Teacher Version: The Power of Colorful Fruits and Vegetables

This activity was developed by Dr. Susan Hershberger and Susan Gertz for the *Fighting with Food* project, a partnership between Miami University, the University of Cincinnati, and the University of Kentucky. The project is funded through the National Center for Research Resources and the Division of Program Coordination, Planning, and Strategic Initiatives of the National Institutes of Health through Grant Number R25 ODO01190-02. These materials have been developed and reviewed upon the advice of for the following research scientists at partnering institutions: University of Kentucky—Dr. Bernhard Hennig, Dr. Lisa Gaetke, and Dr. Lindell Ormsbee; University of Cincinnati: Dr. Kim Dietrich and Dr. Mary Beth Genter. Pedagogical review has been provided by Dr. Aeran Choi, Kent State University

Introduction:

In addition to taste and aroma, the color of food is part of what makes different foods appealing. Colorful foods aren't just attractive—colorful foods contain beneficial nutrients. One suggestion nutritionists give for healthier eating at holidays, celebrations, or buffets is that people eat the more colorful foods. Why do nutritionists give this advice? In the following activity, two properties of some colorful foods may be compared and contrasted, helping students distinguish between these two properties and two different types of chemical reactions. This activity could be approached by directing or demonstrating the reactions with one food, followed by student exploration of other colorful foods.

Many colorful fruits and vegetables contain anthocyanins. Anthocyanins belong to the larger group of chemical compounds called flavonoids and are distributed throughout the tissues of plants. Anthocyanins have a basic chemical structure that is often modified by different attached groups called glucosides. The many different variations in attached glucosides plus minor substitutions of some atoms for others in the basic anthocyanin structure provide the wide variety of water soluble pigments in colorful fruits and vegetables. Some of the foods containing anthocyanins include apples, peaches, grapes, blueberries, raspberry, blackberry, black currants, cherries, eggplants, cranberries, choke cherries, and acai and red cabbage, as well as black rice and beans. Anthocyanins are also present in red and purple flowers and some plant leaves.

Anthocyanins are both antioxidants and weak acids. As antioxidants, anthocyanins can act as reducing agents and become oxidized, therefore protecting another compound from oxidation. Anthocyanins will react with oxidants such as iodine, iodine plus starch, or 2,6-dichlorophenol indophenol. These oxidants are often used in the laboratory to study reactions of another common antioxidant found in food—Vitamin C. Like vitamin C, anthocyanins will cause the color of these oxidants (brown, blue, and blue respectively) to be converted to a their colorless products. However, if the anthocyanin is highly colored, the color of the anthocyanin will persist at the end of the reaction.

As weak acids, anthocyanins are capable of donating a H+ ion to a base. The base form of anthocyanins (A-) can accept a hydrogen ion (H+) from an acid and be converted back into the weak acid (H+A-). The colors of the acid form of the anthocyanin (H+A-) are often strikingly different from the colors of the base of the anthocyanin (A-). A neutral solution of pH 7 will often have an intermediate color between the acid and the base color.

Oxidation/reduction and acid/base chemistry are two different, but common, types of reactions. Anthocyanins are unique compounds because they undergo both types of reactions. It is possible for students to focus exclusively on either the oxidation/reduction properties of anthocyanins, to focus exclusively on the acid/base properties of the anthocyanins, or to compare and contrast these two processes.

Anthocyanin A–H (an acid) > donates H+ and produces A- (the corresponding base of the acid)

Anthocyanin + [O] (reactive oxygen species) > A[O] (oxidized form of anthocyanin) + [R] (reduced oxidant)

> ***Note:*** *If introducing oxidation/reduction or acid/base properties for the first time, we do not recommend doing both parts of this activity close together. Ideally, teach one of these two reactions first, and then a few weeks later teach the other.*

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
oxidation		
reduction		
acid		
base		
neutralization		

Materials:

- safety goggles
- colorful foods such as purple cabbage, berries, fruit teas, green teas, juice concentrates
- household acids such as vinegar, citric acid (fruit fresh), lemon juice
- household base solutions, baking soda, washing soda
  Note: If ammonia and washing soda solutions are used, safety goggles are mandatory.
- neutral solutions such as table salt, sodium chloride
- oxidant solutions such as povidone iodine solution, starch povidone iodine solution, or 2,6-dichlophenolindophenol solution
- small plastic cups or plastic sheets
- disposable pipets or dropper bottles

Getting Ready

Prepare the oxidant solutions as previously directed in the *Determination of Vitamin C* procedure. Dissolve the citric acid in water. Prepare purple cabbage juice by cutting cabbage and heating the cut cabbage in a small amount of water. Students may also prepare the cabbage by tearing cabbage leaves and stirring the pieces into warm water. With this preparation, the cabbage juice may be more dilute.

Part 1 Reactions of Acidic, Basic or Neutral Solutions

Part 1 Pre-Activity Discussion

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.

Beginning with a display of colorful fruits and vegetables, ask students how they might find out about the "chemicals" that are contained in these foods. Students may suggest that one could either crush them to extract the juice, or possibly add water to extract the juice. Explain that although the extracted juice probably still contains many different compounds, some chemical reactions might allow students to decide if various foods contain chemicals that belong to the same group. One way to test the food extracts is to see if the colors change when certain chemicals are added. If the patterns of color change are similar in different foods, the same kinds of chemicals may be present.

