Enzymatic Browning

Unit: Culinary Science

Problem Area: Food Science

Lesson: Enzymatic Browning

Student Learning Objectives.

Instruction in this lesson should result in students achieving the following objectives:

1. **Define enzymatic browning and susceptible foods.**
2. **Explain how enzymatic browning is controlled.**

Resources.

The following resources may be useful in teaching this lesson:

Barham, Peter. *The Science of Cooking*. Springer, 2001.

Culinary Institute of America. *The Professional Chef*, 9th ed. Wiley, 2011.

Duncan, A.W. *The Chemistry of Food and Nutrition*. Benediction Classics, 2011.

"Enzymatic Browning," *Food-info.* Accessed Aug. 15, 2011. <http://www.food-info.net/uk/colour/enzymaticbrowning.htm>.

McGreal, Michael J. *Culinary Arts Principles and Applications*, 2nd ed. American Technical Publishers, 2011.

"What Causes Browning of Foods," *Science of Cooking*. Accessed Aug. 15, 2011. <http://www.edinformatics.com/math_science/science_of_cooking/browning_of_foods.htm>.

Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

Key Terms.

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

- anthocyans (anthocyanins)
- blanching
- dehydration
- enzymatic browning
- enzymes
- high-pressure processing (HPP)
- irradiation
- melanin
- oxidation
- pH
- phenolase
- pigment
- polyphenol oxidase
- polyphenols
- sulfur dioxide
- ultrafiltration
- vacuum-packing

Interest Approach.

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

You will need:

- *2 apples (Red or Golden Delicious, Jonathan, or Macintosh)*
- *a vegetable peeler and paring knife*
- *a sauté pan*
- *1 to 2 tablespoons butter*
- *1 to 2 tablespoons granulated sugar*
- *2 plates and forks*
- *a stove or burner*
- *a cutting board*

There are two primary ways foods brown: heat-based and enzyme-based methods. To illustrate the difference, peel, core, and slice an apple. Leave it uncovered and untreated at room temperature. Keep it hidden.

Then peel, core, and slice another apple in front of the students. In a sauté pan, melt a tablespoon of butter, and place the apple you just sliced into the butter. To the apple and butter, add a tablespoon or two of sugar, and cook the apple over a medium-high heat. Sauté the apple in the sugar and butter mixture until the apple slices brown. Remove the sauté pan from the heat.

Remove the first apple you sliced. It should be well browned. Ask students which apple slices they want to eat and why? Both apples look brown. What is the difference? Play the "devil's advocate" with the students and ask the following: Why is one apple more acceptable to our senses than the other? What turned each apple brown? Why is one apple appealing to our palate and the other unappealing? If someone indicates that air turned one slice apple brown, ask what explains how air browns the surface of an apple? What is in the apple or in the air that affects browning, and why did it brown one apple and not the other—or did it?

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Define enzymatic browning and susceptible foods.

Anticipated Problem: What is enzymatic browning, and what foods does it affect?

I. Enzymatic browning

A. ***Enzymatic browning*** is the browning of foods caused by enzymes. It is a chemical process that creates an undesirable browning or graying of foods. When a food (often a fruit or vegetable) is cut or bruised, the exposure of the cut or bruised surface to oxygen releases an enzyme from the cells that is highly reactive to oxygen—browning. Enzymatic browning is associated with a loss of quality in regards to appearance, nutritional value, flavor, and natural coloring. Undesirable browning occurs in some fruits and vegetables and even in some seafood. For the majority of foods affected, the browning diminishes quality as well as the natural color. For others, however, the browning is essential for quality and color.

1. ***Enzymes*** are proteins that act as a catalyst (a substance that increases the rate of reaction) in a chemical reaction. The portion of food on which enzymes react is called a substrate, and enzymes convert that substrate into different molecules. In fruits and vegetables affected by enzymatic browning,

phenolase or ***polyphenol oxidase*** is the enzyme that converts the phenolic compounds present in foods to brown pigments. The pigment is known as ***melanin*** (an insoluble polymer caused when a substrate comes in contact with a catalyst, such as oxygen). Therefore, the food becomes tinged with black or brown coloring. However, melanin also has antibacterial, antioxidant, and anticancer properties.

