Coloring Foods & Beverages

Natural and synthetic colors play several roles in foods and beverages. Here's how they are regulated in the United States.

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Color is the first notable characteristic of a food and often predetermines or "colors" our expectation. We use color as a way to identify a food and a way to judge the quality of a food.

Studies demonstrate that color predetermines our expectations of flavor and taste. Consumers perceive that yellow goes with "lemon" and pink goes with "grapefruit." Reversing the colors changes the perception. Consumers either misdiagnose yellow tangerine flavor and orange raspberry flavor or deem them inferior to the correct match. Color also affects the apparent level of sweetness. Consumers perceive a strongly red-colored strawberry-flavored drink to be sweeter than a less strongly colored version. And we often forget that "color" includes white, black, and gray.

Color additives reinforce the colors already present in the food and ensure uniformity of the food from season to season and batch to batch. They also add color to "virtually colorless foods," such as red raspberry sherbet and provide a dramatic color to "fun foods," such as candies and holiday treats.

Until the mid-1800s, the only external sources of colorings used in foods were natural: animals, vegetables, and minerals, including saffron, carrots, mulberries, flowers, and copper and iron ores. The first synthetic dye derived from organic coal tar entered the artistic palette in the latter part of the 19th century and first appeared in butter and cheeses. Demand increased for more varieties and more-stable and vivid colors, as more and more processed foods fed our growing nation. Refrigeration, canning, dehydration, smoking, bottling, and exposure to light, air, moisture, and temperature extremes all tend to alter the natural color, making color additives a hot commodity to restore expectations. Like most good things taken too far, it was easy for the unscrupulous to use unsafe or intentionally deceptive colors to hide poor quality and to pass off imitation as real.

Certified (Synthetic) Colors

The first synthetic organic dye, a purplish lilac color, was discovered in 1856 by William Henry Perkin and called "mauve." Over the next 50 years, scores of similar organic aniline dyes, representing every color and tint of the rainbow, were developed, and many were used to color food with little thought or testing regarding their safety. Significant toxicity of many early aniline and coal-tar based colors prompted regulators to examine exactly what was being used to color food.

Of the 80 synthetic food colorants sold in 1907, only 16 were deemed to be "more or less" harmless. By 1907, this list was pared to seven synthetic colorants, which eventually were subjected to "batch certification" to detect and limit toxic impurities. The list of "certified" colors has expanded and contracted over the decades to the current group of nine certified colors chemically classified into four chemical families: azo, xanthene/fluoroscein, triphenylmethane, and sulfonated indigoid (Table 1).

Synthetic certified colors remain the most popular type of food colorings, as they are brighter, more uniform, better characterized, and of higher tinctorial strength, encompass a wider range of hues, and are less expensive than colors derived from nature. The downside to working exclusively with synthetic certifiable colors is use limitations based on amounts added

Colors help consumers identify products, as illustrated by Glacéau's use of colors to differentiate its 13 *vitaminwater*™ nutrient-enhanced water beverages.

via good manufacturing practices and the perceived "baggage" the synthetics add to an ingredient label.

To protect the public health from toxic impurities, each batch must be rigorously examined and "certified." It cannot be used in foods and must be stored separately from certified batches until certification is complete. Upon certification, the Food and Drug Administration issues a certificate with a unique lot number and allows the industrial or common color name to be changed to the mandatory Federal Food, Drug, and Cosmetic Act designation, such as FD&C Red No. 40.

Certification applies to both domestic and foreign manufacturers, requiring that every "lot" of color be submitted as a batch sample to FDA and extensively analyzed by sophisticated techniques to ensure that it meets established specifications for residual contaminants, heavy metals, pesticides, and unreacted contaminants.

If a color requiring certification has not been certified and is used in food, the food will be deemed adulterated and subject to seizure.