Tell the students that one possible experiment is reacting one sample of a food extract with vinegar (acetic acid) and another sample of the same food with baking soda solution. Ask the students what types of chemicals they expect vinegar (acetic acid) and baking soda to be. Students may recognize these as an acid and a base. Depending upon student level, ask students what type of solution is in between an acid and a base. They may know that this is a neutral solution, one that is neither acidic nor basic. Suggest that a neutral solution could be tested as well.

While students may want to mix a cup of extract with a cup of vinegar, suggest that the same reaction can be observed by mixing one drop of each solution on the top of a plastic bag or plastic sheet, and the reaction with be easier to clean up and generate less waste. Once students observe the changes for one fruit or vegetable they may want to observe the changes for other fruit juices or extracts.

Part 1 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.

Students should decide on a procedure, conduct their experiments, and record their results in tables similar to the one below. One approach is to have each group select one food to test.

Food	Color of	Color	Color with	Color with	Color with	Color with	Color with

	food, Juice or Water extract	with added vinegar CH_3CO_2H	added lemon juice	added citric acid	added baking soda $NaHCO_3$	added washing soda Na_2CO_3	added salt NaCl

Part 1 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

- The colors of one food extract are nearly identical with added vinegar, lemon juice, or citric acid.
- For the same food extract, a different, but consistent, color is observed when either baking soda or washing soda is added.
- The color in the salt solution is in between the colors of the vinegar, lemon juice and citric acid and the colors of baking soda and washing soda.

Claims/evidence

- What claims can you make about the vinegar, lemon juice and citric acid used to test the foods? *The substances of vinegar, lemon juice and citric acid must have similar chemical properties. Some students may realize that they are all acids.*
- What claims can you make about the baking soda and washing soda used to test the foods? *The substances baking soda and washing soda must have similar properties. Some students may realize that they are both bases.*
- What claims can you make about the chemicals that cause the foods to be brightly colored? *In many of the foods, the chemicals that cause them to be brightly colored have similar properties.*
- What is the evidence for your claims? *Since the food extract turns the same color in vinegar, lemon juice and citric acid, and turns a very different color in baking soda and washing soda, it seems reasonable to conclude that each of these are groups of chemicals with similar properties. Since the food extract turns a different color in the salt solution, it makes sense that the salt solution is not part of either of the other two groups. Since most red and blue fruits and vegetable turn a red or pink color in the vinegar, lemon juice, or citric acid and a green color in baking soda and washing soda, the colorful chemicals found in different foods must have similar properties. If students tested tea, they*

may notice that the color changes in tea are an exception to this pattern. Tea becomes more yellow in vinegar, lemon juice and citric acid, but retains more of the tea color in baking soda and washing soda. This difference is because the fruit and vegetable extracts contain anthocyanins, but tea leaves are rich in other kinds of flavonoids.

What additional questions do you have and what additional experiments would you like to investigate? *Answers will vary, but students may want to test other foods. They may want to see which foods follow the pattern of red/pink in an acid and green in a base and which have color changes more like tea or possibly altogether different color changes. As students test a variety of foods, they may notice that the red/pink color of many fruit juices or extracts does not significantly change when treated with acidic solutions, although the color may become more red. This observation fits with the fact that many fruits are already moderately acidic.*

Part 2: Reaction with Oxidant Solutions

Part 2 Pre-Activity Discussion

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.

If students follow their investigation of the color changes of the fruit and vegetable extracts with online research into the properties of anthocyanins, they may discover that anthocyanins are also considered antioxidants. What does it mean that they are antioxidants? Oxygen is an oxidant, and it is found on the right side of the periodic table. Iodine is also an element on the right side of the periodic table, and it also has oxidant properties. Discuss that the role of an antioxidant is to protect other compounds from becoming oxidized by becoming oxidized itself. Suggest that student might look for evidence of the ability of the fruit and vegetable juices and extracts to be oxidized by either povidone iodine solution or starch povidone iodine solution. Students can do these tests by adding a drop of each juice or extract to a drop of the oxidant solutions.

In the acid/base reactions, students observed a color change in the food extract. In these oxidation/ reduction reactions, students will observe a change in the color of the oxidant when the food is added. Note that the strong color of some test foods may make the outcome of these tests a bit harder to discern. That is why the best procedure is adding the food to the oxidant and not adding the oxidant to the food.

Part 2 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.*

Students should decide on a procedure, conduct their experiments, and record their results in tables similar to the one below. One approach is to have each group select one food to test.

Food	Color of food extract	Color of the oxidant, povidone iodine	Color of food extract plus povidone iodine solution	Did the color of the povidone iodine change?	Color of the oxidant, starch povidone iodine	Color of food extract plus starch povidone iodine solution	Did the color of the starch povidone iodine change?

Part 2 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

- The color of the oxidant changes when a food extract is added. Povidone iodine changed from brown to colorless. Starch povidone iodine changed from blue to colorless. In some cases, the color of the food extract did not dramatically change. In other cases, the food extract became colorless.

Claims/evidence

- What claims can you make from the reaction of the food extract and the colored oxidants? *The colored food extract can be oxidized by an oxidant. Since the food extracts are able to become oxidized, it is possible that they function as antioxidants in the body.*
- What is the evidence for your claim? *Since the oxidants (povidone iodine and starch povidone iodine) change color when they oxidize something, and since these oxidants changed color when the food extract was added, this is evidence that they oxidized the food.*

Reflection

- What other questions should be investigated? *Answers will vary.*

- How are the reactions with the oxidant solutions different from the reactions with vinegar, lemon juice, citric acid, baking soda, washing soda, and salt solutions? *Answers will vary depending upon grade level, however students should recognize that two different processes occurred since the resulting color changes for these two sets of reactions are different.*