolic compounds to react to oxygen, leading to browning. This reaction is called “oxidation” or “enzymatic browning.”**

**Phenolic compounds (fee-nawl-ik) . . . Substances in the cells of fruit that turn brown when exposed to oxygen and enzymes.**

**Enzymatic browning (en-zahy-mat-ik) . . The process that occurs when some fresh fruits or vegetables are cut and exposed to air; a darkening of color is the result. Enzymes in the fruits and vegetables help the physical and chemical reactions occur. The process causes unfavorable results such as browned fruit, or favorable results such as the brown color of raisins, prunes, and tea.**

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Full size page can be found in the Youth Science Journal on page 5.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce

Variable 3: Vitamin C + Water
In a cup, mix crushed Vitamin C tablet with ½ cup water and dissolve. Label using masking tape/pen “Vitamin C.” Using a spoon, put one apple slice in to Vitamin C solution for 20 seconds, making sure all sides are coated with the solution. Remove the apple slice. Place on a paper plate with name of variable, “Vitamin C.”

Use spoon to dip shredded apple sample for 20 seconds—gently submerge the spoonful of shredded apple into the solution; use a spoon to hold shredded apple in place. Gently press on the shredded apple as it is taken out of the cup to remove excess solution. Place on “Vitamin C” plate.

Variable 4: Sugar + Water
Measure and combine 2 teaspoons sugar and ½ cup water into a cup and mix thoroughly. Label using masking tape/pen “Sugar.” Mix thoroughly. Place one apple slice and a spoonful of shredded apple into solution and let soak for 10 minutes. Remove the apple slice. Place on a paper plate with name of variable “Sugar Water.” Pour contents of cup through a small sieve to retrieve shredded apple; put on “Sugar Water” plate.

Variable 5: Cool Water
Place two ice cubes in one cup of water. Label using masking tape/pen “Cool Water.” Place one apple slice and small portion of shredded apple in cool water and let soak for 10 minutes. Remove the apple slice. Place on a paper plate with name of variable, “Cool Water.” Pour contents of cup through a small sieve to retrieve shredded apple; put on “Cool Water” plate. Wait 20 minutes. While waiting, taste a variety of apples. After 20 minutes observe apple samples and record your observations.

After 20 minutes, use the following numbers to indicate amount of browning
1 = no browning present, natural color
2 = very light brown—mostly around edges
3 = light brown—around edges
4 = moderately brown—around edges
5 = dark brown on most surfaces

WHAT'S ON YOUR PLATE? Exploring Food Science
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ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

EXPERIMENTAL APPLE SAMPLES OBSERVATION LOG

<table>
<thead>
<tr>
<th>NO TREATMENT (CONTROL)</th>
<th>LEMON JUICE</th>
<th>VITAMIN C</th>
<th>2 TEASPOONS SUGAR IN ½ CUP WATER</th>
<th>COOL WATER WITH ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple slice</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Shredded</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

EXPERIMENT 2—POTATO SAMPLES

1. Cut potato into thirds.
2. Make several slices from ⅓ of the potato.
3. Shred one-third of potato using the largest holes on the grater. Divide into two portions of about two tablespoons each.
4. Finely grate about two tablespoons of the remaining potato using smaller holes on grater.

Variable 1: No Treatment
Put one slice and a portion of each potato sample onto paper plate labeled with name of variable: “No Treatment.”

Variable 2: Cold Water Soak
Place two ice cubes in 1 cup of water. Place one potato slice and small portion of shredded potato in cool water and let soak for 20 minutes. Remove slice with spoon, put on plate labeled with name of variable, “Cold Water Soak.” Pour contents of cup through a small sieve to retrieve shredded potato; put on plate labeled “Cold Water Soak.” Immediately record color in Observation Log.

While waiting, taste a variety of apples. After 20 minutes, observe potato samples and record your observations.

Full size page can be found in the Youth Science Journal on page 7.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

Use the following numbers to indicate amount of browning:
1 = no browning present, natural color
2 = very light brown—mostly around edges
3 = light brown—around edges
4 = moderately brown—around edges
5 = dark brown on most surfaces

POTATO SAMPLES OBSERVATION LOG

<table>
<thead>
<tr>
<th>TYPE OF POTATO</th>
<th>NO TREATMENT (CONTROL)</th>
<th>COOL WATER WITH ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Shredded</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Grated</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

APPLE VARIETIES COMPARISON LOG

If you tasted several types of apples while waiting for browning reactions to occur, record your observations here.

<table>
<thead>
<tr>
<th>TYPE OF APPLE</th>
<th>DESCRIBE TEXTURE (DRY, JUICY, FIRM, MEALY, ETC.)</th>
<th>DESCRIBE TASTE (SWEET, TART, ETC.)</th>
<th>HOW MUCH I LIKED IT</th>
<th>OTHER COMMENTS</th>
</tr>
</thead>
<tbody>
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The following are SAMPLE values only—these numbers may vary from actual observations.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

The answers provided are what you might expect from the learners. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

**Talk It Over**

**SHARE**
Which apple samples browned the least? Which browned the most? Which potato samples browned the least? Which browned the most?

Learners describe what they did in the experiments and their observations.

**REFLECT—LEARN ABOUT THE SCIENCE OF THE BROWNING REACTION**

1. Why do cut apples and potatoes brown?
   - First, consider what were the untreated samples exposed to.
   - Air, specifically oxygen
   - What is happening between the air and the untreated samples to cause browning?
   - The substances in the damaged cells interact with each other and with the air (oxygen).
   - Air + plus substances in cells = browning. The oxygen, phenolic compounds, and oxidase enzyme form a brown pigment, called melanin.

2. Why do samples that are treated not brown as much as untreated ones?

   Anti-browning agents act as antioxidants. Ascorbic acid and citric acid interact with the enzymes and phenolic compounds, preventing them from interacting with oxygen. When oxygen is added to these substances, it produces melanin, a brown pigment. Sugar coats the fruit, limiting the exposure to air. Water prevents oxygen from coming into contact with the potato.

Post the reactions you wrote on large paper on the wall. Use them to describe the science behind what the learners observe, and to teach the terms.

Learners at this point may be able to name substances found in fruit and vegetable cells. List those, then link to the Physical and Chemical Reactions Poster.

**Unit 3: The Inner Mysteries of Fruits and Vegetables**

Full size page can be found in the Youth Science Journal on page 8.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

3. Describing the physical reaction, explain what happened to your apple and potato samples? Hint: Compare and contrast untreated slice, shredded, and grated potato.
   1. Fruit or vegetable is cut, shredded, or grated
   2. Fruit or vegetable sample is exposed to air (oxygen)
   3. Untreated fruit and vegetable samples turn brown

4. As a food scientist, describe the chemical reaction.
   1. Phenolic compounds + oxidase enzyme from damaged cells mix together
   2. The above substances come into contact with air (oxygen)
   3. Melanin (brown pigment) is produced

Terms: Fruit, vegetables, produce, enzyme, phenolic compounds, brown, browning, enzymatic browning, vitamin C (ascorbic acid), lemon juice, oxygen, oxidase, oxidation, antioxidants, melanin
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

GENERALIZE
Considering what you’ve learned in this activity, how should freshly cut fruits and vegetables be handled and stored?

_**Gently and carefully to avoid bruising.**_

APPLY
1. Taking apple slices in your lunch could be one way to help you eat the recommended two cups of fruit each day. Describe how you would prepare apple slices to take with your lunch so that they would not brown and still taste great!

_**Dip in ascorbic acid or citrus juice before putting into a plastic bag to take in lunch.**_

2. Imagine you want to make baked oven fries for dinner. You want to slice the potatoes before going to a movie and then cook them when you get back. To prevent browning while you’re away, what could you do?

_**Cover with cool water until time to cook them.**_

BE A FOOD SCIENTIST

DOWN WITH BROWN!
More about Enzymes in Fruit and Vegetable Cells
Enzymes help chemical reactions occur. One kind of enzyme found in fruits and vegetables is called an oxidase (ok-si-dees), which acts together with oxygen. In whole, uncut fruit, the phenolic compounds and oxidase enzymes do not mix or react with one another, so browning does not occur. However, when produce is cut, it damages the cells, allowing these substances to mix and be exposed to air (oxygen). When phenolic compounds and oxidase enzymes mix and are exposed to air, enzymatic browning occurs. It is easy to see this chemical reaction when cut fruits or vegetables turn brown. The brown color is a pigment (coloring substance) called melanin (mel-uh-nin).
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

If working with young students, discuss only the physical reactions.

WHAT INFLUENCES BROWNING?

Food Scientists work to control chemical reactions so that unfavorable physical reactions do not happen. Below are some of the ways the unfavorable reaction can be avoided or prevented.

A. Use Anti-oxidants or Anti-browning Agents or Treatments

- **Acid.** Common acids found in most kitchens and food development labs include lemon juice and orange juice. Both juices contain citric acid, which prevents enzyme action. Apple slices treated with acids stay fresh looking for a long time before browning.

- **Antioxidants.** Vitamin C (ascorbic acid) is an antioxidant. It stops oxygen from being used in the reaction. Citrus juices contain vitamin C so they help prevent browning in two ways: 1) Their acid interferes with the browning enzymes, and 2) their antioxidant action interferes with oxygen.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

- **Cool temperatures.** Storing cut produce in a refrigerator or placing sliced or grated produce in cold water slows down the browning process.

- **Heat.** Heat changes the structure of the enzymes (protein) so they cannot cause a reaction. Cooked produce will not brown—but then it is no longer raw. This would not be a good solution for produce that is going to be served fresh such as sliced apples, avocados, or lettuce.

B. Limit Contact With Oxygen

- **Water.** When cut produce is put in water, the water limits the amount of oxygen that comes into contact with cut surfaces. Cold water works best.

- **Sugar solutions.** Sugar coats the surface of the produce, keeping oxygen from mixing with enzymes and phenolic compounds.

What’s the Best Solution?

- **Vitamin C (Ascorbic Acid).** is inexpensive and usually works the best. It is used in the food industry to prevent browning of sliced fruit. For example, McDonald’s uses vitamin C to treat the packaged apple slices served in kid’s meals.

- **Lemon juice** may change flavor. Orange and pineapple juice work, but not as well since their acid content is lower. Use juice only for foods where a slight citrus flavor is acceptable.

- **Sugar + Water** coats the surface, but is not as good as vitamin C or lemon juice to control browning. Use only for foods where a slightly sweet taste is acceptable.

- **Water** slows the reaction. It is least effective as treatment for fruit, but is highly effective for potatoes.

Cool temperatures are also good for food safety! Once produce is cut, it must be handled properly to prevent foodborne illness. Refrigerate fruit and vegetables within two hours of cutting to prevent harmful bacteria from growing.
ACTIVITY 3.1: Down with Brown—Prevent Browning in Freshly Cut Produce (cont.)

Point out the pictures of the bruised banana in the Youth Science Journal and explain that cells also contain oxygen. When the fruit is dropped or handled roughly, the damaged cells release compounds that mix together and interact with oxygen so enzymatic browning occurs. It is the same reaction that occurs in grated potatoes and apples, but inside of the food. Apples also bruise easily.

Dropping or Roughly Handling Fresh Produce Causes Bruising

DROP IT, BRUISE IT.
HANDLE FRUIT GENTLY.
If a pear, peach, apple, or banana is dropped or crushed, the cells break down inside the skin, allowing the phenolic compounds to interact with the enzymes. There is enough oxygen present in cells to start enzymatic browning. Even though the skin of the fruit or vegetable is unbroken, the phenolic compounds and oxidase react with the oxygen inside the cells. Bruising may take up to a day to develop. Fruit and vegetable growers and harvesters use a variety of practices to reduce bruising and crushing as produce makes the trip from farm to table.

Example of a bruise on outside, which means enzymatic browning has occurred on the inside.

ENZYMATIC BROWNING CAN BE GOOD!
The enzymatic browning of fresh produce can make it unappealing to eat. But browning isn’t all bad. It’s a helpful part of processing some foods. Food scientists use enzymatic browning in positive ways to make foods such as raisins, cider, prunes, figs, and tea. Enzymatic browning adds an appealing brown color and a certain flavor to these foods.

Raisins
The next time you eat raisins, think like a food scientist. You are seeing and tasting the results of enzymatic browning. Most commercially produced raisins are processed by placing grapes on large trays and allowing them to dry in the sun for several weeks. During the sun drying, the grapes lose water (dehydrate) and cell walls weaken. The same enzymatic process that makes apple slices brown occurs in the grapes, turning them into raisins and giving them the dark brown color and flavor we have come to expect. Golden raisins have been treated with sulfur to prevent browning.

WHAT’S ON YOUR PLATE? Exploring Food Science
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MATERIALS LIST

Supplies:
- 1-cup liquid measuring cup
- Measuring spoons
- Vegetable scrub brush
- Stainless steel kitchen knife for adult
- Plastic knives for youth
- Vegetable peeler
- Cutting board
- Four small bowls or custard cups (these will be used more than once)
- Plastic or metal sampling spoons, plastic or metal tasting spoons
- Metal fork with sharp tines for testing doneness of vegetables
- Three to four one-quart sauce pans with lids
- Can opener
- Pot holders
- Sanitizing solution
- Hand soap
- Paper towels
- Paper plates
- Large paper for posting in room, tape
- Masking tape for labels
- Marking pens
- Pencils
- Video (downloaded) of carrot processing plant

Food:
- One-pound bag fresh carrots
- 1 can canned carrots
- 1 small package frozen carrots
- 1 small package of frozen peas
- 1 can canned peas
- Vinegar
- Baking soda

Printed Materials:
- Order Youth Science Journal for each learner

Have you ever stopped to appreciate the beauty of the produce department at the grocery store? Next time, take a few moments focus on the vast array of colors. Compounds called pigments create the beautiful colors. Many plant pigments are a type of phytochemical. They naturally occur in plants.

SKILL LEVEL:
Intermediate

LEARNER OUTCOMES
- Understands how cooking affects the color, flavor, texture, and nutrient value of vegetables.
- Knows how acidic and alkaline ingredients affect color and texture of vegetables.
- Knows how to compare and contrast the color, texture, flavor, and nutrient content of fresh, frozen, and canned vegetables.
- Understands how science and technology are used in vegetable processing.

SUCCESS INDICATORS
- Conducts simple tests to show the effect of heat/cooking on vegetables.
- Demonstrates effects of acid and alkaline ingredients on pigments in vegetables.
- Compares nutrient content of fresh, frozen, and canned vegetables.
- Demonstrates preparation of vegetables in a way that retains nutrients and visual appeal.

SUGGESTED GROUP SIZE
8 – 12 youth

TIME NEEDED:
Minimum completion time: 60 minutes

SPACE
- Kitchen with sink and stove with multiple burners
- Alternatively, classroom with sink and three hot plates. (If only one hot plate is available, Facilitator should prepare some items in advance—see “Variations” section.)
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

DURING THIS ACTIVITY, YOU WILL:

- Emphasize three pigments:
  - Yellow/orange—carotenoids (kuh-roh-NOYdz)
  - Green—chlorophyll (klaw-uh-fil)
  - Purple/blue—anthocyanin (an-thuh-sahy-uh-nin)
- Facilitate learner experiments cooking vegetables with ingredients which affect original pigment colors and vegetable texture. It’s surprising, colorful, but not always desirable to eat!
- Assist learners to understand the effects of heat, acid (vinegar), and talkali (baking soda) on the color, texture and flavor of vegetables.
- Assist learners while they compare and contrast the color, texture, flavor, and nutrient content of fresh, frozen, and canned carrots.
- Encourage and inspire learners to consider a career in food science.

GETTING READY

Organizing the Activity

Prior to the Activity

- View the tutorial video, other videos, including knife safety, glossary and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal. The What Do We Need to Know? and Be a Food Scientist sections explain the science behind the experiments.
- Gather supplies needed from materials list, perhaps have learners bring additional sauce pans from home.
- Download the carrot processing video.
- Set up two stations/areas—one for each activity.
- If sufficient number of learners, divide them into teams. One team could work with carrots, one with cabbage.
- Print out instructions given below for each experiment and place at each station.

Note: Optionally, you may include the broccoli activity in the Youth Guide as an additional activity to do now, especially if you have a large group. If so, prepare an additional station.
BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. Name a vegetable you like to eat at home.
2. How does your family prepare that vegetable?
3. What if the grocery store didn’t have it in the produce section, yet you wanted to have it that day. Where else could you look for it in the grocery store?
4. Do you know what gives vegetables their colors?