2. ***Polyphenols*** are substances that form the substrate (the base substance acted upon by an enzyme) for the browning enzyme. Polyphenols are unstable and oxidize when exposed to air. As a result, the conversion of a substrate into a product occurs, such as potato flesh into a brown melanin. In the case of apples, the substrates are the flesh and the peel. The coloring of apples is due to polyphenols.
    a. ***Anthocyans (anthocyanins)*** are the red, blue, and purple plant pigments in fruits and other plants; they are responsible for most of the natural ***pigment*** (colored matter) in plants and animals. Even the brown color of enzymatic browning is a pigment. Anthocyanins are predominantly located in the outer cell layers (skin). Edible plants that contain anthocyanins include avocados, blackberries, blueberries, eggplant, and grapes.
    b. Flavonoids, such as catchins and tannins, are found in tea and wine.
3. Enzymatic browning occurs naturally (in foods with the polyphenol oxidase enzyme) as a fruit, vegetable, or seafood ages. The process is hastened after damage or injury. With produce, whenever the skin is cut or injured in any way, cells are ruptured, thereby exposing the flesh to oxygen that reacts with the polyphenols and creates the brown color.
    a. Enzymatic browning differs from browning foods as a result of cooking (e.g., caramelizing sugars or searing proteins). It occurs more rapidly in warmth, but it happens regardless of temperature.
    b. Enzymatic browning occurs due to air exposure, age of produce, and/or bruising of the item.

B. Foods susceptible to enzymatic browning
1. Foods that benefit in color and flavor from enzymatic browning are tea, coffee, cocoa beans, dried fruits, chocolate, and fruit butters.
2. Produce whose appearance and quality is quickly diminished by enzymatic browning are:
    a. Apples
    b. Apricots
    c. Avocados
    d. Bananas
    e. Eggplants
    f. Peaches
    g. Pears
    h. Plums
    i. Potatoes

3. Produce whose appearance and quality is diminished at a slower rate by enzymatic browning are:
    a. Grapes
    b. Lettuce
    c. Mangos
    d. Mushrooms
    e. Sweet potatoes
4. Protein foods that are particularly perishable and sensitive to air and heat include fish and seafood. Seafood displays what appears to be enzymatic browning as the flesh decays, but it is just that—decay. Seafood susceptible to enzymatic browning include:
    a. Shrimp
    b. Crab
    c. Lobster

Teaching Strategy: *Use VM–A. Assign LS–A.*

Objective 2: Explain how enzymatic browning is controlled.

Anticipated Problem: How is enzymatic browning controlled?

II. Controlling enzymatic browning

A. Deactivating the enzyme polyphenol oxidase prevents enzymatic browning. Controlling or preventing the browning of food is important to the food industry's bottom line because appearance and color impact purchasing decisions. Customers often equate browning with spoilage, so cut fruits and vegetables should be eaten within a short period of time.

1. Several methods can be applied to avoid enzymatic browning, based on two factors:
    a. Deactivating the enzyme (via heat)
    b. Removing essential components (most often oxygen) from the product
2. Polyphenol oxidase is deeply dependent upon three elements:
    a. Oxygen
    b. Moisture
    c. A favorable pH level

B. ***Oxidation*** is a destructive process that results in the formation of compounds that discolor fruits and vegetables. Oxidation can cause the loss of a food's nutritive value and can cause rancidity in oils. Polyphenol oxidase and polyphenol enzymes in food react with oxygen to create the "browning" effect. Keeping oxygen from the flesh of many fruits and vegetables occurs naturally via the skin of the produce.

When that skin is peeled, damaged, or otherwise ruptured, the flesh is exposed and browning begins. To prevent oxidation:

1. Physical barriers, such as water and syrup, can be added to the cut flesh. Placing peeled potatoes in water prevents browning.
2. ***Vacuum-packing*** is the removal of most of the air from food before hermetically sealing the package. This prevents most bacterial growth and browning.
3. ***Sulfur dioxide*** is a chemical that inhibits and/or prevents oxygen from reacting with an enzyme.
   a. The addition of chemicals to prevent oxidation is most widely used in the preparation of snacks and wines.
   b. Chemicals act as a preservative. Yet there is considerable debate about their use because of possible cancer-causing agents.
   c. The commercial product Fruit Fresh™ is a sulfur dioxide-based enzymatic-browning agent.

