A Rainbow of Uses

Principle of Plant Biology #8

Plants are a primary source of fiber, medicines, and countless other important products in everyday use.

For thousands of years, people have relied on plants for a huge number of things. Over 70% of medicines are made or derived from plants. Your clothing is probably made of cotton. Spices and perfumes such as vanilla, pepper, cinnamon, nutmeg, oregano, garlic, and lavender are plant products. Beverages such as coffee, tea, and lemonade are made from plants. The list is essentially endless. Without the use of plants, modern civilization could not exist.

Another way people use plants is to make dyes. China, Persia, Greece, Egypt, and other cultures began using plant dyes thousands of years ago to color fabric, pottery, and other things. Simply grinding up plant tissue is sometimes all that is needed to obtain a desired color. Other times, plant dyes can be mixed with other substances. In particular, adding acids or bases to some dyes will cause color changes.

Plant dyes are colorful because they contain pigments. Pigments are chemicals produced by plants that absorb some wavelengths of light and reflect others. For example, leaves are green because the pigment chlorophyll reflects the green wavelengths of light. Reflected light is not used by the plant whereas absorbed light is used in processes such as photosynthesis. Plant pigments such as carotenoids and anthocyanins produce the great diversity of colors you often see in flowers, fruits, and leaves.

Over 5000 different pigments are produced by plants and these pigments have numerous uses. Some are used to color flowers (to attract pollinators) and fruits. Some protect plants from harmful radiation somewhat like a "sunscreen." We call these antioxidants. Pigments can also control cell membranes and regulate hormones.

In the following activity, you will make natural dyes from plant pigments and test the effects of adding acids and bases to the pigments.

Real-world Connection:

From pants to painkillers, plants provide thousands of different products that people use every day.

Activity: Effect of pH on the Color of Plant Pigments

Procedure:

1. Weigh 5 grams of plant material and tear or cut it into small pieces. Place the plant material in a mortar with 2 pinches of sand and 20 mL of distilled (or bottled) water. Grind this material with the pestle for 2 minutes or until it is pulverized. Filter the solution using filter paper (or 2 layers of cheesecloth) into a small beaker or small cup.

2. In a small well plate with 10-12 wells (or in cups or a styrofoam egg carton) add 2 mL of the plant solution in each of three wells. Observe and record the color of the plant solution in the table on the next page.

3. Well #1 is the control. In Well #1, add 5 drops of water to the 2 mL of plant solution. Observe the color and record in the table.

4. In Well #2, add 5 drops of vinegar (acetic acid) to the 2 mL of plant solution. Observe the color and record in the table.

5. In Well #3 add 5 drops of bicarbonate of soda solution (base) to the 2 mL of plant solution. Observe the color and record.

6. Measure the pH of each solution and record in the table.

7. Obtain a square of white cloth or paper towel. Using a dropper, place 5 drops of plant solution from Well #1 onto one spot on the cloth. Next place 5 drops of the solution in Well #2 onto one spot on the cloth (next to the first spot). Finally, place 5 drops of the solution in Well #3 on the cloth (next to the other two spots). Record the colors in the table on the next page.

Observations:

Are the colors different on the cloth/paper towel than they were in the well plate or egg carton? How so?

If the colors are different what might have caused this change?

Student-Designed Experiments

Using the methods you learned in the activity above and the "Guide for Student Experimentation" below, design and carry out your own inquiry. Question topics you might consider include the effects of pH on the color produced using different parts of a a variety of plants. You could test different colors of fruits, flowers, roots, stems, and leaves. Consider testing leaves in the fall after they have changed colors. You might test the effect of the plant pigment solutions on different types of cloth and/or paper. You could also test the effect of using something other than water as the solvent, such as alcohol, to extract the pigment.

Observations of Plant Pigments in the Wells:

	Sample 1:	Sample 2:	Sample 3:
Color of Control			
pH of Control			
Color with Acid Added			
pH with Acid Added			
Color with Base Added			
pH with Base Added			

Observations of Plant Pigments on the Cloth or Paper Towel:

	Sample 1:	Sample 2:	Sample 3:
Color of Control			
Color with Acid Added			
Color with Base Added			

Guide for Student Experimentation

Guidelines for Achieving Great Experiments

1. Ask a very specific, testable question.
2. Test a control for comparison (a group that does not receive the experimental treatment).
3. Use a sample size large enough to allow firm conclusions.
4. To understand a whole population, obtain a random sample of that population to avoid bias.
5. Replicate each part of the experiment (at least 3 times).
6. Hold all variables constant between trials except the variable being tested.
7. Collect quantitative data whenever possible.
8. Measure using metric units.
9. Gather data carefully and accurately.
10. Be objective and honest.