Open the Youth Science Journal

As learners look at the pictures and read the statement, “Some Vegetables Change Color When Cooked,” guide them to ask questions such as those listed in the Answer Key.

Share an Overview and Key Science Essentials with Learners

- Substances called pigments give fruits and veggies their various colors.
- Some plant pigments may be phytonutrients. Phytonutrients are substances that are beneficial to human health.
- Pigments react differently to heat from cooking or with added ingredients such as being combined with an acid (e.g. lemon juice or vinegar) or something alkaline, (such as baking soda). Pigments may change color and/or look less appealing.
- This activity highlights three pigments in three vegetables. Your objectives as the Food Scientist are to observe what happens to them under various conditions and develop a best practice for preparation—based on the science.
Demonstration and Experiments

See Youth Science Journal for instructions.

Begin with Pea Demonstration. See pictures below for anticipated results.

Explain to learners that chlorophyll is not water soluble when cooked normally. However, the high temperature and length of processing time in making commercially canned peas causes leaching of chlorophyll into the water.

The bright green color of frozen peas comes from processing. Fresh peas are cooked (blanched) for a very short time period. This helps peas retain their color during frozen storage. Blanching is used in home freezing for vegetables such as broccoli and green beans to help preserve color.

This experiment illustrates how pigments and texture are affected by acidic and alkaline ingredients. They are examples, not necessarily used in cooking red cabbage.

Left: The anthocyanins in cabbage cooked in tap water appear blueish-purple. Most water supplies have a pH that is slightly alkaline, a number above 7.0. The slight alkalinity helps to protect water pipes, but causes a purple/blue color.

Middle: Acidity (vinegar) gives cabbage a bright, reddish-blue color. It also affects texture so the cabbage remains firm. Acids are often used in recipes for red cabbage to maintain color and texture.

Right: Alkalinity (baking soda) turns anythocyanins a blue-green color—not associated with a quality product. It also affects the texture, turning the cooked cabbage very mushy. The greater alkalinity level of this experiment produces greater changes in the pigment and texture of the cabbage.
The anthocyanin pigment is highly water soluble. Colors are easily seen in the cooking water. Recipes for red cabbage call for small amounts of acid such as vinegar or fruit juices. This compensates for starting with cooking water that is alkaline and makes the cooking water slightly acidic—yielding a red instead of purple color.

- A number of fruits have the anthocyanin pigment, so in commercial juice processes, food scientists control the pH to achieve ideal color of the juice.
- Baking soda is not used in vegetable recipes and is included only as an illustration of what happens to anthocyanin when the pH is basic (alkaline), i.e. a number greater than 7.0 on the pH scale.

**VARIATIONS**

- If you have a large group, you may wish to include the broccoli activity in the Cooking Up Food Science at Home section of the Youth Science Journal.
- If only one hot plate is available, prepare the carrots ahead of time and put in containers for learners to observe and sample.
- If working with high school or advanced students, have them identify additional pigments found in fruits and vegetables. Visit the “Colorful Carrots” link to learn more about pigments: 4-H.org/curriculum/FoodSci.
STATEMENT: SOME VEGETABLES CHANGE COLORS WHEN COOKED.

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .
• Why do some cooked vegetables look appealing and others don’t?
• Why are some firm and others mushy?
• What’s the best way to cook vegetables so that they look appealing, are nutritious, and taste delicious?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions.

My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .
WHAT WILL WE DO?
The demonstration and experiments highlight three vegetables. Your objective as the Food Scientist is to observe what happens to the vegetables when cooked in different ways. Then figure out the best way to cook vegetables so they look appealing and keep as many nutrients as possible.

First, do the Perfect Pea demonstration and answer the questions. Then divide into two groups and do the experiments.

WHAT DO WE NEED TO KNOW?
Have you ever appreciated the beauty of the produce department at the grocery store? Next time you are there, look carefully at the vast array of colors. Compounds called pigments create these beautiful colors! This activity explores three of these pigments:

- Yellow/orange—carotenoids (kuh-rot-n-oidz)
- Green—chlorophyll (klawr-uh-fil)
- Purple/blue—anthocyanin (an-thuh-sahy-uh-nin)

Pigments may change color when they are heated or have other ingredients added. The orange, green, and reddish-blue pigments highlighted in this activity react differently to heat, acids (vinegar), and alkali (baking soda). Sometimes the change in color makes them look more appealing. Other times, the change makes them look less appealing. In this activity, you will see, feel, and sometimes taste vegetables prepared with different heating times and ingredients. See for yourself the best way to prepare vegetables you and your family will enjoy eating!

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where food will be prepared. Visit www.FightBac.org for tips and handouts regarding food safety. Use the two-spoon method for sampling vegetables.
DEMONSTRATION: PERFECT PEAS

This demonstration is an example of how a green pigment, chlorophyll, changes color when cooked. Compare the color of frozen peas to that of canned peas.

1. Open canned peas. Place them in a small bowl along with some of the water in the can.
2. Open frozen peas and place them in a small bowl.

Evaluate the peas by circling the number which best describes what you observe.

<table>
<thead>
<tr>
<th>Color</th>
<th>Least Natural</th>
<th>Most Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Frozen, thawed peas</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2. Canned peas</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Consider your ratings.
Which form of peas is most visually appealing to you?
_________________________________________________________________________________

Using a fork to poke the canned and thawed peas, are there any differences in texture? Why?
_________________________________________________________________________________

Why is There A Difference?
Heat causes changes in texture, color, and nutrients. Heat breaks down the cell walls of plants. When vegetables are heated for an appropriate cooking time, it softens cell walls, making them easier to chew and digest. Excessive heat during cooking or keeping vegetables at hot temperatures for a long time (like when keeping dinner warm for a late family member) causes more severe damage, especially to green vegetables, which have chlorophyll. This leads to unappealing changes in color. With excessive cooking times, vegetables also undergo undesirable changes in texture (get soft and mushy) and lose nutrients (vitamins are destroyed and minerals move into the cooking water, which often gets drained away).
EXPERIMENT 1—CRAZY FOR CARROTS
Predict which form of carrots—fresh, frozen, or canned—has the color, taste, and texture you prefer.

1. With vegetable brush, wash one pound of fresh carrots under cool, running water. Peel and cut into bite-sized coins of equal thickness, approximately ¼-inch.
2. Place about one cup of fresh carrots in a custard cup or small bowl. Use for taste testing.
3. Place about one cup of fresh carrots in one cup of boiling water. Bring back to a boil as quickly as possible with the lid on. Cook over medium heat until the carrots are fork tender, approximately eight minutes. Place cooked carrots in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.
4. Follow package directions for cooking one cup of frozen carrots. Place in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.
5. Follow label instructions for heating canned carrots using the liquid in the can. Place in a custard cup or small bowl with a little of the cooking water. Label with masking tape/pen.
6. Using the two-spoon method, taste-test each type of carrot. Record data in the Observation Log.
7. Record the nutrient information provided in the Observation Log for the various forms of carrots. Answer the questions.

CARROT OBSERVATION LOG
Evaluate the carrots by circling the number which best describes what you think.

<table>
<thead>
<tr>
<th>Flavor</th>
<th>Least Appealing to You</th>
<th>Most Appealing to You</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fresh (cooked)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>B. Frozen (prepared)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C. Canned (prepared)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D. Fresh/raw carrots</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Texture
Which carrots have the softest texture? **Canned**
Which carrots have the firmest texture? **Fresh/raw**

Color
Which carrots have the most natural color? **Fresh cooked, frozen cooked, fresh raw**
Which carrots have the least natural color? **Canned**

Fork tender means to cook a food until it is tender enough that it can be easily pierced with a fork or tip of a sharp knife.
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

Evaluate the carrot cooking waters by circling the number which best describes what you observe.

<table>
<thead>
<tr>
<th>Cooking Water Color</th>
<th>None</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fresh (cooked)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B. Frozen (prepared)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>C. Canned (prepared)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Consider your ratings. Which form of carrots do you prefer to eat? ________________

NUTRIENTS IN VARIOUS FORMS OF CARROTS

<table>
<thead>
<tr>
<th>CARROTS 100 grams (about 3.5 ounces)*</th>
<th>VITAMIN A, I.U.**</th>
<th>VITAMIN C (MG)</th>
<th>SODIUM (MG)</th>
<th>POTASSIUM (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh (cooked)</td>
<td>17,033</td>
<td>4</td>
<td>58</td>
<td>235</td>
</tr>
<tr>
<td>Frozen (prepared)</td>
<td>16,928</td>
<td>3</td>
<td>59</td>
<td>280</td>
</tr>
<tr>
<td>Canned (prepared)</td>
<td>11,170</td>
<td>3</td>
<td>242</td>
<td>179</td>
</tr>
<tr>
<td>Fresh/raw</td>
<td>16,706</td>
<td>6</td>
<td>69</td>
<td>320</td>
</tr>
</tbody>
</table>

*3.5 ounces by weight, not by liquid measurement. **I.U. = International Units, a unit of measurement

Canned Carrots with juice: Some carotene (yellow/orange) pigment leaches into the cooking water. Carotene is not very water-soluble. This only happens when carrots are exposed to high heat for long cooking periods such as in canning. The cooking water in the fresh carrots and frozen carrots will be nearly clear.

ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

WHAT’S ON YOUR PLATE? Exploring Food Science

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ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

1. Which form of carrots has the most Vitamin A? _______ Fresh _______ The least? _______ Canned
2. Why do you think there is a difference? [Hint: Think about the effect of heat on vitamins.] _______ Heat of canning
3. Which form of carrots has the most Vitamin C? _______ Fresh _______ The least? _______ Canned
4. Considering a single orange has about 90 mg of vitamin C, are carrots a good source of vitamin C? _______
5. Which form of carrots has the most potassium? _______ Fresh _______ The least? _______ Canned
6. Why do you think this is so? [Hint: Heat does not destroy minerals. Also consider the color of the cooking water.] _______ Some potassium leaches into the cooking water...
7. Which form of carrots has the most sodium? _______ Canned
   Note: Too much sodium can be bad for heart health. Sodium dissolves and can be washed away with water.
8. Describe how you could get rid of some of the sodium in the carrots that have the most: _______ Drain and rinse...

EXPERIMENT 2—RADICAL RED CABBAGE
This experiment shows changes in pigment color. You do not taste the cabbage.
1. Wash a small head of red cabbage under cool, running water. Remove the core. Cut cabbage in half. Cut into strips about ¼ inch wide. Divide the cabbage into four portions.
2. Portion one: Place ¼ teaspoon of baking soda in saucepan with one cup water. Stir to dissolve baking soda. Bring to a boil. Add cabbage, cover, and boil for eight minutes. Place in a small bowl with a little of the cooking water. Label with masking tape/pen.
3. Portion two: Bring one cup water with ½ teaspoon of vinegar to a boil. Add cabbage, cover, and boil for eight minutes. Place in a small bowl along with a little cooking water. Label with masking tape/pen.
4. Portion three: Bring one cup of tap water to a boil. Add cabbage, cover, and boil for eight minutes. Place in a small bowl along with a little cooking water. Label with masking tape/pen.
5. Portion four: Leave raw to observe contrast between raw and cooked forms.

RED CABBAGE OBSERVATION LOG
Evaluate the cooking water by circling the number which best describes what you observe. You do not need to taste the cooked cabbage samples.

<table>
<thead>
<tr>
<th>Color Cooking Water</th>
<th>None</th>
<th>Highly Colored</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cooked w/ baking soda</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2. Cooked w/ vinegar (acid)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3. Cooked plain</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Unit 3: The Inner Mysteries of Fruits and Vegetables
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ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

**Texture**
1. Which form of cabbage has the softest texture? ___________ **baking soda** ___________ **Vinegar**
2. Which do you think would be most appealing to eat? ___________ **Cooked in vinegar**

**Color**
1. Which form of cabbage has the most natural and appealing color? ___________ **Vinegar**
2. Which form of cabbage has the least natural and appealing color? ___________ **Tap water and Baking Soda**
3. Consider your ratings of color and texture. Which form of cabbage is most visually appealing? ___________ **Vinegar**

**SHARE**
1. Describe what you did that changed the flavor and texture of carrots.
   
   **Added heat.**

2. Describe what you did that changed the color and texture of red cabbage.
   
   **Added heat plus vinegar or baking soda.**

3. Describe the differences in the cooking water of carrots and red cabbage.
   
   **The cooking water from carrots, except canned carrots, is nearly clear but has a slight yellow-orange color.**
   **The red cabbage water is deeply colored red or blue-green.**
REFLECT / PROCESS

1. How does heat change vegetables?
   
   Heat breaks down cell walls, so the texture softens. Heat also changes the chemical structure of pigments, thus altering the color of the cooked vegetable.

2. Which pigments, carotene or anthocyanin, are most soluble in water? Hint: Look at the amount of color in the cooking water.

   Anthocyanins. You can tell they are most soluble in water because the cabbage water is deeply colored. The carrot water is less colored and only in the canned product, indicating that carotenes are not as soluble in water.

GENERALIZE

Have you ever eaten cooked vegetables that did not appeal to you because of their color or texture? Thinking about what you saw today, what do you think caused the undesirable changes to the vegetables?

Undesirable color may have been from overcooking and/or holding at a high temperature. The heat alters the chlorophyll pigment, which alters the color.

At this point in the activity, ensure the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.

Terms: vegetable processing, pigments, phytonutrients, chlorophyll, carotenoids, carotenes, anthocyanins, flavonoids, pH, acid, base, alkali, blanching.
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

APPLY
Thinking about the demonstration and experiments, how would you cook fresh broccoli or frozen green beans to maintain taste, texture, appearance, and nutrient value?

The keys to preparing the best fresh and frozen vegetables are:

- Use a small amount of water: about ½ to 1 inch in bottom of saucepan.
- Bring it to a boil.
- Add vegetables. Leave lid off for the first three minutes when cooking vegetables like broccoli and beans. This allows volatile acids to escape so they don’t affect the chlorophyll. It keeps the broccoli bright green.
- Avoid overcooking. Cook until fork tender. Usually six to eight minutes.
- Do not add acidic or basic ingredients unless you are cooking red cabbage.

BE A FOOD SCIENTIST

Pigments give fruits and vegetables beautiful, bright colors. During cooking, it is easy to see how some pigments react to heat and the addition of acid (vinegar) or alkali (baking soda), changing their color.

Carotenoids
Carotenoids are bright yellow, red, or orange pigments. There are over 600 known carotenoids. Many carotenes (kar-uh-teenz) have important roles in protecting human health. Some carotenes are converted to vitamin A in the body. Carotenes are only slightly affected by cooking or adding acid or alkaline ingredients. Their color is stable, therefore it is easy to prepare vegetables, such as carrots and winter squash, with a desirable color.

Are the carrots in this picture real? Investigate “Colorful Carrots” and the role pigments play in the food we eat at: http://www.ars.usda.gov/is/ar/archive/nov04/carrot1104.htm
Chlorophyll

Chlorophyll is a green pigment plants use for photosynthesis. In the early stage of cooking green vegetables, the chlorophyll brightens in color. This is because the heating action removes air from the plant tissue and the underlying bright green of chlorophyll is more visible. During processing in frozen food plants, this short, initial cooking is called blanching. Blanching intensifies the color so that when you open a package of frozen peas, broccoli, spinach, or green beans, the color is bright. Canned versions are often a yellow-green color due to the heat and length of processing.

Correctly cooking green vegetables keeps chlorophyll a bright green. If green vegetables cook too long or with high heat as in commercial or home canning, chlorophyll changes from bright to an olive green color.

Overcooking changes the chemical structure of chlorophyll, as does the addition of acid and alkali ingredients. The changes in chemical structure result in color change. Because of the changes that happen to chlorophyll in cooking, it requires knowledge and skill to prepare green vegetables so that they are bright green and have a desirable texture.

Anthocyanins

Anthocyanins are in red, blue, and purple vegetables and fruits. They are water-soluble pigments. During cooking, some of the pigment (color) spreads through the cooking water. Adding an acid such as lemon juice or vinegar turns anthocyanins bright red. Adding baking soda (alkaline) turns the pigment blue-green. Recipes for cooking red cabbage always contain acidic ingredients such as vinegar, lemon juice, or other fruit juices so cabbage has an appealing color.

Note: Most tap water in the US is slightly alkaline. If used to cook red cabbage, without the addition of acid ingredients, it makes an undesirable texture and color, i.e. blue/purple.