C. Preventing and/or controlling enzymatic browning

1. ***Blanching*** is a short heat treatment (scalding) that destroys or deactivates enzymes by plunging food into simmering or boiling liquid for a very short period of time (e.g., 10 to 30 seconds). Blanching does not cook the product, but it does enhance the color and soften the texture. For blanching to inactivate the enzyme, the liquid must be very hot (e.g., 158° to 212°F or 70° to 100°C), depending on the resistance of the enzyme in question. Blanching is a common technique to prevent browning, and it assists in retaining color prior to canning or freezing fruits and vegetables.
2. Chilling (refrigerating) or freezing prevents food from spoiling. Warmth speeds enzymatic browning, so it is logical that chilling slows it. Temperatures at or below 45°F (7°C) reduce the browning process to a crawl, and freezing stops it altogether. When the food returns to warmer temperatures, the polyphenol oxidase browning resumes. Chilling and freezing do not deactivate the enzyme.
3. Enzyme activity is ***pH*** (a scale that represents the level of acidity of product) dependent. The scale ranges from 0 to 14, with 7 being neutral (water). Anything lower than 7 is considered acidic; and anything above 7 is considered alkaline.
   a. Most fruits and vegetables susceptible to enzymatic browning have pH levels close to water.
   b. Adding acid in the form of citrus juices or vinegar inhibits the browning reaction.
   c. In addition, a pH level of 4 or less stops the browning.
4. ***Dehydration*** (the process of drying by removing water molecules from a product) of food is an effective method to prevent enzymatic browning. Dried fruits (e.g., banana chips, mangos, and apricots) are common examples of dehydrated foods.
   a. Common methods of dehydration are:
      (1) Freeze-drying

(2) Irradiating
(3) Lowering water activity (via salts, sugars, syrups, and honey)

b. Although the enzyme is inhibited (not killed) while the food remains in a dried state, it returns to an active state when the food is re-hydrated.
c. Additionally, the availability of the moisture to react with the enzyme is further inhibited when binding chemicals are added that absorb the available moisture, rendering it unavailable. Sweeteners (e.g., sugar, corn syrup, and honey) are typically used for this purpose.

5. ***Irradiation***, or the exposure of food to X-rays, gamma rays, or other radiation forms, is another intervention that effectively deactivates enzyme reactions. Irradiation destroys bacteria and some natural nutrients in the food.
6. ***High-pressure processing (HPP)*** is a treatment that uses elevated pressure to deactivate enzymes and to kill bacteria. It is a widely used technique in the food industry. Food is placed into chambers and is subjected to extremely high air pressure. Heat is not required and the food retains its nutrients. However, the process is rather expensive.
   a. HPP causes minimal changes in foods compared to thermal-processing techniques.
   b. HPP treatment results in foods with a fresher taste. In addition, HPP items have a better appearance, texture, and nutrition than thermally processed foods.
   c. HPP eliminates "off flavors" associated with thermal processing techniques.
   d. The technology is especially beneficial for heat-sensitive products.
7. ***Ultrafiltration*** is a membrane separation technique used with beverages (e.g., fruit juices and wine) in which the liquid is separated by forcing it through a membrane that prevents large molecules (e.g., polyphenol oxidase but not polyphenol) from passing through. Ultrafiltration effectively removes the enzyme from the liquid and prevents enzymatic browning.

Teaching Strategy: *Use VM–B and VM–C. Assign LS–B.*

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. Questions at the ends of chapters in the textbook may also be used in the Review/Summary.

