

Teacher Version: Trouble with Fresh Food

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Background

Many plant foods, fruits, roots (tubers), and leaves contain a wide variety of compounds related to flavonoids called phenols. Enzymes that are also present in the fruits, roots, and leaves cause browning of these phenol compounds in the presence of oxygen. Understanding how the three pieces of the reaction system—the *phenol* substrates in the food, the *enzymes* that act on the substrate, and *oxygen* in the air around the food—make for a challenging chemical reaction system for students of many different levels to investigate. After a discussion that engages students in the problem, students can discuss and explore the browning of different sizes of cut foods, where changes in the surface area will allow changes in the amount of *both* substrate and enzyme in the presence of a constant amount of oxygen. If the size of cut food is controlled, students can also explore reducing oxygen by placing the food in water or an antioxidant (Vitamin C) solution. Other food preparation techniques also explore changing the pH of the solution to denature or decrease the activity of the enzyme. Natural extensions of these experiments might include other antioxidant solutions or different varieties of apples or potatoes or other foods. Students may notice differences in browning due to temperature but control of temperature may be difficult in the classroom.

Concept checklist

To help you plan for using this lesson in your classroom and potentially modify it to meet your needs, consider the following list of targeted concepts and note whether your students will be introduced to them for the first time or will be revisiting concepts they have been exposed to previously.

Targeted concept	Introducing	Revisiting
experimental design		
chemical change or reaction		
oxidation		
enzyme reactions		
substrates as the reactant in an enzyme reaction		

Materials:

- unflavored, uncolored Vitamin C tablets (500 milligrams)
- water
- Red Delicious apples
- Russet potatoes
- lemon juice and/or vinegar and/or Fruit Fresh
- knife to cut the apple or potato (strong plastic is OK.)
- graters to grate the apple or potato (a grater with two different sizes is most useful.)
- cutting boards or paper towel or waxed paper
- small cups
- paper towels

Getting ready:

Prepare a Vitamin C solution by dissolving a crushed Vitamin C tablet (500 milligrams) in 500 mL water. Colorless Vitamin C tablets are preferred. Additional concentrations of Vitamin C could also be tested. Other solutions such as salt water or antioxidant solutions could be prepared by students, according to their proposed experiments.

Pre-Activity Discussion and Demonstration

The pre-activity brainstorming discussion outlined below is designed for instructors to engage students in understanding the goals of the investigation and possible approaches to doing the investigation. In cases where teachers use inquiry and facilitate student proposed and designed investigations, this discussion provides a starting point for that process. In cases where teachers supply students with a procedure for the investigation, this discussion incorporates some elements of student inquiry into the activity.

Generate student interest by asking or demonstrating what they think would happen if they cut an apple the night before school and brought it to school to eat with their lunch or for an after school snack. Students will probably volunteer that the apple will turn brown. Allow them to continue the discussion as to why they think the apple will turn brown. They can also discuss any food preparation techniques that they may know to try to prevent extensive browning of the apple. Tell students that they will work in teams or together to design experiments to find out what factors cause the browning of an apple. You may suggest to students that the tools they might find useful would be a knife, grater, and ingredients related to food preparation such as lemon juice, vinegar, or Fruit Fresh. Encourage students to consider what variable will be changed as they either cut or grate the food samples. They may recognize that the surface area increases as the food pieces get smaller. (They are not likely to recognize that cutting or grating the food into smaller pieces also releases more enzyme, and that idea can be left for the discussion after the activity.) As needed, review basic experimental design. Depending on the students' experience, you may want them to propose a procedure to you for approval before

they begin. You also may want to assign apples as a test food to some groups and potatoes to others.

Possible Procedure

The procedure outlined below is written to the teacher. In cases where teachers have students propose and design their own investigations, this procedure serves as an example for the teacher of a tested procedure that produces observable outcomes. While finding no observable outcome is a viable result in itself, and certainly may happen in student-directed investigations, having a tested procedure as a reference point can help teachers facilitate discussions with students as they propose their own procedures. In cases where teachers supply students with a procedure for the investigation, the written procedure can be quickly adapted for students to read directly.

Depending upon student input they may choose to each begin with a standard size sample, such as 2 cm X 2 cm X 2 cm (about 1 cubic inch of food), and cut or grate the standard size sample into various sizes pieces. Students could also consider sharp cut surfaces and rough-cut surfaces. Students can also compare the browning of the food in water or an antioxidant solution of Vitamin C. Although the extent of browning is qualitative, students should record their results in a table, possibly similar to one below.

Sample data from browning of Red Delicious Apples

Food type	Initial size	Treatment	Extent of Browning	Comments
Delicious Apple, peeled	2X2X2 cm	Whole cube in air	Some browning on the surface after 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Whole cube covered with water	Very little browning after 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Whole cube covered with Vitamin C solution	Very little browning After 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Match stick pieces (16) 0.5 cm wide in air	Some browning on the surface of each piece after 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Match stick pieces (16) 0.5 cm wide covered with water	Very little browning After 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Match stick pieces (16) 0.5 cm wide in air covered with vitamin C solution	Very little browning After 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Large grate in air	Medium amount of browning on the surface of the grated shreds after 5-10 minutes	The thin edges of the grated pieces of apple are the most brown
Delicious Apple, peeled	2X2X2 cm	Large grate covered with water	Very little browning After 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Large grate covered with vitamin C solution	Very little browning After 5-10 minutes	

Delicious Apple, peeled	2X2X2 cm	Small grate in air	Red-brown coloration on all the surfaces after 5-10 minutes	These small grated pieces are the most brown and the shred stand in a brown solution
Delicious Apple, peeled	2X2X2 cm	Small grate covered with water	Very little browning After 5-10 minutes	
Delicious Apple, peeled	2X2X2 cm	Small grate covered with Vitamin C solution	Very little browning After 5-10 minutes	

Post-Activity Discussion

The post-activity discussion is designed to help the teacher facilitate student learning as students summarize their observations and make claims about the outcome of the investigation using their data as evidence. Whether students use a provided procedure or have designed one of their own, this discussion incorporates key components of inquiry-based learning into the lesson.

Observations/Data

- The smallest pieces of apple or potato browned most quickly and developed the darkest color.
- Covering the food sample with either water or vitamin C solution reduced browning.

Claims/Evidence

- What claim can you make about any reaction occurring when either delicious apples or russet potatoes are cut? *Answers will vary but students should claim that reducing oxygen exposure or denaturing the enzyme responsible for browning may reduce browning of apples and/or potatoes.*
- What is the evidence for your claim? *Answers will vary, especially depending upon individual student experiments.*
- What further experiments would you like to conduct to further test your claim?

Points for Discussion or Reflection

- The extent of browning varies with the surface area of the food sample. As the surface area increases, there is greater exposure to oxygen, which will increase browning. Additionally, as the surface area increases, there is more enzyme and more substrate on the increased surface area of the food. In light of this fact, students can discuss how they attempted to control some variables by beginning with a the same size samples and changing only surface area, but in fact also changed the concentration of the substrate and enzyme on the cut surfaces.

Writing Prompt

- Fellow students in a life-skills course are assigned to write both the directions for and benefits of freshly made applesauce, and to prepare the recipe. However, they were dismayed to find their cut apples turning brown prior to cooking. What advice can you provide them to reduce the browning of their apple pieces and applesauce?