Acid and Alkali Also Affect Cooked Vegetable Texture

Cooking vegetables with an acid (e.g. vinegar or lemon juice) maintains firmness. Cooking with an alkali (e.g. baking soda) softens the vegetables. You’ll notice that red cabbage with acid feels very firm, while the red cabbage with baking soda is soft and mushy. Acids and alkali may alter pigment color, texture, and flavor. They have limited use when cooking fruits and vegetables.
The Nutritional Value of Vegetables
Knowledge and practice of these concepts is important to prepare vegetables that are nutritious and the whole family will enjoy eating! Nutrition experts recommend most American adults and youth need to eat 2½ to 3 cups of vegetables each day to be healthy and manage weight. Vegetables are rich in vitamins, minerals such as potassium, fiber, and phytonutrients. Some pigments are phytonutrients, which have many health benefits. Experts recommend eating a “rainbow of colors” to get a wide variety of phytonutrients.

ARE FROZEN AND CANNED VEGETABLES A GOOD NUTRITIONAL CHOICE?
Heat, air, and light gradually destroy some vitamins and phytonutrients. Therefore, cooked vegetables and fruits may have fewer vitamins than fresh. However, many times canning and freezing processing plants are in or near fields where fruits and vegetables are harvested. Within minutes of picking, produce may be canned or frozen, thus preserving nutrients and making a high quality product. Compare this to the long journey fresh produce takes from the field to the table. Experts estimate that many foods travel an average of 1,200 miles from farm to table. Consider the conditions along the route—heat, air, and light—all of which damage some nutrients. At the grocery store, the fresh produce is stored, then displayed for a length of time while being exposed to more air and light. After purchasing, it may sit in someone’s refrigerator for a long time before being eaten. All the while, nutrients degrade. Thus, canned or frozen produce may have as much or more vitamins as fresh.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD SAFETY SPECIALIST
Food safety specialists make sure our food is wholesome and safe. “Safe” means free from contamination or bacteria and viruses that cause illness. In food processing, they apply government regulations to food and food products from the farm to the table. Food safety specialists working for food processors often develop, implement, and evaluate HACCP programs. HACCP stands for Hazard Analysis and Critical Control Points. HACCP is a set of processes that identify possible food safety hazards and controls them. HACCP along with Good Agricultural Practices (GAPs) are part of food safety in fruit and vegetable growing, harvesting, storage, processing, and transporting. HACCP also comes into play in food product manufacturing, bakery operations, meat and seafood processing, and grocery stores.

WHAT’S ON YOUR PLATE? Exploring Food Science
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Fruits and vegetables get their wide array of beautiful colors from pigments. One pigment, chlorophyll, is green. When cooked correctly, chlorophyll remains a bright green. If green vegetables cook too long, the chlorophyll changes into another compound that has an olive/yellow green color. Adding ingredients such as lemon juice or baking soda makes a difference in the texture as well as the color of green vegetables. Cooking with an acid (e.g. vinegar, lemon juice) maintains firmness. Cooking with an alkali (i.e. baking soda) softens the tissue of vegetables.

Materials List
- Supplies: Paper towels, hand soap, dish soap, tasting spoons, metal fork with sharp tines for testing doneness of vegetables.
- Equipment: Sauce pan with lid, pot holders, small bowls or custard cups, knife, cutting board, measuring spoons, clock or timer
- Food: Medium-size head of broccoli, salt, vinegar, baking soda, water

Personal Safety
- Before beginning each activity, clean and sanitize kitchen surfaces, cutting boards, etc. Wash hands with soap and warm water for 20 seconds. Dry with a paper towel.
- Use caution when working with hot liquids and equipment; have adult oversight.
BROCCOLI PREPARED THREE WAYS—YOU CHOOSE!

Compare the effect of heat, cooking time, and the addition of acid and a base on chlorophyll.
Wash fresh broccoli head under cool, running water. Cut into three portions of about equal size.

**Variable 1**
1. Bring one cup water to a boil.
2. Reduce heat.
3. Add broccoli, simmer first three minutes with lid off, then add lid, cook just until tender, about 5 more minutes.
   - Test doneness by piercing broccoli with fork. Test frequently; DO NOT OVERCOOK.
4. Place in small bowl along with a small amount of cooking water.
   - Note: Salt is used to enhance flavor; it does not interact with the chlorophyll. Leaving the lid off for a few minutes at the beginning of cooking allows naturally occurring acids to escape with the steam so they don’t react with the chlorophyll; thus the broccoli will retain its bright color.

**Variable 2**
1. Bring one cup water with ¼ teaspoon of baking soda to a boil.
2. Reduce heat.
3. Add broccoli and simmer with lid on for 8 minutes. Place in small bowl along with a little of the cooking water.

**Variable 3**
1. Bring one cup water with ½ teaspoon of vinegar to a boil.
2. Reduce heat.
3. Add broccoli and simmer with lid on for 8 minutes. Place in a custard cup or small bowl along with a little of the cooking water.

Describe the effects of the different variables on color and texture; you do not need to taste them.

<table>
<thead>
<tr>
<th>COLOR</th>
<th>TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1—Plain Water</td>
<td></td>
</tr>
<tr>
<td>Variable 2—Baking Soda</td>
<td></td>
</tr>
<tr>
<td>Variable 3—Vinegar</td>
<td></td>
</tr>
</tbody>
</table>
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

PUTTING YOUR KNOWLEDGE TO WORK
Describe what you did that changed the color, taste, and texture of broccoli. (Use the terms heat, acid, alkali, chlorophyll, and pigment.)

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

After tasting and touching, which form of broccoli did you prefer and why?
_________________________________________________________________________________
_________________________________________________________________________________

Did You Know?
Broccoli is one of the most nutritious vegetables you can buy! It is packed with calcium, vitamin C, and phytonutrients that may help protect you from cancer.

Full size page can be found in the Youth Science Journal on page 29.
ACTIVITY 3.2: The Science of Cooking Vegetables: Heat It and Treat It (cont.)

**Fruits and Vegetables**

**What You SEE & What You FEEL**

**The Physical Reactions**
- Cooking in Water Only: Color brightens, natural green
- Cooking in Water + Baking Soda: Color intensifies, bright green
- Cooking in Water + Vinegar: Color is olive-green

**What Happens from a FOOD SCIENTIST’S Point of View**

**The Chemical Reactions**
- Cooking in Water Only: Chlorophyll does not change
- Cooking in Water + Baking Soda: Chlorophyll changed to Chlorophyllin
- Alkaline Cooking Water
- Cooking in Water + Vinegar: Chlorophyll changed to Pheophytin
- Acidic Cooking Water

**Special Note:** Chlorophyll can also be changed to a dull olive-green color by overcooking, holding vegetables at high temperatures for long time periods, and by the high heat of canning. Chlorophyll chemically changes to pheophytin and/or pyropheophytin.

**LEARN MORE!**

**VIRTUAL FUN**

On the Food Science website, www.4-H.org/curriculum/FoodSci, you’ll find lots of additional resources for this unit! See videos on how carrots and peas are harvested and processed, learn how phytonutrients are important to human health, look up the nutrients in your favorite foods at the U.S. Department of Agriculture Nutrient Database, and discover how food safety practices are established to make sure your food remains fresh all the way from the farm to your table.

**WHAT’S ON YOUR PLATE? Exploring Food Science**

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Full size page can be found in the Youth Science Journal on page 30.
MATERIALS LIST

Supplies:
• Cutting board
• Apple corer, if available
• Vegetable peeler
• Paring knife for adult
• Plastic knives for youth
• 1-cup liquid measuring cup
• One-half cup dry measuring cups
• Measuring spoons: 1 tablespoon
• 2 glass 2-cup measuring cups
• Several ice cubes
• Food coloring
• 4 one-quart sauce pans with lids
• Pot holders
• 3 large paper plates

Food:
If you have more than 8 learners, increase number of apples
• 6–7 apples, Golden Delicious variety if possible or substitute with Gala or Red Delicious.
• 1 cup dried apricots OR prunes (often labeled as dried plums)
• 1 ½ cup sugar
• 1 fresh cucumber
• 1 tablespoon salt

Printed Materials:
• Order Youth Science Journal for each learner

Have you ever considered the many ways in which fruit can be prepared? Apples can be turned into sauce or pie filling, dried into semi-soft rings, made into crisp chips or chewy leather. The basic food science principles of osmosis and diffusion play a role in these types of processing. Using a kitchen laboratory, learners will experiment with fruit and a fresh vegetable to “see” examples of osmosis and diffusion in food preparation.

Activity 4.1 Exploring Food Science Careers requires advance planning. Please review ahead of time to determine which of three activity choices you will do:

a. Find a food science guest speaker
b. Locate recorded interviews with food scientists
c. Lead a discussion about food science careers

SKILL LEVEL:
Advanced

LEARNER OUTCOMES
• Knows how to observe, and describe scientific principles of osmosis and diffusion.
• Knows how osmosis and diffusion are used in food preparation.
• Knows how to compare, evaluate, and contrast the texture and flavor of cooked fruit processed with different variables.

SUCCESS INDICATORS
• Defines and describes the principles of diffusion and osmosis.
• Able to follow written directions, measure and prepare solutions.
• Conducts simple tests to show the effect of cooking and sugar solutions on fruits.

SUGGESTED GROUP SIZE
8–12 youth

TIME NEEDED:
Minimum of 60–75 minutes

SPACE
Room with a sink, stovetop, and microwave is preferred but not mandatory. Any setting with a work table and electricity for hot plates is fine.
ACTIVITY 3-3: The Science of Cooking Fruit (cont.)

DURING THIS ACTIVITY, YOU WILL:
• Have learners demonstrate diffusion using food coloring.
• Assist learners as they demonstrate osmosis in salted cucumber and apple slices.
• Assist learners as they demonstrate how diffusion affects preparation of applesauce, apple rings, and rehydrating dried fruit.
• Provide opportunities to view videos of osmosis, diffusion, and related food processing. Videos available at http://www.4-H.org/curriculum/FoodSci will help illustrate diffusion and osmosis.

KEEP LEARNERS SAFE

• FOOD SAFETY: Clean and sanitize kitchen surfaces, cutting boards, etc. Wash hands with soap and warm water for 20 seconds; dry with paper towel. Wash apples thoroughly before cutting. Do not leave cut apples at room temperature for more than two hours to prevent bacterial growth that may cause foodborne illness. Refrigerate leftovers immediately. Visit www.FightBac.org for tips and handouts regarding food safety.
• TOOL SAFETY: Use caution when working with knives and peeler. An adult should be in charge and do the food preparation if children are young. Before doing this activity, review the important information on knife safety posted on the food science website: www.4-H.org/curriculum/foodsci.
• EXPERIMENTING: Use caution when working with hot liquids and equipment; an adult should be in charge. Keep sauce pan handles turned in, away from the edge of the stove or hotplate. Have pot holders available. Use medium and low heats, not high.
• TASTING: When taste testing use the two-spoon (or fork) method:
  » Sampling spoon (or fork): Use to remove small amount of food from cooking pan. Place onto tasting spoon (or small bowl or plate) WITHOUT touching tasting spoon, bowl or plate.
  » Tasting spoon: Use to place food into mouth. Never let the sampling spoon touch the tasting spoon. If it does, wash or replace sampling spoon.
• Tie back long hair.
• Roll up long sleeves.

OSMOSIS AND DIFFUSION IN CUCUMBER, APPLES AND DRIED FRUIT
Osmosis and diffusion occur during fruit and vegetable processing. They influence the final characteristics of food products—characteristics such as taste, texture, retention of shape, and how the food feels in the mouth.

In case it has been a while since high school chemistry, reading the Facilitator Tips along with viewing the supporting videos will make the key points of this activity easy to understand and easier to explain to learners. Reading and preparing ahead is critical for this activity.
GETTING READY

Organizing the Activity

Prior to the Activity

• View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The What Do We Need to Know? and Be a Food Scientist sections explain the science behind the experiments.
• Gather all equipment, supplies, and materials.
• If no stove is available, use two hot plates to complete the activity within the time frame. If using hotplates instead of stove, you will need to re-hydrate dried fruit prior to the activity.

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.
1. What are some words that describe the different textures of raw apples, applesauce and dried apples? (Crisp, hard, crunchy / soft, mushy / leathery, firm, etc.)
2. What do you think causes the difference in textures? (Method of preparation.)
3. In what way does cooking affect the texture of fruit? (Softens)

Open the Youth Science Journal

As learners look at the pictures and read the statement, “Apples can be cooked into a soft sauce or firm rings. How might sugar affect this process?” Guide them to ask questions such as those listed in the answer key.
EXPERIMENTS WITH OSMOSIS

Conduct experiments as instructed in Youth Science Journal. See tips below.

Experiment 1: Osmosis in Fresh Cucumbers and Apples

Key Points to Emphasize about Osmosis and Osmotic Pressure

- Most fruits and vegetables consist of 75% or more water: cucumber 96%, apples 86%.
- Plant cell walls have a semi-permeable membrane that, under certain circumstances, allows water to move back and forth.
- Concentration of sugar and salt determines water movement; their concentration creates a pressure gradient called osmotic pressure. Because fruits and vegetables are high in water, when fresh fruits and vegetables are salted or sugared, water moves across the semi-permeable membrane toward the sugar and/or salt to equalize the pressure both inside and outside the cells.
- Sugar and salt cannot move across the semi-permeable membrane found in fresh fruits and vegetables; only water can move. This movement of water is shown visually when salt and sugar are sprinkled on slices of fresh fruit and vegetables. Our experiments are simple, but these principles are critical in food processing.
- Refer to diagram about osmosis found in the Youth Science Journal. Using that diagram, count blue water molecules, and determine in which direction water moves.

Water droplets form on the surface of salted and sugared slices of fresh cucumber and apple. Vegetables and fruit are naturally low in salt and sugar, therefore there is less salt and/or sugar inside the fresh slices than on the outside once they are salted or sugared. This creates osmotic pressure. To equalize the osmotic pressure, water moves from inside the cell to outside, accumulating on the surface. This process is osmosis. It occurs as water passes through the semi-permeable membrane.

Additional Examples of Osmosis in Fruits and Vegetables

- Many people add sugar to sliced strawberries. The “juicing” is a result of water movement across the semi-permeable membranes of the strawberry cells toward the sugar sprinkled on the surface.
- Sugar and salt may be used in dehydrating fruits, vegetables, fish, and meat based on the principle of osmosis. Some commercial processes are called osmotic dehydration. For instance, this process is used in producing a commercial product such as Craisins® Dried Cranberries.
- Recipes with cucumber and eggplant often start with directions to slice and salt the slices. Water quickly moves across the semi-permeable membrane and beads on the surface. With less water inside the cells, the cucumber and eggplant more readily retain their shape.
- Learners will be able to see the effects of placing salt and sugar on sliced apples, cucumber, and/or zucchini.

EXPERIMENTS WITH DIFFUSION

Do diffusion demonstration as described in Youth Science Journal.

A simple demonstration of diffusion is done in this activity with food coloring in hot and cold water. The coloring diffuses (spreads) throughout both samples of water, but diffuses much faster in hot water. When water molecules are heated, they move faster, which helps substances diffuse more quickly than when the temperature is cold.
Diffusion Explained
What happens to fruit cells when cooked with and without sugar? The following two recipes contain apples and water but one recipe also has sugar. Conducting these experiments shows the difference sugar makes in the texture of the apples primarily due to diffusion. The principle of diffusion is illustrated while making apple sauce and apple rings (Experiment 3).

Key Points to Emphasize about Diffusion
• Diffusing substances, in this case food coloring, move from an area of high concentration (the droplet of coloring) to an area of lower concentration (the surrounding water).
• Diffusion occurs when fruits or vegetables are cooked or heated because the cell structure is permanently changed, allowing not only water but small molecules such as sugar and salt to diffuse into and out of fruit and vegetable tissues.
• Diffusion is all about equalizing concentrations of water, sugar, and salt found inside and outside fruit and vegetable cells after being altered during heating and cooking.
• As in the food coloring demonstration, heat accelerates diffusion.
• Experiments use differing concentrations of sugar and water in the cooking solutions showing diffusion is a two-way process.

Experiment 2: Applesauce and Diffusion
Conduct experiment as described in Youth Science Journal.

Fresh apples contain about 15% fruit sugar. In this experiment, learners cook apples in plain water. The sugar in the apple, once the cell wall is changed by heating, moves from the apple into the cooking water and some water moves from the cooking water into the apple pieces. The two-way movement of water equalizes the concentrations of sugar and water and softens the end product. The apples "sauce" and the cooking water tastes slightly sweet.

Experiment 3: Apple Rings and Diffusion
Conduct experiment as described in Youth Science Journal.

