Cooking up colors from plants, fabric and metal

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Cooking Up Colors from Plants, Fabric, and Metal

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In this Activity, students dye fabric squares with two plant dyes: aqueous extracts of tea leaves and of marigold flowers. They investigate how the addition of iron to a dye bath affects the resulting color and fastness of the dyed fabrics and observe that the type of fabric affects the results.

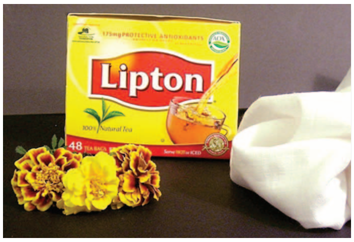

photo by J. E. Mihalick and K. M. Donnelly

Background

This project demonstrates the usefulness of chemistry in the visual arts. Throughout history people have tried to capture the beautiful colors of plants, through dyeing fabric and other means. Polar organic molecules in a sample of plant material dissolve in hot water, creating a dye bath. The molecules will stick to fibers through London dispersion forces, dipole–dipole interactions, or hydrogen bonding. Protein-based fibers such as wool and silk have the greatest variety of functional groups so usually develop the most intense color compared to other fabric types. The addition of metal ions to a dye bath, as a salt or extracted from iron cooking pans, improves the binding of dyes by adding ion–dipole interactions with the fibers and with dye molecules. The aluminum salt, alum, has been used since medieval times to improve dye "fastness" to fibers. Transition metals such as iron can also change the color of a dyed fabric by forming transition metal complexes *(1)*.

Integrating the Activity into Your Curriculum

This Activity can accompany a discussion of the impressive array of chemicals produced by plants. Students can learn that the different appearances and textures of fibers are due to differences in chemical structures. The importance of intermolecular forces in the dyeing process can be demonstrated.

About the Activity

Most of the materials are available in local stores. Collect marigold flower heads as they wilt and dry on the plants during summer and early fall, or pick fresh flowers for drying. (Flower heads can be stored in a paper bag for months if kept dry.) White fabric can be purchased at fabric or hobby stores. Alternatively, white clothing can be purchased at thrift stores or old white clothing can be collected from students for cutting. Some fabrics such as white linen and wool may only be available in stores seasonally. Cut a variety of white fabric samples into ~5 cm squares. Use a variety of natural (cotton, linen, and wool) and synthetic (rayon, nylon, and polyester) fabrics and blends (cotton/polyester). Twelve total sets of samples are required for each group. Three sets of fabric samples are placed in each of four dye baths. For each dye bath, one set is tested for fading in soapy water, one is tested in sunlight, and one serves as a control. A day or two before performing the Activity, the instructor should prepare the brewed tea solution by placing a black tea bag into 500 mL of boiling water. Turn off the heat, allow it to stand for 24 hours, then remove the tea bag. Each group requires 500 mL of brewed tea, so scale the preparation as needed. Inexpensive cast iron pans are sometimes available at thrift stores or yard sales. The pans should not be seasoned for cooking. The pans will tend to be rusty after they have been used for the dye baths. Additional experiments with metals and fabric dyes are described in a related *JCE* article *(2)*. Other *JCE* Classroom Activities related to natural dyes have been published *(3, 4)*.

Instructors may wish to have students try dyes made from other plant matter such as red cabbage or other flowers, and to experiment with different metals such as alum (available in the spice aisle of grocery stores).

Answers to Questions

1. The tea leaves are dark brown and the marigolds can be yellow, orange, or a combination. The tea dye is brown, and the marigold dye is yellow; the dyes become grayer with iron.
2. Depending on the available samples, differences in texture and weave will be observed.
3. Tea: tan; Tea with iron: dark gray to black; Marigold: yellow; Marigold with iron: gray–green (olive).
4. Natural fibers usually develop a more intense dyed color than synthetic fabrics.
5. The iron changed the dye colors and improved the fastness.

References, Additional Related Activities, and Demonstrations

1. Grae, I. *Nature's Colors: Dyes from Plants;* Macmillan Publishing Co.: New York, 1974.
2. Mihalick, Jennifer E., Donnelly, Kathleen M. Using Metals To Change the Colors of Natural Dyes. *J. Chem. Educ.* **2006**, *83*, 1550–1551.
3. *J. Chem. Educ.* Staff. Anthocyanins: A Colorful Class of Compounds. *J. Chem. Educ.* **1997**, *74*, 1176A–B.
4. *J. Chem. Educ.* Staff. Colors to Dye for: Preparation of Natural Dyes. *J. Chem. Educ.* **1999**, *76*, 1688A–B.

