ChemSumer

YOUR COLORFUL FOOD

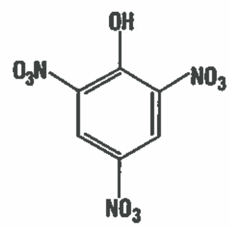
By Jane Hersey and Carl Heltzel

We humans place a lot of value in the colors of the foods we eat. We learn to associate certain colors with certain flavors so the color of our food influences the perceived taste. Artificial colorants are added to help identify foods, enhance their natural colors, mask undesirable colors, or for decoration, among other reasons.

The use of artificial (not necessarily synthetic, just not naturally occurring) colors in foods, including a variety of questionable ingredients, stretches back to antiquity. In ancient Greece and Rome, government-appointed inspectors monitored the use of artificial colorants in wine. The color of bread was often adjusted using lime, chalk, and even crushed bones in the Middle Ages in Europe. The ends of the 18th and early 19th centuries were marked by significant increases in the use of food colorants. It was common to find naturally occurring, but toxic copper salts added to green cake icing for example. The English chemist Frederick Accum warned the public about the toxic effects of some poisonous colorants found in candy, including red sulfuret (HgS), and sugar of lead (lead acetate, $Pb(C_2H_3O_2)_2$).

Early synthetic dyes

For thousands of years, colorings were derived from plants, animals, and minerals. This began to change after 1771 when a British chemist treated indigo, a natural dye, with nitric acid and created a beautiful yellow compound. Called picric acid, the compound was able to stain fabrics a strong yellow hue but had the unfortunate property of being explosive.



picric acid

Then in 1856, William Perkin, an 18-year-old English chemist, produced the first practical synthetic dye. Called aniline purple, or mauve, it was synthesized from coal tar (see sidebar).

Soon vivid colorings were being synthesized from coal tars, and later from petroleum, the current source of most dyes. These synthetic dyes have many advantages over natural ones; they are inexpensive, vibrant, and long-lasting. Their colors are consistent, as opposed to natural colorants, which may vary from batch to batch. Initially, synthetic dyes were used indiscriminately in foods and other consumer products. After the passage of the Pure Food and Drugs Act in 1906, government regulators began to take a closer look at them, and their numbers were trimmed down, as more of them were banned from use in food.

Modern dyes and lakes

Today, the United States Food and Drug Administration (FDA) allows only seven synthetic dyes to be used in foods, and one of these, erythrosine (FD&C Red No. 3), is questionable because it has been shown to cause thyroid cancer in rats. Each of the dyes is a single, complex organic molecule with a simple FD&C (Food, Drug, and Cosmetic) name: Red 3, Red 40, Yellow 5, Yellow 6, Blue 1, Blue 2, and Green 3. A sample of each batch must be submitted to the FDA for analysis and certification. They are used either as water-soluble dyes or as "lakes," which indicates that the FD&C dye is adsorbed onto aluminum hydroxide and dispersed throughout the food. Lakes are used when you want to color some oil or otherwise nonpolar food, or to prevent bleeding, such as in a candy cane where the colors need to be in highly defined stripes.

Beginning in 1981, the FDA required food manufacturers to list tartrazine (Yellow No. 5) on labels because of the link between the dye and health problems, including itching and hives. Today, all FD&C dyes are required to be listed by name on food labels.

Linking dyes to health problems

As long ago as the 1950s, allergy journals have published information on health effects that can be triggered by artificial food coloring. These include hives, asthma, headaches, as well as learning and behavior problems, including hyperactivity, in children. Studies have linked petroleum-based dyes to cancer, DNA damage, reproductive damage, and neuromuscular damage, as well as behavior and learning disorders. Back in 1977, Dr. Herbert Levitan of the University of Maryland found that the dye Red No. 3 interfered with the transmission of nerve impulses to the muscles in frogs.