Making apple rings demonstrates how a higher concentration of sugar in the cooking water influences diffusion and the firmness of cooked fruit. Again, heating changes the cell wall. In this experiment, there is a greater concentration of sugar in the cooking water as compared to the amount of sugar inside the apple cells. So, water moves, or diffuses, from the apple ring (less concentrated sugar) out into the more concentrated sugar water cooking solution to equalize. Sugar also diffuses into the apple rings. Because of this, the apple rings soften, but retain their shape.

Experiment 4: How Sugar Affects Dried Fruit Rehydration—Diffusion
Conduct experiment as described in Youth Science Journal.

As dried plums or apricots cook, discuss what is happening from a food science perspective. Dried fruit is very concentrated in sugar since its water has been removed via dehydration. Dried fruit will rehydrate when soaked in water. However, the diffusion process is quicker when the dried fruit and water are heated. Water diffusing into the fruit plumps it and the fruit softens. In Variable 1, sugar is added after the cooking process, which allows maximum diffusion of water into the dried fruit. In Variable 2, sugar is added at the beginning of cooking, which slows down and interferes with diffusion of water into the dried fruit. Variable 1 yields a plump and soft fruit, and is generally the recommended way to rehydrate dried fruit. Note: Differences will be small if dried fruit is rather moist to begin with; differences will be larger if dried fruit is very dry and hard.
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

APPLES CAN BE COOKED INTO A SOFT SAUCE OR FIRM RINGS. HOW MIGHT SUGAR AFFECT THIS PROCESS?

Ask as many questions as you can about these pictures and this statement. Start your first question with, “I wonder . . .”

Don’t stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder . . .

• How do apples become applesauce?
• What makes hard apples turn soft enough to become sauce?
• Why do apple rings look like they’ve held their shape and not become sauce?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

_________________________________________________________

Describe what you think will happen when you do the experiment. I think . . .

_________________________________________________________

BE SAFE! Follow safe practices for handling the knives and stove or hotplate. Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds, before handling produce. Wash apples thoroughly under cool, running water. Wash and sanitize area where produce will be prepared, as well as the cutting board and knives. Visit www.FightBac.org for tips and handouts regarding food safety.
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

WHAT WILL WE DO?
You get to see how osmosis and diffusion affect fruits and vegetables when they are raw and cooked. Sometimes, you may want cooked fruit or vegetables to be soft or, at other times, slightly firm. You’ll see firsthand that the time at which sugar is added in the cooking process makes a difference in the final texture of the food. You’ll make apple sauce, apple rings, and rehydrate dried fruit using the food science principles of osmosis and diffusion.

WHAT DO WE NEED TO KNOW?
Have you ever considered the many ways in which fruit can be prepared? For instance, apples can be turned into sauce or pie filling, or into semi-soft rings, or made into crisp chips or chewy leather, to name a few. The basic food science principles of osmosis and diffusion play a role in food processing. Osmosis happens mostly with raw fruits and vegetables. Diffusion happens mostly in cooked fruits and vegetables after the cell wall has been damaged by heat.

PLANT CELLS
You may remember from Activity 3.1 that plant cells have a cell wall and cell membrane that surround the contents of the cell. The cell membrane is pressed close to the cell wall, both of which give strength and structure to fruits and vegetables. The cell membrane is semi-permeable, which means that under some conditions, water can move across the membrane.

Cooking changes the cell wall of fruits and vegetables eventually damaging the cell membrane. Once damage occurs, water, sugar and salt can pass into and out of the fruit and vegetable cells. Length of cooking time and addition of sugar or salt during or after cooking changes texture and flavor. You’ll learn more as you experiment with diffusion and osmosis during the activity.
UNDERSTANDING OSMOSIS!

Osmosis is the movement of water across a semi-permeable membrane from an area of lower concentration to an area of higher concentration. In food science, osmosis occurs as the result of sugar and salt concentrations that influence the movement of water into and out of a cell. The unequal concentrations of things like sugar and salt create a pressure called osmotic pressure. The diagram shows what osmosis looks like using sugar in water as an example. The red dots represent sugar molecules. Water moves across the semi-permeable cell membrane, decreasing the pressure. Count the blue dots representing water molecules on the left and right sides of each drawing. Water molecules are pulled, via osmotic pressure, to the area with the most sugar, on the left. Note some water molecules remain on the right side, but fewer of them.

![Diagram of osmosis]

Count the blue water molecules in each section of the beakers.
EXPERIMENT 1: OSMOSIS IN CUCUMBER AND APPLE SLICES

Observe osmosis in raw vegetable slices.

**Ingredients:**
- 1 cucumber
- 1 apple
- Salt
- Sugar

**Directions:**
1. Wash cucumber and an apple under cool, running water.
2. Cut three cucumber slices about ¼-inch thick. Cut three apple slices about ¼-inch thick.
3. Put one slice of each on three plates.
   - Variable 1: Generously sprinkle both the slices on one plate with salt. Label “Salt Treatment”
   - Variable 2: Generously sprinkle both the slices on one plate with sugar. Label “Sugar Treatment”
   - Variable 3: Do not salt or sugar the slices on one plate. Label “Untreated”
4. After 15 minutes, compare and contrast the untreated slices with the salted and sugared slices.

Describe the surface of the salted cucumber: _________________________________________________
Describe the surface of the sugared cucumber: _________________________________________________
Describe the surface of the untreated cucumber: _________________________________________________
Describe the surface of the salted apple: ______________________________________________________
Describe the surface of the sugared apple: _____________________________________________________
Describe the surface of the untreated apple: _____________________________________________________
Which samples show the process of osmosis? _____________________________________________________

**Why does this matter?** A special kind of pressure, called osmotic pressure, is created as a result of adding salt and/or sugar. Osmotic pressure causes movement of water across the semi-permeable cell membrane. Removing water from vegetables in this way helps them to make a less watery final product, such as cucumbers in sour cream or eggplant parmesan. Removing water like this also helps the vegetable retain its shape. At other times, a watery product is desirable. Sugar is often added to sliced strawberries to make them juicer.
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

UNDERSTANDING DIFFUSION!

1. Put several ice cubes into a clear glass 2-cup measuring cup. Fill with water to the 1½ cup line.
2. In a saucepan, heat 1½ cups of water until almost boiling. With adult supervision, carefully pour the hot water into another clear glass 2-cup measuring cup. Have two learners simultaneously add 2 drops of food coloring to each glass. Observe. Compare and contrast how the food coloring moves throughout the cold water and hot water.

Describe the rate at which food coloring moves throughout the cold water:____________________________________

Describe the rate at which food coloring moves throughout the hot water:___________________________________

Why do you think the rate of diffusion is faster in one sample than the other? ________________________________
____________________________________________________________________________________

As opposed to osmosis, diffusion mostly occurs after fruits and vegetables are cooked or heated. During heating, the cell walls and membranes are damaged so their structure changes. Water, salt, and sugar can then move into and out of the cells. Diffusion is the mixing or spreading of molecules equally throughout a mixture. Ingredients that are diffusing go from an area of high concentration to an area of lower concentration. For instance, when sugar dissolves in water, the molecules of sugar mix in with water molecules. Sugar molecules move throughout the water until equilibrium is achieved (see illustration). Equilibrium means that the molecules are evenly spread throughout the water.

As opposed to osmosis, diffusion mostly occurs after fruits and vegetables are cooked or heated. During heating, the cell walls and membranes are damaged so their structure changes. Water, salt, and sugar can then move into and out of the cells. Diffusion is the mixing or spreading of molecules equally throughout a mixture. Ingredients that are diffusing go from an area of high concentration to an area of lower concentration. For instance, when sugar dissolves in water, the molecules of sugar mix in with water molecules. Sugar molecules move throughout the water until equilibrium is achieved (see illustration). Equilibrium means that the molecules are evenly spread throughout the water.

![Diffusion Diagram](image)

Sugar cube is dropped into water.
Molecules of sugar separate from the cube.
Molecules of sugar continue to separate from the cube and move throughout the water. Eventually the cube dissolves— all sugar molecules have become evenly distributed in the water.

Full size page can be found in the Youth Science Journal on page 35.
FUN WITH FRUIT—VARY THE TEXTURE AND THE FLAVOR!

The following two recipes contain apples and water, but one recipe also has sugar. These experiments show how the amount of sugar in the cooking water makes differences in the texture and flavor of the apples. The differences occur primarily as a result of diffusion.

**EXPERIMENT 2: APPLESAUCE—OSMOSIS AND DIFFUSION**

Apples contain naturally occurring fruit sugar called fructose. They usually have about 15% fruit sugar. Sweeter apples have more fructose than tart apples.

**Ingredients**

2–3 medium apples, peeled, cored and cut into 1½ inch chunks  
½ cup water

**Directions**

1. Wash and prepare apples.  
2. Put apples and water in a saucepan. Cover and cook apples over medium heat until they begin to break down, 15–20 minutes.  
3. Check and stir occasionally to break up chunks.  
4. Remove from heat.  
5. Put in tasting bowl.  

May be served hot, warm, at room temperature, or chilled. For food safety purposes, do not leave at room temperature for more than two hours. Can be covered and refrigerated for up to five days.

Use proper tasting technique to taste the applesauce.

Describe the texture of the applesauce:

_________________________________________________________________________________  
_________________________________________________________________________________

Describe the flavor and sweetness of the applesauce.

_________________________________________________________________________________  
_________________________________________________________________________________
ACTIVITY 3-3: The Science of Cooking Fruit (cont.)

EXPERIMENT 3: APPLE RINGS—OSMOSIS AND DIFFUSION
How does sugar influence the firmness of cooked fruit?

Ingredients
2 medium or large apples
1 cup sugar
2 cups water

Directions
1. Wash apples.
2. Core apples using an apple corer if one is available.
3. Cut each apple into ½-inch thick rings.
4. If not cored, remove seeds and cores by putting apple slice flat on cutting board and cutting around seeds and core with a small knife.

Variable 1
1. Place 1 cup water in small saucepan.
2. Put half of the apple rings into water.
4. Carefully lift apple rings out of cooking water and arrange on a plate labeled Variable 1.
5. Save some of the cooking water in a small bowl for tasting. Label Variable 1.

Variable 2
1. Combine 1 cup water and 1 cup sugar in small saucepan.
2. Stir over moderately low heat until sugar is dissolved.
3. Put half of the apple rings into the sugar water solution.
5. Carefully lift apple rings out of cooking water and arrange on a plate labeled Variable 2.

Cut apple slices into pieces so everyone can sample each variable. Using proper tasting technique, also taste the cooking water for each variable after it has cooled. Record your observations in the Observation Log.
### Apple Ring Observation Log

<table>
<thead>
<tr>
<th>THE APPLES</th>
<th>VARIABLE 1 WATER</th>
<th>VARIABLE 2 WATER + SUGAR 1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAPE</td>
<td>Describe the shape. Did the apple rings hold their shape? Do they look like a firm ring, or a misshapen floppy ring?</td>
<td>Rings lose shape, appear more like applesauce</td>
</tr>
<tr>
<td>TEXTURE</td>
<td>Taste the apple slice and describe the texture. (Soft, mushy, firm? Use your own words.)</td>
<td>Soft and watery</td>
</tr>
<tr>
<td>FLAVOR</td>
<td>Describe the flavor. Taste an apple ring. Is it bland, flavorful, or sweet? Does the flavor of the apple come through?</td>
<td>Sweet, not overpowering Apple flavor comes through</td>
</tr>
</tbody>
</table>

### The Cooking Water

| FLAVOR | After the cooking water has cooled, taste it. Describe the flavor. Is it bland, flavorful or sweet? Can you taste the flavor of the apple? | Slightly sweet with slight apple flavor. | Very sweet, no apple flavor |

---

*WHAT’S ON YOUR PLATE? Exploring Food Science*

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EXPERIMENT 4: REHYDRATION OF DRIED FRUIT—DIFFUSION

This experiment uses dried apricots or plums, which are also called prunes. Dried fruit has been dehydrated—it’s water content greatly decreased. As a result of less water, the dried fruit has a higher concentration of sugar than fresh fruit.

Variable 1 needs to be started at least a few minutes before Variable 2 because the amount of water and cooking time is determined by Variable 1.

**Ingredients**
- 16 dried plums or apricots
- 12 tablespoons sugar
- Water

**Directions**

**Variable 1—Sugar Added After Cooking**
1. Place eight dried plums or dried apricots in a small saucepan.
2. Fill a one cup measuring cup with water. Slowly add just enough water to cover the fruit. Record the amount of water it took to cover the dried plums.
3. Using medium heat, bring to a simmer (do not cover). Note the time that dried plums start to simmer.
4. Cook until tender when pierced with a fork or tip of sharp knife. Note time.
5. Remove from heat.
6. Add six tablespoons of sugar and stir gently to mix.
7. Pour cooking water into a small bowl. Place plums/apricots on a plate labeled “Variable 2” for observation and testing.

Amount of water: ___________
Cooking Time Start: ___________ End: ___________ Length of Time: ___________
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

Variable 2—Sugar Added Before Cooking
1. Measure out the same amount of water as used for Variable 1. Pour into small saucepan.
2. Add six tablespoons of sugar, mix to dissolve sugar.
3. Place eight dried plums or apricots into sauce pan.
4. Using medium heat, bring to a simmer (do not cover). Note time that dried fruit starts to simmer.
5. Cook for the same amount of time as in Variable 1. Note time.
6. Remove from heat.
7. Pour cooking water into a small bowl. Place plums/apricots on a plate labeled “Variable 2” for observation and testing.

Amount of water: ___________
Cooking Time Start: ___________ End: ___________ Length of Time: ___________

Cut fruit into pieces if necessary so everyone can sample each variable.

DRIED FRUIT OBSERVATION LOG

<table>
<thead>
<tr>
<th>THE DRIED FRUIT</th>
<th>VARIABLE 1 SUGAR ADDED AFTER COOKING</th>
<th>VARIABLE 2 SUGAR ADDED BEFORE COOKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPEARANCE: Describe the appearance of the fruit.</td>
<td>Slightly more plump than sugar water</td>
<td>Slightly less plump than plain water</td>
</tr>
<tr>
<td>TEXTURE: Taste and describe the texture (Soft, mushy, firm? Use your own words.)</td>
<td>Softer than those cooked in sugar water</td>
<td>Soft, but not as soft as those cooked in plain water.</td>
</tr>
<tr>
<td>FLAVOR: Taste and describe the flavor.</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

THE COOKING WATER

| FLAVOR: Taste the cooking water. Describe the flavor. Is it bland, flavorful, sweet, or overly sweet? Can you taste the flavor of the dried plums/apricots? | Slightly sweet, slight taste of plums | Sweet, no taste of plums. |
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

Below are answers you might expect from the learners. Do not give these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

**SHARE**

1. What made a difference in whether the food coloring spread throughout the water quickly or slowly?
   
   Temperature of water. The hotter the water, the faster the rate of diffusion.

2. Compare and contrast the differences between treated and untreated cucumber slices and apple slices. What do you think is the reason for the differences?
   
   Salted and sugared slices have water droplets on the surface. As result of differing concentration of salt/sugar inside and outside the cell membrane and wall, osmotic pressure was created. Water moved to the surface of the slices. This is an example of equalizing osmotic pressure.

3. Describe what you did that changed the flavor and texture of apple rings.
   
   Added heat, water, and sugar.

4. Which apple rings held their shape the best?
   
   The ones cooked with the equal amounts of sugar and water.

5. Describe the taste of the cooking water of the apple rings.
   
   Cooking water without sugar tasted a little sweet and had a bit of apple flavor. Cooking water with sugar was very sweet but did not taste like apple.

6. Describe what you did that changed the color and texture of dried fruit.
   
   Added heat and water. Added sugar to one variable.

7. Describe the differences in the texture of the dried fruit. (Differences will be small.)
   
   Variable 1: Re-hydrates more quickly and more thoroughly than Variable 2. Variable 2: Re-hydrated more slowly, not as plump as Variable 1.
REFLECT

1. How do you use/control sugar to make cooked fruit firmer and keep its shape?

   Use more sugar in cooking water to keep fruit firm and make it keep its shape.

2. Why does this help fruit stay firmer and keep its shape?

   There is more sugar in the water than in the apple slices, so water diffuses toward the concentrated sugar solution, keeping the cells intact.

3. Why did the fruit cooked without sugar get soft and lose its shape?

   There is more sugar in the apple cells than in the water, so cooking water diffused into the apple cells, softening their cell walls and turning the mixture from apple chunks to applesauce. This is a result of diffusion.