Introduction

Question:

Hypothesis:

Materials and Methods

Independent variable:

Dependent variable:

Experimental constants:

Control:

Protocol:

Results

Data collected:

Other observations:

Graph(s):

Discussion

Interpretation of data:

Conclusions:

Teacher's Guide to "A Rainbow of Uses"

Links to National Science Education Standards

Grades 5-8:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Structure and function of living systems
- Diversity and adaptations of organisms
- Science and technology in society

Grades 9-12:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- The cell
- Matter, energy, and organization in living systems
- Science and technology in local, national, and global challenges

Materials

Per group:

- 10 mL Graduated Cylinder
- Beaker or small plastic cup
- Water (bottled or distilled) for solutions
- Well plates or Styrofoam (not cardboard) egg cartons (1 per group)
- Mortar and Pestle (or some method to crush plant material)
- Several pinches of sand
- Cheesecloth, filter paper, or coffee filters (all can be found at a grocery store)
- Squares of white 100% cotton cloth, paper or paper towels (about 15 cm square)
- Marking pen
- pH paper

For class use:

- Scales
- Dropper bottles with water.
- Dropper bottles with white vinegar (acetic acid) to be used as the acid. Vinegar has a pH of around 2.5 – 3.
- Dropper Bottles with solution of baking soda (bicarbonate of soda) solution to be used as base. Baking soda in solution makes a weak base with a pH of around 8.
- Plant material to be tested (blueberries, red cabbage, grapes, strawberries, or whatever else you want to try)

Teaching hints

1. **Set-up:** Once you have gathered the materials, then you only need to prepare the base solution. To make a sodium bicarbonate of soda (baking soda) solution, dissolve 2 grams of baking soda in 200 mL of water. Baking soda in solution makes a weak base with a pH of around 8. Distribute the acid and base solutions into dropper bottles. These bottles can be saved for the next time you do the lab.
2. **Selecting plant material:** Teachers and/or students can collect plant material around the school, from home, or from a grocery store. A variety of plants and plant parts can be used including flowers, fruits, stems, roots, leaves and leaves exhibiting fall colors. Also, students can use alcohol as the solvent. Ethanol is best but rubbing alcohols can be tried. Certain plant pigments are extracted better when they are boiled for about 30

minutes. You will get more pigment out of red cabbage and onion skins if the plant material is boiled. Grapes, blueberries, red cabbage, and red onions will turn colors in different pH solutions. They contain plant pigments called anthocyanins that are water soluble. Often red cabbage and blueberry extract solutions are used pH indicators because of their color changes.

3. Safety:

- Students should **NEVER** be allowed to eat the plant material used in the lab.
- Review the safety rules about handling acids and bases. Although vinegar and baking soda solutions are not considered to be harmful it is a good to have students rinse any vinegar or baking soda solution from a part of the body that may have been exposed to the solutions.
- These plant pigments are used in dyeing and can stain clothes. If students get the solutions on their clothes have them rinse the area with lots of water and then use soap to try to remove the stains.

4. Extensions: Students might enjoy learning about the history of dyeing and how Native Americans, early settlers, and other cultures made and used dyes. They also might enjoy dyeing and tie dyeing some articles such as bandanas for art projects. Here social studies and other subjects can be combined with biology and chemistry. A discussion of other substances used in dyeing would be interesting.

5. Successful student-designed experiments:

- Emphasize the "Guidelines for Achieving Great Experiments."
- Before students design experiments, tell them how much time they will have.
- Allow students to present their experiments and lead a short discussion about each one. Encourage other students to ask questions.

Web Resources

Information on pH and anthocyanin pigments: http://web.chemistry.gatech.edu/~williams/bCourse_Information/red_cabbage_pH_indicator/cabbage.html

Egan, T. P., J. F. Meekins, D. Maluso. 2004. Dyes, Fibers, and Paper: A Botany Lab Exercise For Non-Biology Majors. Bioscence 30(1): 15-18.

A Lesson to Dye For www.thebakken.org/education/scimathmn/plant-dyes/dyes1.htm

Amy Hoffmann: Fun with Natural Plant Dyes www.hort.cornell.edu/gbl/planting/hortandyouth/pdfs/plantdyes.pdf

Acknowledgements

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