Application. Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

Answers to Sample Test:

Part One: Short Answer

1. Blanching is a better solution to enzymatic browning than freezing because blanching destroys the enzyme, totally solving the browning problem. Freezing is temporary and lasts as long as the item remains frozen.
2. Wine does not turn brown because it is processed via ultrafiltration, which removes the enzyme. Wine may also be treated with sulfur dioxide.
3. Anthocyans are found in the pigments (colors) of fruits and vegetables.

Part Two: Completion

1. 7
2. sulfur dioxide
3. enzymes
4. citrus
5. crab OR shrimp OR lobster OR shellfish OR crustaceans OR seafood
6. irradiation
7. oxygen

Part Three: True/False

1. F
2. T
3. T
4. F
5. F
6. T
7. T
8. T
9. F

Sample Test

Name _____

Enzymatic Browning

Part One: Short Answer

Instructions: **Answer the following.**

1. What makes blanching a better solution to enzymatic browning than freezing?

2. Wine is made from grapes, and grapes turn brown. Why doesn't wine turn brown?

3. Where are anthocyanins found?

Part Two: Completion

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

1. To be considered acidic on the pH scale, the ingredient must be lower than _____, the pH of water, on the scale.
2. A chemical that prevents enzymatic browning but is a potential cancer risk is _____.
3. Protein structures that speed up a chemical reaction are _____.

4. A common way to prevent enzymatic browning is to sprinkle the food item with _____ juice.

5. One of the few non-fruits or non-vegetables that experiences enzymatic browning is _____.

6. The exposure of food to X-rays or gamma rays to prevent enzymatic browning is called _____.

7. When a food (often a fruit or vegetable) is cut or bruised, the exposure of the cut or bruised surface to _____ releases an enzyme from the cells that causes browning.

Part Three: True/False

Instructions: **Write *T* for true or *F* for false.**

_____1. Eggplant is a food that slowly shows signs of enzymatic browning.

_____2. Polyphenol oxidase and polyphenols react and brown foods due to oxidation.

_____3. Freeze-drying is a type of dehydration that prevents enzymatic browning.

_____4. Irradiation slows enzymatic browning but will not stop it.

_____5. Potatoes slowly show signs of enzymatic browning.

_____6. When French fries brown in the fryer, it has nothing to do with enzymatic browning.

_____7. Enzymatic browning diminishes food quality as well as appearance.

_____8. High-pressure processing (HPP) is a treatment that uses elevated pressure to inactivate enzymes and to kill bacteria.

_____9. Oxidation is a process that adds color to fruits and vegetables.

ENZYMATIC BROWNING

- Apples and bananas turn brown quickly as a result of exposure of the flesh and skin to oxygen—enzymatic browning. Peaches also brown and decompose quickly when the flesh is exposed to oxygen.

- Crustaceans—shrimp, lobster, and crab—have very fragile flesh and suffer enzymatic browning if left raw and exposed to warm air. The flesh begins to "gray" when the outer shell is removed.

- Mushrooms oxidize more slowly, but they also brown over time.

CONTROLLING ENZYMATIC BROWNING—PART 1

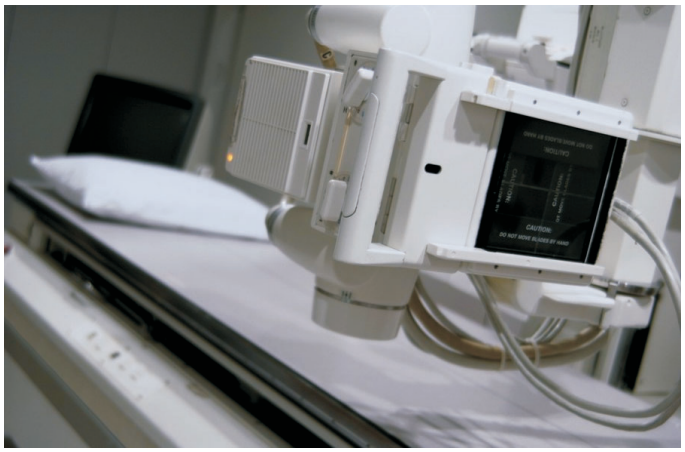
- Blanching—quickly plunging food into simmering or boiling liquid—destroys the enzyme and stops browning. It also allows for the easy removal of the fuzzy peach skin before canning or preserving.