At this point in the activity, ensure the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.

Terms: Fruit, osmosis, osmotic pressure, diffusion, sugar, cell structure, cell membrane, semi-permeable membrane, salt, solution, permeable, simmer
ACTIVITY 3.3: The Science of Cooking Fruit: All About Osmosis and Diffusion (cont.)

GENERALIZE
1. Considering what you have learned in this activity, when is sugar necessary for cooking fruit?

   When retaining its shape is important.

   When you want to create a fresh fruit “sauce,” cook without sugar.

2. Describe the difference between diffusion and osmosis.

   In brief, diffusion is the process of molecules of a substance, such as sugar, moving throughout a solution, such as water. Diffusion occurs in heated/cooked fruit because the heat damages the cell, allowing it to be more permeable so water as well as salt and sugar can move into and out of the cell.

   Osmosis is the shift of water across a cell wall and membrane. Osmosis occurs in uncooked fruit and vegetables.

APPLY

Apples ripen and are on sale in the fall. Perhaps your family buys a large amount of apples but everyone gets tired of eating plain apples. How can you prepare them in a healthful way your family might like?

   Cook them without sugar to make applesauce and freeze.

   Make dried apples for snacks.

See the food science website http://www.4-H.org/curriculum/FoodSci for links to instructions on drying fruit.
Strawberries, Sugar, and Osmosis
Sugar, also causes water to shift from inside the cell to the outside. When sugar is sprinkled on sliced strawberries, there is more sugar on the outside than on the inside of the strawberry cells, and osmotic pressure is created. Water moves out of the strawberry cells and the strawberries produce “juice.” Many people prepare fresh strawberries using this principle of osmotic pressure.

Eggplant, Salt–Osmosis and Diffusion
In a cookbook or online, find a recipe for eggplant parmesan that includes slicing and salting the slices prior to cooking. Why would you do this? Remember osmosis is the movement of water across a semi-permeable membrane prior to cooking which makes permanent changes in the membrane. After these changes, diffusion occurs; salt will diffuse into the cooked eggplant.

Craisins® Dried Cranberries are made with an osmotic drying process that is not used by food processors very often. Osmotic drying uses a syrup with a high sugar content to osmotically draw water from the cranberries.
ACTIVITY 3.3: The Science of Cooking Fruit (cont.)

Here are a couple of examples of how diffusion is used in preparing food—you did these in the experiments!

Cooking Apples in Water—Applesauce
When making applesauce, a typical recipe calls for cut apples cooked in water. The cells in the apples naturally contain 15% fruit sugar and the cooking water has no sugar. Initially, osmosis occurs until the heat of the cooking water damages the cell wall and semi-permeable membrane. After those are damaged, sugar and water can move freely in and out of the cells depending on concentrations. Diffusion dilutes the concentration of sugar in the apple slice. This inflow of water causes the apple cells to soften or sauce; first with osmosis and then diffusion. Some of the sugar from the apple moves into the cooking water. You may taste a slight sweetness in the cooking water.

Cooking Apples in a Concentrated Sugar Solution—Apple Rings
When cooking apple rings in a highly concentrated sugar solution, the reverse occurs. Because of diffusion, water and sugar move in opposite directions. Water moves from the apple rings to the concentrated sugar cooking solution and sugar in the solution moves into the apple cells, creating equilibrium—similar amounts of sugar in the apple rings and in the water. While the apple rings soften during cooking, the slices maintain their shape.
FOOD SCIENCE AND SUGAR IN COOKING—WHAT’S THE LINK?
For health reasons, it’s a good idea to limit the amount of sugar consumed. However, sugar sometimes plays a functional role in food preparation that goes beyond adding sweetness. Occasionally, sugar is needed to achieve a certain result in food processing and cooking. For instance, omitting the sugar in recipes similar to the ones in this activity would change the structure and texture of the fruit.

LEARN MORE!

VIRTUAL FUN
Watch videos that describe how osmosis and diffusion work in food science. Find out more about dried plums, including recipes and learn how to make dried fruit at home. Visit www.4-H.org/curriculum/foodsci

Full size page can be found in the Youth Science Journal on page 46.
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UNIT 3 REFERENCES


www.dictionary.com for pronunciations.

Enzymatic Browning of Apples. Adapted from Institute of Food Technologists, Dr. Cathy Davies.


Oregon State University: http://food.oregonstate.edu/learn/fruitveg.html


"I Pledge my Head to clearer thinking,
my Heart to greater loyalty,
my Hands to larger service,
and my Health to better living,
for my club, my community, my country,
and my world."
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Unit 4 is just one part of exploring “What’s on Your Plate?” Be sure to check out the other units in this curriculum series for more fun experiments you can eat!
FOOD SCIENCE FACILITATOR GUIDE

Welcome to the Food Science Facilitator Guide! This guide is intended to help you lead an effective learning process for youth as they discover the science of what’s on their plate!

This 4-H curriculum uses an inquiry-based learning method designed to help young people first ask questions, then seek answers through hands-on activities, and finally to reflect on what they’ve learned.

We encourage you to preview the activities, watch the short tutorial videos, and then carefully read through each activity. The pages from the Youth Science Journal are inserted so you have all the content of the curriculum as well as questions, answers, and tips to help you lead these activities. The activities are easily carried out in a home kitchen “laboratory” using inexpensive supplies available at grocery stores. If it’s been some time since your last science class, keep smiling—the curriculum and tutorial videos contain everything you need to know!

The activities are written for youth grades 6–9, but may be adapted for younger or older learners. You can limit or expand the amount of information you share or simplify the terms if needed. Explain the concepts to youth in terms they are able to understand depending on their age and level of experience. For younger learners, you might only focus on the physical reactions they can see. Chemical reactions that food scientists explore can be introduced to older or more advanced learners. Paraphrasing instructions and concepts in your own words will help activities and discussions flow more naturally.

For the best learning experience, please follow the instructions and do each part of the activity. Each of the activities within the units should be done in the order presented. The units may be done in any order, however the concepts are more complex in Units 3 and 4. For learners to have positive outcomes, pay close attention to the details and directions of the activities.

It’s easy to get caught up in the hands-on activities and forget to reserve time for the reflection and application questions. These questions are essential though for locking in the learning and assessing if learners grasped the concepts you have been teaching. Many times you’ll “see the light bulb come on” when you ask them to explain what they’ve done and what they’ve learned.

Keep in mind that some youth will prefer to process their thoughts internally and write down their responses. Others will be eager to share verbally. Structuring the time for individual reflection and writing first and then encourage sharing will allow both types of learning to thrive.
Your work with youth is a genuine opportunity to encourage them to consider careers in science, engineering, and technology. Food science and food technology are examples of using applied basic sciences. The work you’re doing with these young people may help someone discover a career path in food science, find a passion for creating meals that amaze, or simply help them be aware of healthy food preparation. You’ll never know how far your influence will reach.

Enjoy exploring What’s on Your Plate?

4-H Mission Mandate Outcomes—Science and Healthy Living
• Improved science skills and knowledge among youth.
• Youth apply science learning to contexts outside 4-H.
• Increased science literacy in general population.
• Increased knowledge, attitudes, skills, and aspirations to promote optimal physical, social, and emotional health habits.

Life Skills
• Cooperation
• Critical Thinking
• Communication
• Contributions to Group Effort
• Keeping Records
• Planning/Organizing

In preparing to do activities, follow these steps for the best success:
• Skim the Facilitator Guide.
• View the short video tutorial. It shows techniques and explains the science to make it easier for you to conduct the activity.
• Carefully read both the Facilitator Guide and the Youth Science Journal portion of the Facilitator Guide.

Note that the Youth Science Journal contains most of the science explanations in the Be a Food Scientist section. This information appears after the experiments and discussion portions. This enables the learners to use inquiry first, then confirm their findings later. It is not expected that learners will read this section during the activity; it may be useful if they want to delve deeper, remember, or share the concepts with others.

There a number of additional materials, including videos, handouts, glossary terms, podcasts, resources, and links to other websites at www.4-H.org/curriculum/foodsci. Links to webpages often change, so rather than printing them here, they will be kept up-to-date on the 4-H webpage dedicated to this curriculum. These materials will enrich you and your learners’ understanding of the content.
**ACTIVITY 4.1**

Exploring Food Science Careers—A Day in the Life of a Food Scientist

Did you know there is a shortage of young people choosing careers in science? This includes careers in science, technology and engineering and applied science careers such as food science and food technology.

By encouraging careers in food science and food technology, you are joining people from organizations including the Institute of Food Technologists (IFT), the IFT STEM Food and Ag Council, National 4-H Council, universities, and representatives from corporations around the world who want to assure there is an abundant, safe food supply for a growing world population.

**SKILL LEVEL:**
Beginner

**LEARNER OUTCOMES**
- Knows how to academically and personally plan for a career in food science and food technology.
- Knows how to use on-line career development materials from the Institute of Food Technologists and universities offering degrees in food science and food technology.
- Understands and identifies diverse employment opportunities in food science and technology across the global food system.

**SUCCESS INDICATORS**
- Defines and describes careers in food science and food technology.
- Able to apply food science career paths associated with academics in middle and high school.
- Identifies the science disciplines associated with food science and food technology, including biology, chemistry, biochemistry, nutrition, science, technology, engineering, and math.

**SUGGESTED GROUP SIZE**
8 - 12 Youth
Note: If you arrange for an in-person guest speaker, you may wish to invite additional youth from other groups.

**TIME NEEDED:**
45 - 60 minutes

**SPACE**
Any setting with space for discussion

---

**MATERIALS LIST**

**Supplies:**
- Poster paper for discussion notes
- Tape
- Markers
- Pens, paper, envelopes for speaker thank-you notes

**Video/Video Conference Equipment**
- If your guest speaker is joining the group via video conference or you plan to share the food science career videos, you will need a computer with Internet access, speakers, and microphone or speaker phone. For larger groups, connect to a screen large enough for all learners to easily see (computer monitor, television, or projector) with speakers loud enough for everyone to hear.

**Food**
- You may wish to provide a healthy snack for learners.
- It’s also courteous to provide drinking water for your speaker.

**Printed Materials**
- Order Youth Science Journals for each learner.
DURING THIS ACTIVITY, YOU WILL:

• Introduce learners to careers in food science.
• Involve learners with experiences encouraging them to do in-depth career exploration in food science, food technology, and STE careers.
• Select among three activity options

ADVANCE PLANNING:

For this activity, there are three options. Pick the one that works best for you and the learners.

Option 1—Guest Speaker

Invite a food scientist to come and speak to your learners. Having a food scientist or food technologist with real-world experience can motivate a young person towards a career in food science and food technology. Whether you live in a rural or urban area, there are opportunities to find experienced adults with a genuine interest to mentor young scientists.

Ways to find a guest speaker

Keep in mind that you can use technology to link learners with professionals anywhere in the country. Don’t be afraid to ask!

• Contact food processing operations: Beverage, dairy, vegetable or meat processors. Through on-line searches there may be opportunities to choose from several of these in your community.
• Find a speaker from the Institute of Food Technologists website for an interview. Several of their member scientists are interested in doing such interviews.
• Find local entrepreneurs—artisan food processors making cheese, jams and jellies, and candy. While the owners may or may not have degrees in food science, they will employ food science principles and practices in their operations.
• Contact the food science department at your Land-grant [state] University. Even though the university may not be nearby, they may be willing to offer a specialized speaker. For instance, a student recruiter might talk about high school preparation for entering the food science program and the college experience in that program. Or the university might have a food science student or alumni in your area or available via technology.
• Contact your local University Extension [Cooperative Extension] office. Request a speaker with connections to the food system. This might be a food scientist, food safety specialist, or agriculture specialist, or other related discipline.
ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

• Talk with the manager of your local grocery store. Request an employee working in Quality Assurance and/or Food Safety; these are two specialties within the realm of food science. The store probably has people in these positions working either locally or regionally.
• Ask your local Extension (Cooperative Extension) office if they have space and available video connections with their university and are able to help with the planning.
• Contact food research and development centers.
• Contact your state Department of Agriculture and Food Safety.

Option 2—Videos or Websites
If you do not have a guest speaker, view several of the recorded interviews with food scientists from the websites listed in this activity. For a small group, a laptop computer with speakers would work. For larger groups, connecting the laptop to a television screen or projector would be a better alternative. There are many excellent videos with interviews from career professionals which are acceptable alternatives to a speaker. Visit website links maintained at www.4-H.org/curriculum/foodsci.

Option 3—Facilitator Discussion
If you cannot arrange a guest speaker and don’t have access to on-line resources, you can conduct the discussion of careers in food science and food technology using materials provided in this section and from your public library or local Extension Office. Investigate the website links maintained at www.4-H.org/curriculum/foodsci. Make certain your presentation includes information that provides learners the information necessary to answer questions in the “Talk it Over” section of the Youth Science Journal.

Share an Overview with Learners
• Give a brief description of the need for food scientists and food technologists and explain the needs and opportunities for careers in science, technology and engineering.
• Post the official definitions of Food Science and Food Technology.
ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

GETTING READY
Organizing the Activity

Prior to the Activity

- View the tutorial video, other videos, glossary, and print resources available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal and the What Do We Need to Know? and Be a Food Scientist sections. If using a speaker, locate one for an in-person or on-line presentation/interview.
- If using videos, preview some of the ones suggested in this activity. Download them onto laptop or tablet for easy viewing and test to make sure audio and video work.
- Gather all equipment, supplies, and materials.
- Test any video conferencing software/equipment or videos far enough ahead of time so you are confident in their use well before the scheduled starting time.
- Visit the Institute of Food Technologists (IFT) website and prepare an overview of it to share with learners. www.ift.org.
- If you are leading the discussion from Option 3, prepare your outline by using the information in these curriculum materials.
- Write the definitions from IFT for Food Science and Food Technology on large paper and post in the room. The definitions are in the Youth Science Journal, What Do We Need to Know? section.

BEGINNING the ACTIVITY
Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What are some different types of science that would be used in a food science or food technology career?
2. Can you imagine what a food scientist or food technologist would accomplish during a day at work?
ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

Open the Youth Science Journal
Learners complete page one of the Youth Science Journal.
• Have learners share their career interests and discuss why they chose those possible career tracks. Are any of them considering careers in food science and food technology?
• If you have time, find the most popular career choices among learners.

FACILITATE THE ACTIVITY
• Option 1: Prior to introducing the guest speaker, have learners write out several questions to ask the speaker. Also ask the speaker ahead of time for help with an introduction that you or one of the learners can read to the group. This is an effective way to share the speaker’s qualifications and build their credibility.
• Option 2: Show previously selected videos of interviews with food scientists.
• Option 3: Lead the discussion about careers in food science and food technology.

VARIATION
High school learners may want to conduct individual interviews with local food scientists. Encourage them to call and/or visit a food scientist and talk with them about their careers. These interviews are an excellent way for learners to explore “real world” opportunities in science.
Imagine you are choosing a career in Food Science and Food Technology! Choose three career options that sound interesting to you and circle them.

### FOOD SCIENCE CAREERS

<table>
<thead>
<tr>
<th>Food Scientist</th>
<th>Analytical Testing Laboratory Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal, Dairy, or Meat Product Applications</td>
<td>Meat Scientist</td>
</tr>
<tr>
<td>FDA/USDA Research Scientist</td>
<td>New Technologies</td>
</tr>
<tr>
<td>Flavor Chemist</td>
<td>Packaging Specialist</td>
</tr>
<tr>
<td>Food Biochemist</td>
<td>Plant Operations Management</td>
</tr>
<tr>
<td>Food Biotechnologist</td>
<td>Project Leader</td>
</tr>
<tr>
<td>Food Chemist</td>
<td>Public Health Official—Food Safety</td>
</tr>
<tr>
<td>Food Engineer</td>
<td>Research and Development</td>
</tr>
<tr>
<td>Food Safety Inspector</td>
<td>Quality Assurance Officer</td>
</tr>
<tr>
<td>Food Microbiologist</td>
<td>Sales Manager</td>
</tr>
<tr>
<td>Food Plant Supervisor</td>
<td>Scientific and Regulatory Affairs</td>
</tr>
<tr>
<td>Food Product Developer</td>
<td>Food Ingredient Sales</td>
</tr>
<tr>
<td>Food Science Professor</td>
<td>Sensory Evaluation</td>
</tr>
<tr>
<td>Food Technologist</td>
<td>Technical Sales</td>
</tr>
<tr>
<td>Food Toxicologist</td>
<td></td>
</tr>
</tbody>
</table>

Source: Washington State University and University of Idaho School of Food Science
WHAT WILL WE DO?
In this activity, you get to do in-depth career exploration of food science and food technology careers. Did you know there is a shortage of young people choosing careers in science? This includes careers in science, technology, engineering, and applied science careers such as food science and food technology. There is a constant need for new scientists, including food scientists and food technologists.