In 1985, the American Academy of Pediatrics Committee on Drugs published a report on the side effects of the synthetic dyes used in medicines. These colorings are typically referred to as "inactive" ingredients. The major reactions reported were hives, edema (excess fluid), bruising, rhinitis (inflammation of the nose), anaphylactoid (hypersensitive allergic) reactions, and various respiratory problems.

Synergistic effect

More recently, researchers at the University of Liverpool exposed nerve cells from mice to combinations of widely used additives and measured the resulting growth of the cells. Unlike most studies that select a single additive, the British scientists used combinations of two additives: blue dye plus MSG (monosodium glutamate) and yellow dye plus the synthetic sweetener aspartame.

They found that the effects of the blue dye plus MSG were up to four times as toxic, and the effects of the yellow dye and aspartame were as much as seven times as toxic as when they were tested individually. This is known as a synergistic effect—"the effect of the whole is greater than the sum of the parts"—the effect of the combination is greater than the sum of the individual dyes' effects.

Behavior problems

Parents and teachers have long suspected that artificially colored foods set some children off and point to the day after Halloween as a time when normal children can be transformed into small monsters. Although sugar is often blamed and has not been conclusively ruled out, dyes and synthetic flavorings may very well be major players in Halloween hangovers.

Discovery of Mauve

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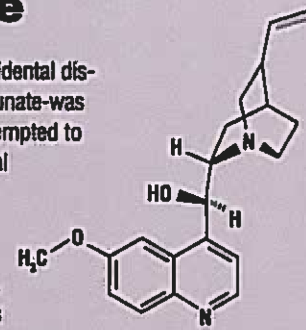
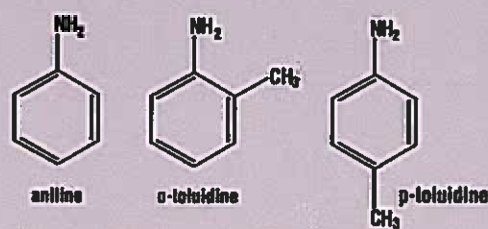
William Perkin in his later years.



quinine

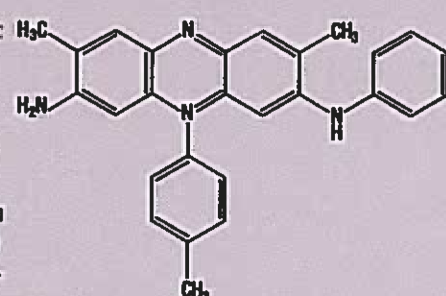
Serendipity -the accidental discovery of something fortunate-was Perkin's fate when he attempted to synthesize the antimalarial drug quinine but instead discovered mauve. The total structure of quinine was unknown at the time. The teen-aged Perkin was making a calculated "shot in the dark" approach to preparing the drug by oxidizing a mixture of compounds which resulted, not surprisingly, in a thick, black sludge.

But Perkin's curious nature helped to turn a failed synthesis into a discovery with very far-reaching implications. He astutely noted a hint of purple color in the sludge, and after adding ethanol to the mixture and filtering, the black goop was left behind and a fantastic purple color came through. He named the brilliant purple compound aniline purple (later called mauveine, or mauve), and the first synthetic dye was made. It was an instant commercial success.



The mixture of compounds oxidized by Perkin.

Perkin started with a mixture of the compounds aniline, o-toluidine, and p-toluidine. His product was therefore a mixture also, but the predominant compound was mauveine. The consequences of Perkin's discovery were far-reaching: For one, he showed the world that studying chemistry could be very profitable (he quit his quinine research and became a very wealthy businessman in the dye industry) and that approaching chemistry from a structural viewpoint was extremely important. His was the first true multistep synthesis of an organic compound, paving the way for the synthesis of many other dyes from coal tar. More importantly, the young Perkins' work kicked open the doors to the field of organic synthesis, and countless numbers of important organic molecules have been synthesized since.



mauveine

Many studies have linked dyes with behavior problems, and even children who are normally calm have been found to be adversely affected by the FD&C dyes. In 2004, researchers in Southampton, England, found that a modest amount of food dye (20 mg, about the amount needed to color one teaspoon of frosting), along with the preservative sodium benzoate, caused one child in four to clearly exhibit disturbed behavior. Reactions to the additives included disturbing others, difficulty settling down to sleep, poor concentration, and temper tantrums. None of the 277 preschoolers had a history of hyperactivity. According to the British Food Commission, this was the first time a UK government-sponsored scientific study has corroborated a link between food colorings and preservatives and changes in children's mood and behavior.