More than 17.2 million lb of synthetic food colors were certified in 2004 (FDA, 2004). FD&C Red No. 40 is the most popular certified food color, followed by FD&C Yellow No. 5. The acronym FD&C indicates that these colors are approved by FDA for use in coloring foods, drugs, and cosmetics. Colors in a more-limited category, D&C, are considered safe to use with drugs and cosmetics. Colors in a third category, Ext. D&C, are only certifiable for external use in drugs and cosmetics, not to be taken orally or applied to mucous membranes.

Table 1—Colors certified for use in foods. From CFR (2004d)

Certified color name	Common or industrial name (hue)	Uses and restrictions	CFR regulation
FD&C Blue No. 1	Brilliant Blue FCF (brilliant blue)	Foods generally	74.101
FD&C Blue No. 2	Indigotine (royal blue)	Foods generally	74.102
FD&C Green No. 3	Fast Green FCF (sea green)	Foods generally	74.203
Orange B	—	Casings or surfaces of frankfurters and sausages	74.250
Citrus Red No.2	—	Skins of oranges	74.302
FD&C Red No. 3	Erythrosine (cherry red)	Foods generally	74.303
FD&C Red No. 40	Allura Red AC (orange-red)	Foods generally	74.340
FD&C Yellow No.5	Tartrazine (lemon yellow)	Foods generally	74.705
FD&C Yellow No.6	Sunset yellow (orange)	Foods generally	74.706

Certified colors in all three categories may be used as dyes or converted to lakes. Dyes will dissolve in water and can be manufactured as a powder, granule, or liquid. They are often used in aqueous beverages, dry mixes, confections, and dairy products. Lakes, on the other hand, are prepared by precipitating the soluble synthetic dye onto an approved insoluble base or substratum. For FD&C colors, the base is aluminum hydroxide, with an aluminum cation serving as the precipitant, such that the color adsorbs onto the surface of aluminum hydroxide, which is then dried and ground to appropriate fineness. The advantage to the food manufacturer is that the lakes are insoluble in most nonaqueous solvents. They provide opacity, can be used in dry products, have significant stability to heat and light, and are the only colorants suitable for fats, gums, waxes, oils, and food-packaging materials. Unlike colors that dye a food via adsorption or attachment from the solution to the food material, lakes impart color by dispersing into the medium.

Exempt (Natural) Colors

Natural colors have always been part of the diet. They have been isolated and added back to foods for the same reasons as the certified colors—identity and appeal. Chlorophylls, carotenoids, and anthocyanins are consumed in the foods we eat every day. Common natural colorings include annatto, saffron, paprika, grape skins, zinc oxide, caramel, beetroot, cochineal, and turmeric (Table 2). FDA uses the term "exempt color additives" to indicate that they are exempt from the certification process. From the United States regulatory perspective, for the remainder of this article "exempt" will be used instead of "natural" when referring to these types of colors.

Exempt colors need to be used at higher levels than their synthetic brethren. As a consequence, they may unexpectedly change the texture, odor, or flavor of the food. They are less stable and less consistent, causing the food at times to be unacceptable to the consumer. Exempt colors are often duller, more pastel, and more easily affected by the food matrix, pH, salts, vitamins, flavors, and other factors. They are also more likely to be contaminated with undesirable trace metals, insecticides, herbicides, and bacteria.

Nevertheless, exempt colors are perceived by the consumer as being less of a health hazard than the petroleum- (coal-tar-) derived synthetics, with names like tartrazine, indigotine, and erythrosine. Exempt colors add a cachet to food products marketed as "natural" and "organic" that the growing population of health-conscious shoppers seek.

An interesting ancillary use for colors derived from natural sources is that many are bioactive. The antioxidant effects of many green, red, yellow, blue, and orange fruits and vegetables derive from their indigenous and quite-vivid bioactive colors, such as astaxanthin, lycopene, lutein, anthocyanin, and beta-carotene.