JCE Classroom Activities **are edited by Erica K. Jacobsen and Julie Cunningham**

Cooking Up Colors from Plants, Fabric, and Metal

Fabric dyes can be extracted from colorful plant materials such as marigold flowers, blueberry skins, and black walnut hulls. When fabric is added to a bath of dye solution, the dyes are attracted to the polymers in the fabric by intermolecular forces. Cotton and linen are cellulose fibers, loaded with hydrogen-bonding –OH groups. Wool and silk are protein fibers, composed of long chains of amino acids. Synthetic fibers such as nylon and polyester contain other functional groups. Mordants are extra chemicals, such as metal compounds, added to the dye bath that make additional bonds between dyes and fibers. Adding different metals to the dye bath can have surprising results! The first discoveries of these effects were made when people used metal cookware for dyeing fabric. In this Activity, you will dye several types of fabric using two natural dyes, extracted from tea leaves and dried marigold flowers. You will determine whether the type of fabric makes a difference in the dyed result, and will investigate the effects of adding a mordant, iron, to the dye bath.

Be Safe! Don't touch the hot plates! Protect clothing from unwanted dye with a smock or apron.

photo by E. K. Jacobsen

Marigold flowers can be used to dye cloth.

Try This

You will need: two cast iron pans (clean and not seasoned for cooking); four hot plates or stove burners; two 600-mL glass beakers or stainless steel pans; water; black tea bag; brewed tea (obtain from your instructor); vinegar; 50-mL graduated cylinder or measuring cups; 6–10 dried marigold flower heads; stirring rods; aluminum foil or pan lids; 12 sets of 5 cm × 5 cm white fabric squares (a set should include a variety of fabrics including at least one natural and one synthetic fabric); tongs; indelible marker; soap; sunny day (for colorfastness test).

__1. Examine several dried marigold flower heads and the contents of a black tea bag.

__2. Place two clean, unseasoned, cast iron pans and two 600-mL glass beakers or stainless steel cooking pans onto four hot plates or stove burners.

__3. Obtain 500 mL (~2 cups) brewed tea from your instructor; pour 250 mL (~1 cup) into one of the cast iron pans. Measure 25 mL (~2 tablespoons) of vinegar and add it to the pan. Pour 250 mL (~1 cup) of brewed tea into one of the beakers or stainless steel cooking pans.

__4. Pull the dried flowers from 3–5 dried marigold flower heads and add them to the second cast iron pan. (The remaining plant parts will not be needed.) Add 250 mL (~1 cup) of water. Place the same number of marigold flower heads into the second beaker or stainless steel cooking pan with 250 mL (~1 cup) water. (Vinegar is not needed in this dye bath.)

__5. Bring the mixtures in all four containers to a simmer (small number of bubbles appears) over medium-high heat. Reduce heat and simmer for 20 min. Cover the containers loosely with aluminum foil or pan lids to minimize evaporation.

__6. While the dye baths are simmering, note the appearance and texture of the different types of white fabric squares within a set. After the baths have simmered for 20 min, add three complete sets of squares to each of the four dye baths. Cover the baths again and simmer for an additional 20–30 min with occasional stirring. Turn off the heat and let the squares soak in the baths overnight. Be sure the squares are all submerged in the liquid.

__7. After the squares have soaked overnight or longer, use tongs to remove them from the dye. Rinse the squares in water and lay them on labeled paper towels to dry.

__8. Using an indelible marker, label each square from the three sets of squares dyed with marigolds. (For example, M1, M2, and M3 for the three sets.) Test the dye stability or "fastness" by washing the M1 set in soapy water, placing the M2 set in the sun to test for fading, and keeping the M3 set as a control. Uniquely label the sets from the remaining three dye baths and repeat the tests for fastness and fading.

Questions

1. Describe the appearance of the original plant materials. What color dye bath does each plant produce?
2. What differences did you observe among the undyed fabric samples?
3. What colors are the dyed fabrics?
4. Is there any difference in the result for natural and synthetic fibers within the same dye bath?
5. What effect did the iron have on the result?

Information from the World Wide Web *(accessed Oct 2006)*

Natural dyes and recipes. *http://www.paivatar.com/AFA/library/aa00/aa062100.htm*

Making natural dyes from plants. *http://www.pioneerthinking.com/naturaldyes.html*

Dye history from 2600 BC to the 20th century. *http://www.straw.com/sig/dyehist.html*

Polymers up close and personal. *http://www.pslc.ws/macrog/level2.htm*