Schools that remove synthetic dyes and other additives from their food report that not only does behavior improve, but test scores rise. A study of 803 New York City public schools found that removing artificial colors, flavors, and preservatives from the school food resulted in a dramatic rise in test scores.

Natural alternatives

The ancient technologies of extracting colorings from natural sources are receiving renewed attention as the FDA dyes become linked with numerous problems, and more consumers seek out natural alternatives.

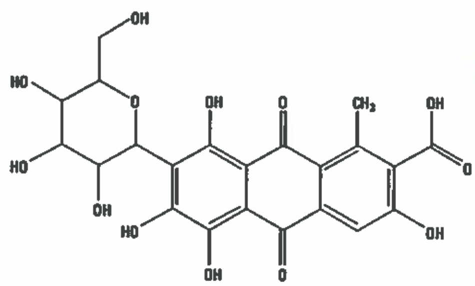
R. SILVA

Cochineal infested prickly pear cactus.

Natural dyes are much more expensive than their synthetic counterparts, but they are being used in a growing number of products from jelly beans to lollipops to Sundrops, a natural version of M&Ms. These colorants are exempt from FDA certification and fall into one of two categories: natural and natural-identical colors. Natural colors are derived from natural sources. Paprika provides coloring in hot dogs and cheese puffs. Grape skin extract can make lemonade pink, while annatto and carotene give cheese and butter their varying shades of yellow. Natural-identical colors are synthesized in the lab and are considered chemically and functionally identical to the same colorant found in nature.

Natural ≠ safer

Of course *natural* does not always mean safer, even though this misconception can be pervasive. And although they are often better tolerated than synthetic dyes, natural dyes can be allergens for some people. Natural colorings often do not identify their source, so avoiding them can be difficult both for allergic individuals and for those on a special diet. Vegans and those following a kosher diet need to avoid cochineal (also called carmine), a widely used red coloring, because it is made from insects.

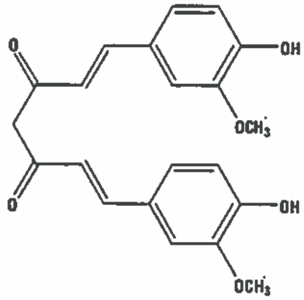


Carminic acid

Natural = bugs!

Cochineal has a long and rich history. It was used by Aztec and Mayan people of South America to dye fabrics and is still used as a fabric dye today. Cortez introduced cochineal to Europe around 1519, but its source was kept secret until the 18th century, in order to protect the Spanish monopoly over this scarlet dye. Later, British soldiers became known as "redcoats" from their cochineal-dyed jackets.

Carmine is the name given to the pigment extracted from the female insects of the *Dactylopius coccus* species (cochineal), which are often found infesting prickly pear cacti. It takes hundreds of thousands of the little bugs to make a pound of dye. The red color is due to carminic acid. The color of the pigment can be altered by changing the pH of its medium; in neutral media, carminic acid is bright red. Under acidic conditions, say a pH of 3, carminic acid is orange, and at a pH above 7, it is purple.



curcumin

MIKE CIESIELSKI

Where do you place bugs on the food pyramid?

Curry = brain food?

Turmeric, the spice that gives mustard its characteristic deep yellow color, contains the active ingredient, curcumin, which has profound anti-inflammatory effects. For thousands of years turmeric has been used in traditional medicine in India and other Asian countries, and it is a major ingredient in curry.