Your group’s facilitator will arrange for a discussion with a food science professional, or videos of interviews with food scientists.

WHAT DO WE NEED TO KNOW?
An amazing array of sciences is involved in producing food. Think about food science and food technology as “applying” basic science to food—sciences such as chemistry, biology, microbiology, biochemistry, engineering, and mathematics. Food science and food technology are the applications of science to food product research and product development, food manufacturing, packaging, food safety and sanitation, food transportation, labeling, advertising, and marketing. Food science careers extend from the farm to our tables.

Food Science vs. Food Technology—What’s the Difference?
The Institute of Food Technologists (IFT) defines these terms as follows:

Food Science is the discipline in which engineering, biological, and physical sciences are used to study the nature of foods, the causes of deterioration, the underlying principles, and the improvement of foods for the consuming public.

Food Technology is the application of food science to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious, and wholesome food.

Source: Institute of Food Technologists

WHAT’S ON YOUR PLATE?
Exploring Food Science
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ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

If you can’t find a local speaker, consider finding a food scientist who would agree to join your group by video or VoIP (voice over Internet protocol) service.

Whether your speaker attends your site or visits electronically, provide him or her with a copy of this activity and the Youth Science Journal. This will help in preparation for the presentation. Afterward, encourage learners to send thank-you notes to the guest speaker.

Full size page can be found in the Youth Science Journal on page 4.
### Information Log

Fill out the information log before and after the discussions or watching the videos.

<table>
<thead>
<tr>
<th>WHAT DO I WANT TO LEARN?</th>
<th>WHAT DID I FIND OUT?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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To find out more about a possible career in food science you could find a food scientist to visit, learn more about food science programs at a university, or search reliable Internet resources such as those listed at www.4-H.org/curriculum/foodsci. To find out more about a food science career, write an action plan with at least three steps and list three resources you’ll use.

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ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

SHARE
1. What did you like about the activity your group did?
   Learners share their impressions of the interview, videos, or facilitator discussion.

2. In your own words, define food science and define food technology.
   Refer to definitions Facilitator prepared and posted in room.

REFLECT
1. What are several things you found most interesting about careers in food science and food technology?
   Answers will vary.

2. In what way did the information make you more interested in a food science career than you were before?
   Answers will vary.

3. Using a scale of 1 to 10, with 1 being least and 10 being most, how much do you think you would like to pursue a career in food science?
   What were you thinking when you chose that number?
   Answers will vary.

Encourage learners to write thank-you notes to speaker(s).

WHAT’S ON YOUR PLATE? Exploring Food Science
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Unit 4: Be a Food Scientist!
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Full size page can be found in the Youth Science Journal on page 6.
ACTIVITY 4.1: Exploring Food Science Careers—A Day in the Life of a Food Scientist (cont.)

TERMS & CONCEPT DISCOVERY

Terms: Food science careers, food technology, career preparation, career path, food technology, STE education, VoIP service, International Food Technologists (IFT)

GENERALIZE

1. Describe several steps you can do now to prepare for a career in science, food science, or food technology.
   - Research the career: Talk to someone in the field; use online resources, especially those from the professional organizations related to the career in which I am interested (e.g., Institute of Food Technologists, etc.).
   - Education: Find out what universities offer the career I am interested in and look at the course prerequisites. Meet with my school counselor to make sure I can get the courses I need.
   - Use the resources found in my Youth Science Journal.

APPLY

1. Someone asks you what career you are considering for the future. What will you tell them?
   Answers will vary.

2. What other job within the realm of food science would you like to find out more about? Make a plan of how you will learn more.
   Answers will vary.

At this point in the activity ensure that the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.
Food scientists and food technologists specialize in many areas and do a wide variety of things. While they develop and produce new and innovative food products you see at your grocery store, they also develop food products for people with special needs. For instance, they develop foods for backpackers, athletes, military troops, astronauts, and those with conditions such as diabetes, heart disease, or gluten sensitivity.

If your group did not listen to the interviews with several food scientists at the International Food Technologists website, you may wish to do so on your own. See four food scientists who work for a university, Disney, NASA, and in food packaging. These video interviews are linked from www.4-H.org/curriculum/foodsci

- Fu-hung Hsieh: Food Science Professor
- Brian Thane: Food Packaging Professional
- Disney Consumer Specialists
- Michele Perchonok: A Food Scientist at NASA

**Get Started While in High School**
To be competitive for college admission, it is vital to have the correct preparatory high school coursework. Talk with high school counselors, and if possible, visit a nearby university offering degrees in food science or food technology, talk with faculty members and students about careers and programs. It’s never too early to explore a career in food science and food technology.

**Typical Coursework in College**
A Bachelor of Science degree in Food Science and Food Technology includes courses in inorganic and organic chemistry, math and calculus, statistics, food chemistry, quantitative analysis, microbiology, nutrition, biochemistry, physics, food law, food microbiology, food processing, sensory analysis, communication, and food engineering.

Find a list of universities worldwide with food science and food technology undergraduate degree programs recognized by the IFT (Institute of Food Technologists). The link is maintained at: www.4-H.org/curriculum/foodsci
FOOD SCIENCE AND NUTRITION—WHAT’S THE LINK?

Perhaps you like the idea of food science, and you also like the idea of eating healthy foods. These two “likes” can make a very interesting career. A nutritionist or registered dietitian may help guide food scientists to make foods lower in calories, fat, sugar or salt, or higher in beneficial nutrients such as phytonutrients, healthy fats, fiber, calcium, or iron.

Registered dietitians complete at least a Bachelor’s degree and an internship. The coursework includes nutrition, food science, math, chemistry, biology, microbiology, and biochemistry. This credential requires an unpaid internship that can range from six to 12 months. Registered dietitians then take a national exam.

VIRTUAL FUN

To see videos of interviews with food scientists, learn about degree programs, and additional resources on careers in food science and food technology, visit the 4-H Food Science curriculum web site at: www.4-H.org/curriculum/foodsci
ACTIVITY 4.2  
Make a New Beverage

For this activity, learners investigate product formulation from inception to evaluation. They learn about taste, apply principles of flavor, conduct sensory evaluation, and explore packaging, label design, and marketing while creating a new beverage. As a facilitator, you have an opportunity to encourage career opportunities in food science. This activity is a great way to highlight flavor chemists.

**MATERIALS LIST**

**Supplies:**
- 2-cup container to mix drinks (1 per every 2 or 3 learners)
- Liquid measuring cup
- Measuring spoons
- Blender
- Mixing spoons
- Small 3-ounce tasting cups (# of groups times # of learners)
- Colored pencils or fine-tipped colored markers
- Blank paper (8½ by 11) for each learner
- 3” X 5” cards
- Container for heating water in microwave or alternative heat source
- Sanitizing solution
- Hand soap
- Paper towels
- Paper plates
- Post-it notes
- Large paper for posting in room and tape
- Nutrition Facts label from a juice container
- Marking pens
- Pencils
- Laptop and Internet connection if showing Flavor Chemist video (optional)
- Contactor for heating water in microwave or alternative heat source
- Sanitizing solution
- Hand soap
- Paper towels
- Paper plates
- Post-it notes
- Large paper for posting in room and tape
- Nutrition Facts label from a juice container
- Marking pens
- Pencils
- Laptop and Internet connection if showing Flavor Chemist video (optional)

**Food:** Choose a variety of ingredients for drink design, as indicated below. You might have additional items on hand; feel free to use them too.
- **Choose 3 or 4**
  - 100% juice: Orange juice, Grape juice, Apple juice, Grapefruit juice, Apricot juice
- **Choose 2 or 3**
  - Tomato juice, Carrot juice, V-8 juice, Fresh herbs, washed, e.g., Parsley, Mint, Basil
- **Choose 4 or more**
  - Vanilla extract, Almond extract, Mint extract, Orange extract, Cinnamon, Ground cloves, Chili powder, Hot pepper sauce
- **Choose 5 or more**
  - Lemons, Limes, Salt, Sugar (limited amount per drink), Artificial sweetener, e.g. Stevia, Food coloring
- **Choose 2 or more**
  - Coconut water, Water, De-caffeinated tea bags of varying flavors, Plain sparkling water

**SKILL LEVEL:**
Intermediate

**LEARNER OUTCOMES**
- Knows how to observe, describe, and apply basic principles of product development.
- Knows how to use principles of flavor in beverage preparation.
- Knows how to use resources to create a simple front of package label.
- Understands the importance of making nutritious beverage choices.
- Understands and can identify sensory characteristics of food.
- Understands interactions of taste [flavor] and aroma.

**SUCCESS INDICATORS**
- Defines and describes ingredients in beverages.
- Able to follow written directions, measure and prepare solutions.
- Identifies steps in food product development.

**SUGGESTED GROUP SIZE**
8–16 youth

**TIME NEEDED:**
Minimum of 75 minutes.

**SPACE**
- Any setting in a kitchen.
- Microwave available for heating water.
DURING THE ACTIVITY, YOU WILL:

- Discuss taste and principles of flavor development focusing on beverages.
- Assist learners with the application of the steps necessary for creating a new beverage.
  » Using flavor principles, groups of learners make 2 cups of a new beverage.
  » Create marketing plan and label ideas for the beverage.
  » Present their beverage to the group for evaluation.
- Discuss and review questions and answers from the Youth Science Journal.
- Help learners explore a career as a Flavor Chemist.

KEEP LEARNERS SAFE

- FOOD SAFETY: Clean kitchen surfaces, cutting boards, etc. Facilitators and learners wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
- EXPERIMENTING: Use caution when working with hot beverages, especially in microwaves. Water can super-heat in microwaves and cause serious burns; an adult should be in charge. Have pot holders available.
- TASTING: When taste testing use the two-spoon method:
  » Sampling spoon: Use to remove small amount of liquid from beverage container. Place onto tasting spoon WITHOUT touching tasting spoon.
  » Tasting spoon: Use to place beverage into mouth. Never let the sampling spoon touch the tasting spoon. If it does, wash or replace sampling spoon.
  » When taste testing beverage formulations, use a clean cup for each sample so that residues from previous formulations do not contaminate the current sample.
- Tie back long hair.
- Roll up long sleeves.
GETTING READY

Organizing the Activity

Prior to the Activity

• View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
• Preview the content and questions in the Youth Science Journal. The What Do We Need to Know? and Be a Food Scientist sections explain the science behind the experiments.
• Gather all equipment, supplies, and materials.
• Write out Flavor Principles on large sheet of paper to post in meeting room.
• Set up beverage ingredients in a central location.
• Set up group beverage stations with other materials needed for the activity.

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What are some of your favorite beverages?
2. What beverage flavors do you like the best?
3. Have you seen any new beverages come on the market recently?
4. Have you tried them? Why or why not?
5. What kind of advertisements and/or marketing have you seen for them?
Open the Youth Science Journal
As learners look at the pictures and read the statement, “My favorite juices, teas and flavorings could become a beverage sold at the grocery store!” guide them to ask questions such as those listed in the answer key.

BEGIN THE PRODUCT DEVELOPMENT PROCESS
Using the information in the Youth Science Journal (What Do We Need to Know? and Be a Food Scientist sections), explain the five different tastes and how the sense of smell contributes to the “flavor experience.” Further explain that there are several different “Flavor Principles” that are useful to know to create desirable flavors. Share information about the beverage industry given in the sections mentioned above.

- Post the Flavor Principles in the meeting room; have learners read and discuss them. Ask learners if they can think of examples (of the principles) in foods they have eaten or when they have cooked something and adjusted the flavoring.
- Give instructions to learners. Have them follow the steps of developing a new beverage listed in the Youth Science Journal.
  » Form teams of 2 to 4 learners and assign each team a workspace.
  » Look at the ingredients available, consider the flavor and type of drink to create, then write out a formula for their beverage and make it.
  » Each team needs a 2-cup measure—this is the amount of drink to be developed during the activity.
  » Restrict sugar usage to two teaspoons per team.
- Learners continue the development process as described in the Science Youth Journal.
ACTIVITY 4.2: Make a New Beverage (cont.)

Below are answers (bolded in blue) you might expect from the learners. When possible, help them understand the concepts in their own words before you explain. Use this as a guide to ensure learners understand the science behind their observations. Become familiar with the background information provided before doing this discussion. Rating numbers and learners’ opinions will vary.

ACTIVITY 4.2
Make a New Beverage

STATEMENT: MY FAVORITE JUICES, TEAS, AND FLAVORINGS COULD BECOME A BEVERAGE SOLD AT THE GROCERY STORE!

Ask as many questions as you can about these pictures and this statement. Start your first question with, "I wonder...". Don't stop to discuss, answer, or judge any questions. Write them here then share with your group.

I wonder...
• What ingredients could I put together to make a good drink?
• Which juices and flavorings would taste good together?
• How do you go about making a new beverage?

With your group, brainstorm a few ways to figure out the answers to one or more of your questions. My experiment will be . . .

Describe what you think will happen when you do the experiment. I think . . .

WHAT’S ON YOUR PLATE? Exploring Food Science
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WHAT WILL WE DO?
You will experience how beverage formulations are made—you’ll create a brand new beverage! From beginning ideas to beverage evaluation, you’ll go through the process. You’ll learn about taste, apply principles of flavor, conduct sensory evaluations, and explore packaging, label design, and marketing while creating a new beverage.

WHAT DO WE NEED TO KNOW?
Detecting flavor is complex and involves the taste and smell of food. You have probably experienced being unable to taste foods when having a cold with a stuffy nose. With eyes closed and nose held, it is almost impossible to tell what one is eating. That’s because the sense of smell is vital to the sense of taste. In food science, the “flavor experience” is so complex that it isn’t well understood; food scientists continue to research this issue. Flavor is also influenced by the temperature of food (e.g. warm apple pie tastes sweeter than cold apple pie), texture or mouth-feel, and past experiences with food—either good or bad.

Flavor Principles
Knowledge of several basic flavor principles is necessary to food and beverage development. Use this information to help evaluate the ingredients of your drink.
- SALT can mask bitterness and in small amounts enhance sweetness.
- SUGAR increases sweetness, masks saltiness, and decreases sourness.
- SOUR ingredients, used in small amounts, can increase the tastes of sweetness and saltiness.
- Herbs, spices, and extracts change taste and flavor.

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize area where beverage will be prepared. Visit www.FightBac.org for tips and handouts regarding food safety.
FOOD SCIENTISTS—YOUR ASSIGNMENT TODAY . . .

...is to develop a new low-sugar beverage that includes juice and would be suitable for kids ages 8 to 18. Experts are concerned about the growing number of overweight children. A new, low-sugar beverage that has kid-appeal will sell well and may improve the health of the nation’s youth. Each team will present its beverage to the large group.

EXPERIMENT: BEVERAGE RESEARCH & DEVELOPMENT

A beverage company has hired your team of food scientists to develop several options for a new beverage. They will listen to your presentation about the beverage and taste it, then choose the beverage they will produce. Working in teams of 2 to 4 learners, you will play the roles of both food scientists and marketing consultants. Complete each of the following steps with your team members.

1. Marketplace Research
   What’s already on supermarket shelves? What is there plenty of? What is missing? What seems to be selling well? Selling poorly? In a real setting, a marketing consultant would look at sales figures and how much money is produced by each product.
   
   **Fruit juice-flavored tea, combinations of fruit and vegetable juices, fruit juice-flavored water or carbonated beverages, etc.**

WHAT’S ON YOUR PLATE? Exploring Food Science
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2. Consumer Research
Identify consumer needs and wants. What do you and your friends need and/or want to drink? What would taste good? What kind of beverage would other kids want to drink?

Something that tastes good, healthy, inexpensive, unusual—something different.

3. Determine Ingredients
From the ingredients available during this activity, discuss and list the possible ingredients your team will use. How will the Flavor Principles affect the combination of ingredients you are considering?

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4. Product Creation
Before making your new beverage, develop the formula for your drink. Discuss and select the type of beverage you want to develop (sweet, sour, etc.).

Select possible ingredients.
• You must use at least three ingredients.
• Limit sugar to 1 teaspoon per cup or less.
• Be sure to consider the Flavor Principles.

Your team should use a 2-cup measuring cup—this is the maximum amount of drink developed during the activity.

List ingredients and amounts you plan to use.