- Adding an acid in the form of citrus juices or vinegar inhibits the browning reaction. A pH level of 4 or less stops enzymatic browning.

- Dehydrating foods helps prevent enzymatic browning. When the dried food is re-hydrated, does the enzymatic action resume?

CONTROLLING ENZYMATIC BROWNING—PART 2

- Exposure to irradiation—X-rays and gamma rays—inactivates the enzyme and stops browning. However, irradiation also destroys nutrients.



- Sulfur dioxide chemically stops enzymatic browning. It is also a pollutant in the atmosphere.

- Vacuum-packed foods prevent browning by removing oxygen.

Name _____

Enzymatic Browning Worksheet

Purpose

The purpose of this activity is to apply your knowledge of enzymatic browning and to identify foods susceptible to enzymatic browning.

Objectives

1. Apply your knowledge of enzymatic browning to solve food scenarios.
2. Explain why enzymatic browning occurred.
3. Identify foods susceptible to enzymatic browning.

Materials

- lab sheet
- writing utensil
- textbook
- computer with Internet access and/or text material access

Procedure

1. Work independently to complete the following questions and scenarios.
2. Use your textbook, the Internet, and other resources to help you answer the following questions.
   a. Of the following foods, which one does not turn brown due to enzymatic browning—peaches, tea, cauliflower, eggplant, or shrimp? Explain your answer.

b. Mushrooms are susceptible to enzymatic browning, but they brown rather slowly compared to other foods. What explains the slow browning of mushrooms?

c. An apple is cut open, and the surface area of the cut flesh begins to brown. Explain what is happening as the browning takes place. Be specific, and address the chemistry of the browning.

d. Why do coffee beans and cocoa beans benefit from enzymatic browning when other foods are damaged?

e. Polyphenol oxidase is an enzyme. What is an enzyme, and what function does it serve in enzymatic browning? What is the benefit of an enzyme that seems to "ruin" foods?

3. Below you will find a list of foods. They all "brown" at some point due to enzymatic browning, decay, or from sugars or proteins that have caramelized under heat during cooking. In the space provided for each item, identify the cause of browning by writing in one of the following letter choices:

   D = decay EB = enzymatic browning C = caramelize

   a. _____ Broccoli
   b. _____ Grilled salmon
   c. _____ Sliced peaches
   d. _____ Sliced watermelon
   e. _____ Chocolate chip cookie
   f. _____ Roasted chicken
   g. _____ Peeled banana

h. _____ Grapes
i. _____ Sliced tomato
j. _____ Roast beef
k. _____ Baked pie shell
l. _____ Mashed avocado
m. _____ Romaine lettuce
n. _____ Diced onions
o. _____ Cherries
p. _____ Fried bacon
q. _____ Pineapple
r. _____ Strawberries
s. _____ Broiled pork chop
t. _____ Tea leaves

4. Participate in a class discussion of your research and your browning choices.
5. Turn in your completed lab sheet to your instructor.

Enzymatic Browning Worksheet

2. a. *Cauliflower did not color due to enzymatic browning (EB) because cauliflower contains no polyphenol oxidase. Its browning is due to decay.*
   b. *There are two reasons. Mushrooms have low levels (comparatively) of polyphenol oxidase and low levels of polyphenols. Also, cauliflower has a relatively low level of moisture.*
   c. *Apples have high moisture content, are low acid, and contain polyphenol oxidase and polyphenols. When the flesh is cut and exposed to air, the oxygen is a catalyst for a chain reaction to begin. The enzyme causes the polyphenols (specifically anthocyan) to react to the oxygen, turning the flesh brown.*
   d. *Coffee beans and cocoa beans begin as a greenish color with an immature flavor. EB provides minimal color change in these beans. (The dark color we are used to seeing comes from roasting, not from EB.) However, the enzyme reaction that occurs has a profound effect on the flavor. Neither coffee nor cocoa would have the depth of flavor we are used to with EB. Roasting, which darkens the colors, intensifies the flavor development that EB started.*
   e. *Enzymes are usually made of protein, and their sole purpose is to cause and/or speed up chemical reactions in living cells. All fruits and vegetables that contain polyphenol oxidase are moist and rather delicate. The natural browning of these foods when injured provides a visual cue to the area where decay has or will begin. In terms of this lesson, that is the reason this enzyme exists naturally in the food.*