Researchers in Singapore have found that elderly Asians who consume curry have better cognitive performance than their counterparts who don't eat it. Recently, curcumin has attracted the interest of Western researchers, and it is being studied as a possible treatment for many health problems, including cancer, cataracts, and Alzheimer's.

Apple POP

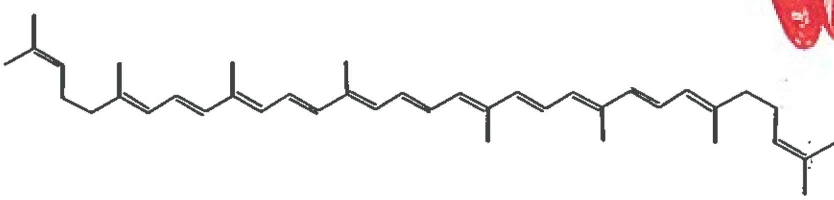
Phloridzine oxidation product, also known as POP, is not yet a household word, but it could become an important product for the millions of people who have adverse reacphloridzine + oxygen + polyphenoloxydase (enzyme) → POP

tions to tartrazine, also known as Yellow No. 5. POP may soon replace tartrazine in many products, as tartrazine has been shown to provoke asthma attacks, urticaria (hives), and has been linked to aspirin sensitivity; it is already banned in Norway and Austria.

A long-time byproduct of the cider industry, POP is created when apples are pressed in the presence of atmospheric oxygen.

A compound in apples called phloridzine reacts with O_2, and an enzyme called *polyphenoloxydase* catalyzes the reaction. POP is a bright yellow naturally occurring substance that can be used in both foods and cosmetics. And whereas the azo dyes, such as tartrazine act as pro-oxidants, POP has natural antioxidant properties, so it should not need the chemical preservatives that are sometimes added to synthetic dyes.

JUPITER IMAGES



lycopene

POP can produce vibrant yellow and orange colors depending on the pH of its solution. The spectral properties of POP pigment are stable at a pH range of 3–5, making it ideal for the majority of foods and drinks. POP is highly water soluble, a desirable property of food colorants, and won't stain plastic packaging.

In France, the Institute for Agronomy Research and the cider company Val de Vire are continuing their research on this natural dye and working on ways it can be produced in large quantity.

Have you ever seen a cow give strawberry milk?

MIKE CIESIELSKI

Seeing red

Tomat-O-Red is the name given to a new dye that derives its red color from lycopene, extracted from tomatoes. Lycopene has attracted a great deal of interest because of its antioxidant properties. The Israeli manufacturer, LycoRed, sees a bright future for this new dye as a noninsect-based replacement for carmine.

Researchers at the Chile Pepper Institute at New Mexico State University have been working for more than 10 years to develop a new variety of chili pepper for use as a natural red coloring. Their variety, dubbed "NuMex Garnet," is a paprika that produces more intense color but less heat than other chilis. It has little flavor and odor, and it can be mechanically harvested.

Does it make sense?

Take a look at your lunch today. Did you ever stop to think about why the food you're eating is the color it is? How about that mac and cheese they're serving for lunch at school? Why is it yellow? It's just macaroni and cheese. You know that cheese comes from milk, and you know what color milk is. How many cows give pink milk? And let's not get started on green ketchup and green applesauce. What are those blue globs in the "blueberry" muffin mix? A well-known brand of instant "strawberry" oatmeal actually contains chopped-up apples that are dyed pink. We should take the time to consider the foods we eat each day.

You might be inspired to see whether your supermarket will let you pay for fake food with fake money from your Monopoly game. Since that's unlikely, take a hard look at the colors of foods and ask yourself if they make any sense. Check ingredient labels and decide for yourself whether the food is healthy. And if it isn't, is it worth the risk? When you avoid unnatural foods, you'll see that real food tastes real good.

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Additional references may be found online in the Teacher's Guide for this issue.

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