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ACTIVITY 4.2: Make a New Beverage (cont.)

Once your team agrees on the formula, make the beverage. Using tasting spoons (using the two-spoon method for tasting during beverage development), taste the beverage within your small team. What do you think about your new beverage?

_______________________________________________________________________________

_______________________________________________________________________________

Adjust flavorings if desired. If you adjust the flavorings, be sure to make a note of it in your list of ingredients. What changes, if any, did you make? Why?

_______________________________________________________________________________

_______________________________________________________________________________

5. Packaging
Working with your team, come up with a beverage name __________________________
As a team, develop a design for the front label using name of beverage, pictures, and/or graphics. Draw the final design on a separate piece of paper to show during presentation to the larger group. List your design ideas.

6. Marketing and Advertising Plan
With your team members, develop a brief but creative marketing and advertising plan for your new product.

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Ensure that learners use the two-spoon method for tasting during beverage development.
ACTIVITY 4.2: Make a New Beverage (cont.)

7. Presenting Your New Beverage Idea
List at least three points you will make in a presentation about your new beverage (each member of the team may present various aspects about the beverage). Write these points on 3x5 cards to use for your team’s presentation (2 minutes or less). Consider such things as what makes it different from other products already on the market, explain the health benefits of the beverage, talk about why you believe your target market (youth ages 8–18) will like it, and creative ideas you have for marketing and advertising the beverage.

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8. Consumer Testing, Ranking, and Sensory Evaluation
• Set up for Consumer Testing and Sensory Evaluation: On a tray, set out a cup for each learner and divide your beverage equally between the cups. Distribute to large group.
• Give a persuasive presentation (2 minutes or less) about your beverage to the large group.
• Make sure everyone gets to taste and rank your drink.

EVALUATION OF NEW BEVERAGE
Use a scale of 1 to 5, with 1 being least desirable and 5 being most desirable.

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Have learners fill out the chart for each beverage. Discuss and review results from groups.
ACTIVITY 4.2: Make a New Beverage (cont.)

Use these questions as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

ACTIVITY 4.2: Make a New Beverage (cont.)

Identify your favorite beverage from the beverage evaluation: ________________________________

What did you like most about your favorite beverage? ________________________________

Identify your least favorite beverage: ________________________________

Why was it your least favorite? ________________________________

What might you change to improve your beverage? ________________________________

Which beverage (besides your own) do you believe had the best marketing and advertising plan? ________________________________

If you were awarding a beverage contract to one of the teams, which one would you choose (besides your own) and why?

SHARE

Briefly describe how you determined which ingredients to use.

Learners share their team’s rationale for various ingredients.

WHAT’S ON YOUR PLATE? Exploring Food Science

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Full size page can be found in the Youth Science Journal on page 16.
ACTIVITY 4.2: Make a New Beverage (cont.)

REFLECT

How do sugar, salt, and sour ingredients change the flavor of beverages?

Learners will describe the Flavor Principles.

What kind of flavor did you want your beverage to have? Did your beverage turn out how you expected?

Learners will describe what they expected, e.g. fruity, slightly salty, tangy, spicy, etc., and whether their formula met their expectations.

How could you determine whether a beverage would be liked by most kids in the country?

Set up sensory panels with flavor chemists, food scientists, and food technologists and youth in the target age range.

GENERALIZE

What things besides taste need to be considered when making a new beverage?

Visual appeal, aroma, need for the product, similar products already on the market, cost of ingredients, how catchy the name is, what the label looks like, how it will be marketed and advertised.

Terms: beverage, taste, flavor, sweet, sour, bitter, salty, umami, product formulation, evaluation, marketing

At this point in the activity, ensure the following terms and concepts have either been discovered by the youth during their exploration, or introduced by you. The goal is to have the youth develop an understanding of the concepts through their own exploration and define the terms using their own words out of their experience.
APPLY

Your school is raising funds for a special field trip. Your group needs something to sell at the fundraiser. School wellness policies discourage selling less-than-healthy food such as soda. Your group decides to make a new low-sugar beverage, with all sales proceeds going to the special event. You speak with the principal, several teachers, and school food service staff—everyone is willing to help you. You go to the county health department and get a “Food Handler’s Permit” so you know how to prepare food safely to reduce the risk of foodborne illness. What steps will your group take to develop and sell a beverage for your school?

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Food and Beverage Preferences

BE A FOOD SCIENTIST

CREATE A BEVERAGE

Taste Starts with the Tongue

The surface of the tongue has thousands of taste buds. Messages are sent from the tongue to the brain then the brain interprets the taste. There are five taste sensations: Sweet, salty, sour, bitter, and umami (ü-'mä-me). You may not be familiar with umami taste sensation. It is the deep, mouth-filling flavor experienced when eating foods such as meat, mushrooms, aged cheese, or ripe tomatoes. Umami is sometimes described with the word “savory.”
There are many things at play that determine if you like certain foods and beverages. Sight, smell, taste, touch, and hearing influence our food and beverage choices. Examples include the crunch of a fresh carrot, the sight of juicy watermelon, the bittersweet taste of chocolate, the sound of popcorn popping in a movie theater, the mouthfeel (touch) of drinking a carbonated beverage, and the smell of a roasting turkey at Thanksgiving. Literally, all of our senses contribute to positive and negative perceptions of food and beverages.

**Developing a New Beverage**

This is a summary of the steps essential in developing a new product such as a beverage.

1. **Explore the existing market**
2. **Identify consumer needs and wants**
3. **Select possible ingredients**
4. Develop the beverage:
   - Determine a formula
   - Make the beverage
   - Taste-test and adjust flavorings
   - Decide on a name
   - Design a label
   - Develop a marketing plan
5. **Consumer testing and ranking**

**FOOD SCIENCE, NUTRITION, AND JUICE DRINKS—WHAT’S THE LINK?**

With today’s emphasis on maintaining a healthy weight, more people are looking to drink low-calorie beverages. Juice usually has a lot of calories, but juice drinks may have a lot or a little, depending on what food scientists created in the laboratory.

When is it good to choose 100% juice and when is it appropriate to choose a fruit drink? It depends on the purpose of the beverage you select. If you drink juice for the vitamins and minerals that juice has, you want to look for a beverage that states “100% Juice” on the label. Otherwise, you are paying for juice, water, and usually added sugar—and getting just a fraction of the nutrients you would otherwise get in juice.

**UMAMI**

Roughly translated from Japanese, umami (o’-mä-më) means delicious. Discovered in the early 1900s, it is a savory taste that blends and enhances other flavors. The location of specific taste buds on the tongue varies for sweet, salty, sour, and bitter. However, all of the tongue’s taste buds can identify the amino acids (molecules of protein) that make up the umami taste. Umami paste, a concentrated mixture of foods rich in the specific amino acid that triggers umami, is available at specialty markets.
Juice is a concentrated food, so experts recommend limiting it to 12 ounces per day. It’s concentrated because it takes a lot of fruit or vegetables to make a single glass of juice. That means you’re getting many vitamins and minerals, but also a lot of calories. For instance, a typical medium-sized orange has just 60 calories, whereas an 8-ounce glass of juice has twice that many—about 120 calories. Consider juice as a food, rather than a thirst-quencher.

If you’re looking for something to drink and quench your thirst rather than provide nutrients, then a juice drink might be a good choice as long as it has little or no added sugar. For instance, water with 5% juice would be refreshing with the juice providing a bit of flavor. However, many times sugar or high fructose corn syrup is added to juice drinks, in which case the drink provides lots of calories and few nutrients. The nutrient content of juice drinks varies greatly depending on how much juice is in the product and whether any extra nutrients were added. Check the label—avoid added sugar and make a smart choice when reaching for a drink.

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FLAVOR CHEMISTRY

Flavor chemists develop ingredients, often derived from natural substances, which are added to food products.

For instance, the Senomyx Company has a library of more than 800,000 flavor ingredients! Working with food processors, their specialized flavor ingredients may block the bitterness of food products or reduce the use of sugar and salt, often improving the nutritional profile of the food.
MATERIALS LIST

Supplies:
- Candy thermometer made especially for this use
- Medium saucepan
- Heavy skillet
- 2 heat-safe liquid 1-cup measuring cups
- 2 kitchen teaspoons
- Heat resistant scraper
- Wooden spoon
- Dry measuring cups
- Measuring spoons
- 3 small paper plates
- Heat-resistant pastry brush
- Large baking sheet (11” X 14” with short edges) or large, heat resistant plate
- Wire cooling rack
- Kitchen knife
- Sanitizing solution
- Hand soap
- Paper towels
- Paper plates
- Spoons or forks for sampling
- Large poster paper and tape
- Marking pens
- Pencils

Food:
- 5 cups granulated sugar
- 2 tablespoons light corn syrup
- Baking soda
- Ice cubes
- Cooking spray

Printed Materials:
- Order Youth Science Journal for each learner

Have you ever wondered about the difference between soft candies and hard candies such as peanut brittle? Some creamy candies are made with fondant. Fondant is a crystalline candy formed by super-saturating a sugar solution with heat, then cooling so crystals are formed. In contrast, peanut brittle is a non-crystalline candy made by caramelization of dry sugar. Caramelization prevents crystallization. This activity focuses on the crystallization of sugar and includes a demonstration of caramelization.

Crystallization is an exciting process to witness! Experimentation, observation, and skill play a part in becoming proficient in crystallizing. Since this is a fundamental concept and skill for food scientists, learners are introduced to it via crystallization of sugar to make candy.

SKILL LEVEL:
Advanced

LEARNER OUTCOMES
- Knows how to observe, describe, and apply principles of caramelization and crystallization.
- Knows how temperature affects the solubility of sugar.
- Identifies, understands, and applies temperature control procedures in sugar crystallization.
- Understands what happens when dry sugar is heated past its melting point.

SUCCESS INDICATORS
- Defines and describes the science behind two major classifications of candy: crystalline and non-crystalline candies.
- Able to follow written directions, measure and prepare solution recipes for crystalline candies.
- Describes basic steps in crystallization via making a crystalline candy.

SUGGESTED GROUP SIZE
8 - 12 youth

TIME NEEDED:
60-75 minutes

SPACE
Kitchen with stove is mandatory.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

DURING THIS ACTIVITY, YOU WILL:
- Demonstrate how sugar dissolves in cold and hot water.
- Participate with learners making fondant, a crystalline candy.
- Demonstrate caramelization by heating dry sugar.
- Support and encourage learners as they understand and apply the “Science of Sugar.”

KEEP LEARNERS SAFE
- Special SAFETY Note: These activities use a stove and boiling sugar-water solutions. Facilitator should heat and handle all sugar-water solutions. The solutions are very hot and sticky so they can cause serious burns.
- FOOD SAFETY: Clean kitchen surfaces, cutting boards, etc. Facilitators and learners wash their hands with soap and warm water for 20 seconds; dry with paper towel. Visit www.FightBac.org for tips and handouts regarding food safety.
- EXPERIMENTING: Use caution when working with hot foods and equipment; an adult should be in charge and directing the group activity. Keep sauce pan handle turned in, away from the edge of the stove or hotplate. Have pot holders available. Follow recipe and directions carefully.
- TASTING: Samples are cut with a plastic knife and placed on paper plate for individual sampling.
- Tie back long hair.
- Roll up long sleeves.
GETTING READY

Organizing the Activity

Prior to the Activity

- View the tutorial video, other videos, glossary, and print resources for this activity. Available at www.4-H.org/curriculum/foodsci.
- Preview the content and questions in the Youth Science Journal. The What Do We Need to Know? and Be a Food Scientist sections explain the science behind the experiments.
- Gather all equipment, supplies, and materials.
- Calibrate candy thermometer. Using boiling water in a saucepan, insert bulb of candy thermometer in water. At eye level, check the boiling temperature of water. The thermometer should read 100º C and 212º F. If it reads above the boiling point, adjust the cooking temperature upward by this amount. If it reads below the boiling point, adjust cooking temperature down by this amount.
- Write out the following on large poster paper and have ready to post in meeting room. This information is located in the Youth Science Journal Be a Food Scientist section.
  » The physical and chemical reactions
  » The three basic steps of making crystalline candy

BEGINNING the ACTIVITY

Ask Lead-In Questions

Before learners open their Youth Science Journal, ask a few questions to get the group thinking about the activity. You do not need to read these questions verbatim, but work the concepts into a discussion.

1. What is table sugar and where does it come from?
2. What are some of the candies you eat, or see others eat?
3. Thinking about ________ candies (from above responses) compare and contrast the physical differences between the candies.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

Open the Youth Science Journal
As learners look at the pictures and read the statement, “Sugar is the main ingredient in soft and hard candies,” guide them to ask questions such as those listed in the answer key.

Explain that to begin to understand how sugar becomes candy, one needs to understand basic principles about the solubility of sugar. Be sure to review the What Do We Need to Know? and Be a Food Scientist sections of the Youth Science Journal for explanations of the science you need to share with learners.

FACILITATOR DEMONSTRATION: CARAMELIZATION OF DRY SUGAR

Ingredients:
2 cups sugar
½ teaspoon baking soda
Cooking spray

Directions:
1. Prepare three small pieces of wax paper by lightly spraying them with cooking spray.
2. Slowly heat 2 cups of sugar in a heavy skillet over low or medium-low heat, constantly stirring with a wooden spoon. Do not rush the process. It may take 10 minutes or longer.
3. After the mixture liquefies (becomes clear), take it off the heat and spoon about ⅓ onto one small paper plate. Set aside.
4. Continue to slowly heat the rest of the mixture until it turns light brown. Immediately remove mixture from heat. Spoon ⅓ onto another small paper plate. Set aside.
5. Immediately add ½ teaspoon of baking soda to the mixture. Stir thoroughly. Spoon remaining mixture onto another small paper plate. Set aside.

Explain that when dry sugar liquefies and turns light to medium brown, the process is called caramelization. Caramelization changes the structure of sucrose creating a characteristic color and taste and changing the structure of sugar molecules so it cannot form crystals. During caramelization, an acid is produced. When baking soda (alkaline) is added to the acid, carbon dioxide is produced, creating small bubbles in the caramelized sugar, making it more porous or brittle. Examples of candy that use caramelization are nut brittles (porous with addition of baking soda), or caramels (non-porous). Note: Learners might remember that baking soda (alkaline) and an acid such as baking powder were combined to produce CO₂ for leavening in baked goods. Clear, liquid sugar is often colored and flavored and used to make lollipops.
STATEMENT: SUGAR IS THE MAIN INGREDIENT IN SOFT AND HARD CANDIES.

Pause for a moment and think about this statement and the pictures. Ask as many questions as you can about these. Start your first question with, “I wonder…” Don’t stop to discuss, answer or judge any questions. Write them here then share with your group.

I wonder…

- How sugar is used to make candy?
- What makes sugar harden?

Because of the high cooking temperatures of candy, your facilitator is in charge of heating and handing the hot sugar solutions. Take precautions. Have pot holders and hot pads available. Avoid serious burns!

BE SAFE! Follow safe food handling practices: Wash hands with soap and warm water, scrubbing for at least 20 seconds. Wash and sanitize cooking area. Visit www.FightBac.org for tips and handouts regarding food safety.
WHAT WILL WE DO?
This activity introduces you to crystallization. Crystallization is an important, basic concept and skill for food scientists. Crystallization is an exciting process to watch! You get to apply the science of crystallization by making fondant, a crystalline candy, and caramelizing sugar to see how non-crystalline candies are made. Crystallization is a combination of science and art—knowledge of the process alone won’t make you an expert at crystallization. In addition, experimentation, observation, and skill are also important to successfully make candy.

WHAT DO WE NEED TO KNOW?
Have you ever wondered about the difference between soft candies, like those pictured above, and hard candies such as lollipops? Some of the creamy candies are made with fondant. Fondant is a crystalline candy formed by supersaturating a sugar solution with heat, then cooling so crystals are formed. In contrast, lollipops are a non-crystalline candy. Non-crystalline candies are cooked to very high temperatures and/or have ingredients that interfere with crystal formation.

Before you start making a crystalline candy, you need to understand sugar solutions and learn more about the solubility of sugar.