3.

a.	D	Broccoli	k.	C	Baked pie shell
b.	C	Grilled salmon	l.	EB	Mashed avocado
c.	EB	Sliced peaches	m.	EB	Romaine lettuce
d.	D	Sliced watermelon	n.	D	Diced onions
e.	C	Chocolate chip cookie	o.	D	Cherries
f.	C	Roasted chicken	p.	C	Fried bacon
g.	EB	Peeled banana	q.	D	Pineapple
h.	EB	Grapes	r.	D	Strawberries
i.	D	Sliced tomato	s.	C	Broiled pork chop
j.	C	Roast beef	t.	EB	Tea leaves

Name _____

Enzymatic Browning Experiment

Purpose

The purpose of this activity is to apply and observe preventive enzymatic browning methods.

Objectives

1. Practice methods of enzymatic browning.
2. Observe the time lapse before enzymatic browning becomes apparent in different foods.
3. Observe the degree of darkening within a specific period of time.
4. Determine which methods of intervention are the most effective and practical.
5. Make a connection between those methods and the foods that brown the fastest.

Materials

- lab sheet
- writing utensil
- timer
- wristwatch with second hand
- 10 small Styrofoam plates
- 9 Styrofoam cups
- ¾ c. granulated sugar, divided into ¼ c. and ½ c.
- ¼ c. corn syrup
- water, as needed
- 1 t. cream of tartar
- ¼ c. lemon juice

- ¼ c. Fruit Fresh™ granules or powder
- 1 vitamin C tablet (500 mg)
- 1 t. baking soda
- ¼ c. white vinegar
- 1 saucepan/sauté pan with burner (or microwave and microwave safe bowl) to boil water
- 9 small pieces of two different foods (preferably one vegetable and one fruit)

Procedure

1. Work in groups of three or four students. Each group needs a timer, a wristwatch (preferably with a second hand), a writing utensil, and paper before beginning the experiment.
2. In this experiment, you will observe enzymatic browning (EB) and various intervention methods to control EB. Your task is to note the length of time that elapses (passes) before visible browning takes place in each item. You will use different techniques to prevent browning, and you will determine how effective each is at controlling or preventing EB.
3. After collecting the items shown in the Materials list, label one plate "control" and set it aside. Label the remaining 9 plates and 9 cups as follows ("a" through "i"). Then add the mixture shown in parentheses into each cup and follow the directions. For example, you would label one cup as "Sugar syrup," then add the granulated sugar and warm water to the cup and stir until dissolved.
    a. Sugar syrup (½ c. granulated sugar and ¼ c. warm water; stir until dissolved)
    b. Corn syrup (¼ c. corn syrup and ¼ c. water; stir until mixed)
    c. Cream of tartar (1 t. cream of tartar mixed with ¼ c. water)
    d. Lemon juice (¼ c. lemon juice)
    e. Fruit Fresh™ (¼ c. granules or powder)
    f. Vitamin C (1 vitamin C tablet and ½ c. water; mix until dissolved)
    g. Vinegar and baking soda (¼ c. vinegar mixed with 1 t. baking soda)
    h. Blanched (½ c. boiling water; do not add this until you are ready to conduct the experiment)
    i. Dry sugar (¼ c. granulated sugar)
4. Review the Enzymatic Browning Experiment Results Chart. Use the chart to record the findings from each experiment.
5. Note the time that you cut and treat each piece of food on the chart. The control plate and column are for food that is NOT to be treated in any way—just cut it and plate it.
6. Dip each of the nine small pieces of each food item (18 total) you are testing in the cups and hold them there for about 30 seconds each. Another option is to coat the food with

the dry ingredient, and then put the pieces on the corresponding plate. Again, note the time that each experiment begins on the chart.

