Natural Dye Lesson Plan

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Age level: Elementary grades, but can be adapted for older students.

Objective:
To identify major pigments occurring naturally in fruits and vegetables.
To introduce the effects of pH on anthocyanin pigments.
To use natural pigments in dye applications (e.g., cloth, string, eggs for Easter, or porcupine quills).

Materials:
1 pint of fresh or frozen blueberries (Maine blueberries are smaller and easier to strain)
3 yellow onions
1 can of spinach
Saucepans
Fine mesh strainer
Vinegar (an acid)
Baking Soda (a base)
Mason canning jars or glass containers
Disposable bowls and spoons

Prep:
Simmer 1 pint of fresh or frozen blueberries in ½ cup of water in a small saucepan over medium heat until a deep blue color is leached from the skins. Strain out blueberry skins with a fine kitchen strainer. (A tea strainer works well).
Simmer yellow onion peels (the yellow papery skins, not the onion flesh) in ½ cup of water over medium heat until the water turns a golden yellow color. Pour liquid through a strainer to remove onion peel.
Simmer cooked spinach in ½ cup of water over medium heat until water turns a dark olive green. Strain out spinach. (Fresh spinach greens do not release chlorophyll pigment well and are not recommended for this exercise.)
Colored pigment solutions can be stored at room temperature in glass containers such as Mason jars. Disposable plastic bowls and spoons are best for dying materials in the classroom.

Plant Pigment Chemistry: (Potter and Hotchkiss 1995; Buchanan et al 2002)

Fat Soluble Pigments:
These pigments are found in many fruits and vegetables and include chlorophyll and carotenoid pigments. These pigments are not easily released from plant tissues. They will not bleed or leach from plant tissues into water, but pigment will leach into oil-based or hydrophobic solutions.
Chlorophyll:
Green pigment used in harvesting of blue and red light by plants during photosynthesis
*Found in spinach, peas, lettuce
Interesting note:
Why is fresh spinach so green but cooked spinach is a drab olive green color?
Chlorophyll is tightly bound to proteins in the plant tissue. The chlorophyll-protein complex denatures during cooking due to the high heat, which releases the magnesium bound to the center of the tetrapyrrole of the chlorophyll molecule. This structural change produces pheophytin (an olive green to brown color) from chlorophyll (bright green color).
Carotenoids:
Yellow to orange to red pigments (tetraterpenes) that function both as accessory light harvesting pigments and as antioxidants that protect plants from the harmful effects of strong sunlight.
*Found in carrots, corn, squash, tomatoes

Water Soluble Pigments:

A large group of phenolic pigments called flavonoids are also found in many flowers, fruits and vegetables. They have a wide range of functions, including attracting insects to plants (e.g. for pollination and seed dispersal). Some flavonoids have been studied for their potential anticancer health benefits (antioxidant effects). These pigments include anthocyanins and yellow flavonoids.

Yellow flavonoids:

*Found in potatoes, yellow onions

These pigments are also pH sensitive. The color turns a deeper yellow in basic pH solutions.

Anthocyanins:

Purple to blue to red pigments that are also flavonoids.

*Found in grapes, berries (blueberries), eggplant, red cabbage

The color of anthocyanin pigment is dependent on pH (measure of acids and bases). Anthocyanins are red at low or acidic pH, and are blue to purple at high or basic pH.

Activity:

First, introduce plant pigment chemistry to students. Excellent reference books for reviewing plant chemistry include: Food Science (Potter and Hotchkiss 1995) and Biochemistry and Molecular Biology of Plants (Buchanan et al. 2002). Educators can also relate pigment chemistry to leaf changes. The same pigments (carotenoids, chlorophyll, and anthocyanins) used in this exercise are involved in the changing colors of leaves in autumn. Older students can be more involved in an inquiry-based exercise (such as the effects of pH on the chemical structure of pigments, and/or enhanced spectral characteristics, light absorption, etc.). Second, begin the activity by pouring pigment solutions into disposable plastic bowls containing spoons. Students can dye materials (e.g. cloth, string, eggs, or porcupine quills) suitable for the range of interests in the class. Students/educators should divide the blueberry solution into three bowls. The students can then add vinegar (acid) to one bowl in small amounts until the blueberry solution turns a pink color and add baking soda (base) to a second bowl in small amounts until that blueberry solution turns a dark purple color. Students will then have three separate anthocyanin shades to dye materials over a range of color. After adding vinegar and baking soda to blueberry pigment, the dye will be weak. If dyeing eggs for Easter, use only white eggs. Hard-boiled eggs work well. Beet pigments will not dye eggs well, but are suitable for light colored cloth or string. Please remind students that fruit and vegetable pigments are natural alternatives to the man-made dyes that can be bought at the store. The plant pigments are very subtle dyes. Adding more than 1 dye to materials such as eggs can produce a muddled color, so a 1 or 2 color limit is recommended during the dyeing process.

Students can do this activity from start to finish in the classroom, including preparation of the pigments. The pigments can be prepared in a saucepan over a stove or electric hot plate. Water can be heated from an electric steam kettle and poured onto fruit and vegetable skins to leach out plant pigments, as well. However, boiling water presents a safety issue, so students need careful supervision.

References:

Buchanan, B.B., Gruissem, W., and Jones, R.L. 2002. Biochemistry and Molecular Biology of Plants. John Wiley and Sons, Inc., 1367 pp.

Potter, N.N. and Hotchkiss, J.H. 1995. Food Science, 5th edition. Chapman and Hall, New York, NY. pp.415-417.

Questions:

1) What range of colors can be found in anthocyanin pigments?

2) If you add vinegar (an acid) to blueberry pigment, how does the color change?

3) If you add baking soda (a base) to blueberry pigment, what happens?

4) Why is canned spinach so different in color from fresh spinach?