DEMONSTRATION: SOLUBILITY OF SUGAR
This demonstration shows two solutions for observation. Here are some terms to know:

<table>
<thead>
<tr>
<th>Common terms</th>
<th>Solute + Solvent = Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Science terms</td>
<td>Solute + Solvent = Solution</td>
</tr>
</tbody>
</table>

**VARIABLE 1**

**Ingredients**
- ½ cup water
- ¼ cup sugar

**Directions**
1. Place two ice cubes into a glass 1-cup measuring cup. Fill with cool water to the ½ cup measuring line, allow time for ice to melt a little.
2. Add ¼ cup sugar (solute) to the water (solvent) and stir to make a solution.
3. Observe and make notations in Sugar Solubility Observation Log.
VARIABLE 2
Ingredients
½ cup water
¼ cup sugar

SAFETY NOTE: Facilitator is in charge of boiling water. If water is heated in a microwave, be cautious of super heating—remove immediately upon boiling, then wait 1 minute before adding sugar. (Immediately adding sugar may cause the mixture to bubble violently.) Facilitator adds sugar. Learners stir after addition of sugar.

Directions
1. Place ½ cup boiling water into a glass 1-cup measuring cup.
2. Add ¼ cup sugar (solute) to the water (solvent) and stir to make a solution.
3. Observe and make notations in Sugar Solubility Observation Log.

SUGAR SOLUBILITY OBSERVATION LOG

<table>
<thead>
<tr>
<th>Variable 1</th>
<th>Cold water sugar solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not all the sugar dissolves. The solution is saturated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable 2</th>
<th>Hot water sugar solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All the sugar dissolves.</td>
</tr>
</tbody>
</table>

In the cold water, some of the sugar does not dissolve. In the hot water, all of the sugar dissolves, showing that the higher the water temperature, the more sugar is dissolved.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

What is a solution? Use the scientific terms to describe a solution.

Solute (sugar) + Solvent (water) = Solution

What did you observe when comparing the solubility of sugar in cold and hot water?

The sugar in the cold water is not completely dissolved. Sugar in boiling water is ________________;
completely dissolved and dissolved more quickly than the sugar in cold water.

What do you think would happen if you continued to heat the sugar and water solution?

The mixture would continue to hold more sugar in solution, become more concentrated
as the temperature increases. We could add more sugar and it would still dissolve.

EXPERIMENT—SUGAR CRYSTALLIZATION

Make fondant to observe crystallization.

Ingredients
2 cups granulated sugar
¾ cup water
2 tablespoons light corn syrup

Directions for Learners
1. Set a large baking sheet or thick, heat-resistant plate on wire rack. Set aside.
2. Combine sugar, water, and light corn syrup in a medium saucepan. Stir until dissolved.
3. Place candy thermometer on side of saucepan. Make sure the bulb is covered by the solution and not touching the bottom or side of the pan.

Proper position of candy thermometer.

Post the Physical Reaction and Chemical Reaction of crystallization and discuss with learners.

Carefully follow recipe and instructions in Youth Science Journal. Endpoint temperature and following instructions exactly are very important when making fondant. Be sure to calibrate the candy thermometer.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

Facilitator or Adult Takes Over

4. Using medium-high heat, stir constantly to boiling point.
5. WITHOUT stirring, heat to end-point cooking temperature of 237ºF/114ºC. This is called the soft ball stage. Carefully read thermometer at eye level for accuracy.
6. While heating, if crystals form on the side of pan, use a heat-resistant, damp pastry brush to dissolve the crystals. If these crystals are not removed, they might act as seed crystals and start the crystallization process too soon. Be sure not to let the brush touch the boiling sugar solution; doing so may also start the crystallization process too soon.
7. Carefully pour the mixture onto a baking sheet/large heat-resistant plate to cool. Use a heat-resistant rubber spatula to quickly scrape out saucepan. Do not stir or disturb.
8. Let cool until mixture is warm, but not hot. After 2–3 minutes, test carefully with finger.

Learners Take Over

9. Dampen a heat resistant rubber spatula or wooden spoon. Push the mixture into the middle of the baking sheet/plate. “Cream” or work the fondant in a figure-8 pattern. Continually scrape the fondant into the center, draw a figure-8, then scrape it together again. Mix for 5–10 minutes. The mixture changes from clear to opaque and creamy, then very stiff, crumbly, and difficult to stir.
10. Moisten clean hands and knead the fondant until the mixture is soft and smooth with no lumps. (Kneading technique is described in Activity 1.1 if a reminder is needed.)
11. Place on plate for tasting. Cut a small piece for each learner to sample. Pay attention to the “mouth-feel” of the crystalized sugar.
12. Record observations.

Post the three basic steps of making crystalline candy; discuss with learners. The end-point cooking temperature is critical in crystallization. Pass around the candy thermometer to let learners practice reading the temperature of 237º F.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

FONDANT OBSERVATION LOG

<table>
<thead>
<tr>
<th>APPEARANCE</th>
<th>TEXTURE WHEN TOUCHING</th>
<th>TEXTURE IN MOUTH (MOUTH-FEEL)</th>
<th>TASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooled Fondant</td>
<td>White color</td>
<td>Smooth</td>
<td>Smooth</td>
</tr>
</tbody>
</table>

DEMONSTRATION: CARAMELIZATION OF DRY SUGAR

Facilitator will do this demonstration. Learners will observe and record in the Observation Log below.

Some non-crystalline candies begin with caramelization. When sugar is heated dry, without water, it caramelizes rather than crystalizes. Nut brittles and caramels are examples of candy formulations using caramelization.

Nut brittle recipes include the addition of baking soda. Baking soda (alkaline) reacts with the acid from caramelization, producing carbon dioxide (CO₂). The reactions produce acid, caramel color and flavor, and the characteristic “brittleness” of nut brittles. The carbon dioxide bubbles are trapped in the molten sugar, producing a porous end product. Without the carbon dioxide bubbles, the end product would be very dense and hard.

Toffee, nut brittles, lollipops, and caramels are examples of non-crystalline candies; these types of candies are also called “amorphous.” Amorphous means the candies lack a crystalline structure. Most amorphous candies are poured to cool and are considered to have no definite shape or form until they are cooled. Recipes for non-crystalline candies contain ingredients and cooking techniques that prevent sugar crystallization. Exposure to high temperatures prevents the sugar from crystallizing during the cooling process; it hardens before crystals have time to form.

Heat slowly. Color change can occur rapidly—check out the tutorial video. When the color is light brown, take the mixture off the heat and continue demonstration. Use the photo of the peanut brittle as a visual guide.

Clean up: allow pan to cool. After group time is over, add water, heat slowly and non-crystalline candy will gradually dissolve.
Below are answers (bolded in blue) you might expect from the learners. Do not give learners these answers, but rather use this as a guide to make sure learners understand the science behind their observations. Be sure that you are thoroughly familiar with the background information provided before doing this discussion.

**DRY SUGAR CARAMELIZATION OBSERVATION LOG**

<table>
<thead>
<tr>
<th>COLOR</th>
<th>APPEARANCE</th>
<th>TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry sugar cooked to clear</td>
<td>Clear</td>
<td>Non-porous, solid</td>
</tr>
<tr>
<td>Dry sugar cooked to light brown</td>
<td>Light Brown</td>
<td>Non-porous, solid</td>
</tr>
<tr>
<td>Dry sugar cooked to light brown with addition of baking soda</td>
<td>Light Brown</td>
<td>Porous, solid</td>
</tr>
</tbody>
</table>

Why does baking soda produce CO2 in caramelized sugar?

Because caramelization produces an acid. Acid + baking soda = CO2.

(Remember the Activity 1.2 about leavening agents.)
ACTIVITY 4.3: Chemistry is Sweet (cont.)

SHARE
1. How is solution made for fondant?
   Sugar and corn syrup are dissolved in water.

2. How do you increase the saturation of the solutes (sugar, corn syrup) while making fondant?
   The amount of sugar soluble in water depends on the temperature of the solution.
   Increasing the temperature allows more sugar to be held in solution before reaching the saturation point.

REFLECT
1. Based on your observation from sugar solutions and temperatures, what do you think happened from a food scientist’s point of view?
   The increased temperature allowed more sugar to dissolve, before saturating the solution.

2. Why is end-point cooking temperature of fondant important?
   End-point temperature determines the concentration/saturation of the solution.

3. What do you think happens as the thick sugar solution for fondant cools on the baking sheet/plate?
   A super-saturated solution has more sugar than it can hold. As the mixture cools, it becomes super-saturated. Therefore the sugar begins to recrystallize, to fall out of solution. As it cools, the super-saturated solution goes from a thick liquid to a soft, creamy solid.

4. What is the major difference between crystalline and non-crystallize candy?
   The presence or absence of sugar crystal formation. Ingredients and cooking temperatures control or prevent crystallization.
5. Give an example of crystalline and non-crystalline candies?

Crystalline: Fudge, fondant
Non-crystalline: Nut brittles, caramels, hard candies such as lollipops and marshmallows.

Terms: Crystallization, caramelization, sucrose, solution, solvent, solute, saturated, supersaturated, corn syrup, glucose, fructose, crystalline candy, non-crystalline candy, amorphous

GENERALIZE

1. List the basic steps of crystallization.
   - Start by making a solution: Dissolve sugar and corn syrup in water.
   - Heat the mixture: Solution becomes saturated.
   - Cool so that mixture become super-saturated, then stir as sugar crystals re-form.

APPLY

1. Thinking of the texture of fondant, how do you think it might be used in manufacturing other types of confections?
   - Fondant can be colored, flavored and used as the soft, creamy filling inside of chocolate candy.
   - It can be used to coat nuts or fruit.
   - It can be rolled out and used to cover wedding cakes, thus giving the smooth, seamless frosting seen on these types of cakes.

Full size page can be found in the Youth Science Journal on page 12.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

THE SCIENCE OF SWEET IS COMPLEX

To understand sugar crystallization, one must understand the science of sugar and solutions.

1. Make a solution: Dissolve sugar and corn syrup in water.

Common terms

Sugar + Water = Solution

Food Science terms

Solute + Solvent = Solution

Sugar dissolves in water. How much sugar is soluble (dissolves) depends on the temperature of the solution—the higher the temperature, the more sugar can dissolve. Once the saturation point is reached, the sugar will no longer dissolve. Increasing the temperature allows more sugar to be held in solution before reaching the saturation point. Later, in a demonstration, you will compare the amount of sugar at the saturation point using cold water to the amount of sugar held in solution in boiling water. Boiling water holds more sugar in solution.

CRYSTALLIZATION AND CARAMELIZATION

Crystalline Candy Starts with a Sugar Solution

The most basic recipe for crystalline candies includes sugar, water, and corn syrup. This combination of ingredients makes fondant, a creamy off-white candy. The corn syrup (which is primarily glucose) controls crystallization of sucrose and keeps the crystal size small rather than large. Small crystal size feels good on the tongue. Besides fondant, fudge is another example of crystalline candy. You may have tasted properly made fudge that is smooth on the tongue due to small crystal size—but when made improperly, it feels grainy because of large sugar crystals.

The basic steps to make all crystalline candy are similar:

1. Start by making a solution.
2. Heat the mixture.
3. Cool and stir.

The procedures look deceptively simple. However, the detailed science of sugar, solutions, and supersaturation behind crystalline candy is complex.

BE A FOOD SCIENTIST

Full size page can be found in the Youth Science Journal on page 30.
2. Heat the mixture: Solution is saturated.
As the solution continues to heat, the boiling point increases. The temperature continues to rise as the solution becomes even more concentrated or saturated. Once the end-point temperature is reached, the mixture is cooled. For fondant, the end-point cooking temperature is 237º F (114º C). The appropriate end-point temperature is critical to the quality of crystalline candy. End-point temperature determines the concentration/saturation of the solution.

When the endpoint temperature is reached, the mixture is poured onto a baking sheet or plate and allowed to cool. A saturated sugar and water solution contains all the sugar it can hold. A super-saturated solution has more sugar than it can hold. As the mixture cools, the sugar begins to re-crystallize, to fall out of solution. As it cools, the super-saturated solution changes from a thick liquid to a soft, creamy solid called fondant.

This is where some of the “art” of crystallization comes into play. Small crystals are desirable and sometimes it takes practice to keep crystals from getting large. The size of crystals that form depends on:

- The amount of small crystals (seed crystals) that start initially and collect other crystals.
- The rate at which crystals form (determined by temperature and stirring).

In crystalline candy, formation of small, numerous crystals after super-saturation is desirable. Other ingredients such as corn syrup, cream of tartar (acid), creams, and chocolate are included to delay and interfere with crystallization to prevent the formation of large crystals. It’s a balancing act to produce a high quality product!

HOW IS FONDANT USED?
Fondant can be colored, flavored, and used as the soft, creamy filling inside of chocolate candy. Or it can be used to coat nuts or fruit. It can even be rolled out and used to cover wedding cakes, thus giving the smooth, seamless frosting seen on these types of cakes.

Full size page can be found in the Youth Science Journal on page 31.
Sugar and Dry Heat Make Non-Crystalline Candy

Some non-crystalline candies are made with caramelization. When dry sugar is heated, it forms a clear liquid at 320°F (160°C). With continued heating, the molten sugar begins to turn brown at 338°F (170°C). This reaction is called caramelization. It is a complex reaction in which the structure of sucrose is changed by the heat. The reaction produces acid and the characteristic caramel color and flavor. Exposure to high temperatures prevents the sugar from crystallizing during the cooling process; it hardens before crystals have time to form.

Nut brittles and caramels are examples of candy formulations using caramelization. Nut brittle recipes include the addition of baking soda. Baking soda (alkaline) reacts with the acid from caramelization, producing carbon dioxide (CO₂). The carbon dioxide bubbles are trapped in the molten sugar, producing a porous end product. Without the carbon dioxide bubbles, the end product would be very dense and hard. Toffee, nut brittles, lollipops, and caramels are examples of non-crystalline candies; these types of candies are also called "amorphous." The word "amorphous" refers to the fact that the sugar has no shape since it has not crystallized.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

Recipes for non-crystalline candies contain ingredients and cooking techniques that prevent sugar crystallization. Additionally, there are many “interfering ingredients” added to amorphous candy recipes that help prevent crystallization. These include cream, evaporated milk, and butter. Marshmallows are an interesting non-crystalline candy using softened, plain gelatin to inhibit crystal formation.

WHAT IS SUGAR?
The green leaves of sugar beets and sugar cane absorb energy from the sun. With the addition of carbon dioxide and water, the plants produce sugars, starch, and fiber. Sugar beets are 16–18% sucrose. Sugar cane is 14% sucrose. Sucrose is usually referred to as table sugar or white sugar. Sucrose is a disaccharide (“di” means two). Sucrose is a combination of two monosaccharaides (“mono” means one). The monosaccharaides fructose and glucose come together to form sucrose. Sucrose is composed of carbon, hydrogen and oxygen.

Sugar goes by many names—sucrose, demara, muscovado, turbinado, brown, and powdered. Sugar is made from sugar beets and sugar cane. After harvesting, these plants are processed in refineries into many types of sugar. To learn more about extracting sugar from sugar beets and sugar cane go to www.4-H.org/curriculum/foodsci.

FOOD SCIENCE AND CRYSTALLIZATION IN FOODS—WHAT’S THE LINK?
There are different types of crystallization in food science. Ice cream is an example of ice crystallization. While ice crystallization occurs as a result of freezing rather than hot, supersaturated sugar solutions, crystalline candies and ice cream share similar quality concerns. In both, having small crystal size ensures a quality product that feels good on your tongue and tastes good. Ingredients such as fat—as often in the form of cream (milk fat)—help keep crystal size small in ice cream as well as in candies by interfering with crystal development.
ACTIVITY 4.3: Chemistry is Sweet (cont.)

IN FOOD SCIENCE AND FOOD TECHNOLOGY—FOOD PACKAGING
A food packaging engineer develops packaging to control air and water transfer and prevent chemical reactions between package and food using glass, metal, and plastic laminate. They also work on packages with sealability. A packaging specialist works with food production teams, sales, and marketing. Not only do they want the package to appeal to consumers, like you, but the packaging must meet food safety standards as well. Today, many consumers want packaging that is eco-friendly. The next time you visit a supermarket, look at the wide array of food packaging on the shelves.

VIRTUAL FUN
Take virtual factory tours to see how jelly beans, candy canes, fudge, and other candies are manufactured. Find recipes for making peanut or almond brittle, and discover the story of chocolate with videos and links maintained at: www.4-H.org/curriculum/foodsci

LEARN MORE!

WHAT’S ON YOUR PLATE? Exploring Food Science
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UNIT 4 REFERENCES

Discovery Education: www.discoveryeducation.com


Institute of Food Technologists: www.ift.org


Washington State University Food Science: http://sfs.wsu.edu/
“I Pledge my Head to clearer thinking,
my Heart to greater loyalty,
my Hands to larger service,
and my Health to better living,
for my club, my community, my country,
and my world.”