7. Note any changes to the small pieces of food at 10-minute intervals for a total of 30 minutes. Therefore, the "end time" should be 30 minutes from the beginning of each experiment.
8. Summarize the enzymatic browning changes at the end of the 30 minutes. Place the food items from each cup on the matching labeled plate.
9. Report your analysis of each intervention method on the "Experiment Summary" based on your group's findings. Explain the reasoning each method produced the results you recorded. Finally, choose the one method you think had the best overall results to control or prevent EB. How realistic is it to use that method in "real-life" settings?

Enzymatic Browning Experiment Results Chart by Treatment			
	Start	**End**	**Results**
Control Plate			
Food 1			
Food 2			
Cup A			
Food 1			
Food 2			
Cup B			
Food 1			
Food 2			
Cup C			
Food 1			
Food 2			

Enzymatic Browning Experiment Results Chart by Treatment			
	Start	**End**	**Results**
Cup D			
Food 1			
Food 2			
Cup E			
Food 1			
Food 2			
Cup F			
Food 1			
Food 2			
Cup G			
Food 1			
Food 2			
Cup H			
Food 1			
Food 2			
Cup I			
Food 1			
Food 2			

10. Experiment summary:

    a. Based on your findings recorded on the experiment page, write a short analysis of the quality of the ability of each cup's and the control plate's contents to control and/or prevent EB. Answer the following questions:
        (1) How effective was each treatment (including the control group)?
        (2) Why were some treatments more effective than others?
        (3) How viable (doable) would each treatment be in practice? Is the treatment doable or unrealistic?

    Control plate at room temperature

    Cup A

    Cup B

    Cup C

    Cup D

    Cup E

    Cup F

    Cup G

    Cup H

    Cup I

    b. At the end of the summary, choose which enzymatic browning treatment was the best, based on your group's results and views about the most viable solution in a real-world setting. Explain your reasons for choosing the "best" treatment solution.

11. The BEST overall enzymatic browning intervention method: _____.

    Rationale:

Enzymatic Browning Experiment

1. There are several probable results noted on the experiment sheet below, but results may vary. The notes are guidelines.
2. The exercise is intentionally open ended to allow you to choose the foods for the treatment experiments. However, it is recommended that you choose one fruit and one vegetable. Bananas and pears are good choices for the fruit because they brown quickly and will guarantee that the experiment is timely. Eggplant and Russet potatoes are good vegetable choices for the same reason.

- Control plate at room temperature: *The **control plate's** foods will brown the fastest.*
- Cup A: *The **sugar syrup** will modestly interfere with browning, but comparatively the results will be fair to poor among the other treatments.*
- Cup B: *The sugar and the acid in the **corn syrup** will slow the browning, but results will still be poor as compared to other treatments.*
- Cup C: ***Cream of tartar** is an acid and will have good preventive results.*
- Cup D: *The strong acid in **lemon juice** will produce strong anti-browning results.*
- Cup E: ***"Fruit Fresh"** is a sulfur dioxide-based preservative and will have great preventive results if adequately applied.*
- Cup F: ***Vitamin C** is ascorbic acid, and it will have strong anti-browning results.*
- Cup G: ***Baking soda** will neutralize much of the acid in the vinegar; results will be moderate to poor.*
- Cup H: ***Blanching** destroys the enzyme and should have the best results if properly applied.*
- Cup I: ***Dry sugar** will cause fluid to "weep" from the food items and will have a moderate interference with browning.*

Item 12: BEST overall enzymatic browning intervention method:

*The application of **Fruit Fresh™** and the **blanching technique** should provide the best results of the treatments in the experiment. Ideally, students will make the connection that the chemical (Fruit Fresh™) is the best choice for the fruit and the blanching technique is the best choice for the vegetables. Yet there are arguments to be made with other rationalizations. Some results may confuse students (e.g., the vinegar and baking soda and the cream of tartar experiments). Time permitting, encourage or allow students to research the real nature of the ingredients they used, and see if they can figure out why they had those results with those two treatments.*

Look for three-dimensional problem solving in which students rationalize their choices for best preventive methods. It should address the viability of the solution as well as its effectiveness.