Many more plant colors will be isolated and added to the portfolio of both functional antioxidants and color-imparting substances in the future. It must be noted, however, that certified synthetic colors are approved for use in all foods to which they can technologically be added, constrained in each food only by limitations of good manufacturing practices. In contrast, exempt colors may be limited to certain applications, such as ferrous gluconate in black olives and iron oxide in sausage casings.

Table 2—Colors exempt from certification. From CFR (2004c)

Exempt color name	Uses and restrictions	21 CFR regulation
Annatto extract	Foods generally	73.30
Astaxanthin	Salmonid fish feed	73.35
Dehydrated beets (beet powder)	Foods generally	73.40
Ultramarine blue	Salt for animal feed	73.50
Canthaxanthin	Foods generally, not to exceed 30 mg per lb of solid or semisolid food or per pint of liquid food; broiler chicken feed; Salmonid fish feed	73.75
Caramel	Foods generally	73.85
Beta-apo-8′-carotenal	Foods generally, not to exceed 15 mg/lb solid, 15 mL/pt liquid	73.90
Beta-carotene	Foods generally	73.95
Cochineal extract; carmine	Foods generally	73.100
Sodium copper chlorphyllin	Citrus-based dry beverage mixes, not to exceed 0.2% dry mix	73.125
Toasted partially defatted cooked cottonseed flour	Foods generally	73.140
Ferrous gluconate	Ripe olives	73.160
Ferrous lactate	Ripe olives	73.165
Grape color extract	Non-beverage foods	73.169
Grape skin extract (enocianina)	Still and carbonated drinks and ades, beverage bases, and alcoholic beverages	73.170
Haematococcus algae meal	Salmonid fish feed	73.185
Synthetic iron oxide	Sausage casings, not to exceed 0.1% (by weight); dog and cat foods, not to exceed 0.25% (by weight)	73.200
Fruit juice	Foods generally	73.250
Vegetable juice	Foods generally	73.260
Dried algae meal	Chicken feed	73.275
Tagetes (Aztec marigold) meal and extract	Chicken feed	73.295
Carrot oil	Foods generally	73.300
Corn endosperm oil	Chicken feed	73.315
Paprika	Foods generally	73.340
Paprika oleoresin	Foods generally	73.345
Phaffia yeast	Salmonid fish feed	73.355
Riboflavin	Foods generally	73.450
Saffron	Foods generally	73.500
Titanium dioxide	Foods generally, not to exceed 1% (by weight)	73.575
Turmeric	Foods generally	73.600
Turmeric oleoresin	Foods generally	73.615

Labeling

A color additive is any material "that is a dye, pigment, or other substance made by a process of synthesis or similar artifice, or extracted, isolated, or otherwise derived, with or without intermediate or final change of identity, from a vegetable, animal, mineral, or other source and that, when added or applied to a food, drug, or cosmetic or to the human body or any part thereof, is capable (alone or through reaction with another substance) of imparting a color thereto" (CFR, 2004a).

FDA regulations also require certified and exempt colors to be declared as "artificial color" or "artificial coloring" on the food labels. When the term "colorant" is used, the agency is referring to a dye, pigment, or other substance that is used to impart color to or to alter the color of a food-contact material but that does not migrate to food in amounts that will contribute to that food any color apparent to the naked eye (CFR, 2004b).

Although the general public and most food companies and color manufacturers would like to carve the world of food colors into two camps—the benign-sounding "natural" and the pejorative "artificial"—FDA wisely avoids that division.

Since the exempt colors are derived from natural sources via solvent extraction and chemical refinement and many use synthetic stabilizers and preservatives (some beta-carotene is prepared entirely by synthetic processes), they are no longer the innocuous "squeezings" of everyday fruits and vegetables. FDA states that exempt colors, which we think of as "natural," must be labeled as "artificial color" or "color added" or "the exempt color," e.g., "caramel color" or "ferrous gluconate" or "turmeric." The only natural coloring excluded from such labeling is the color from the product itself, e.g., using strawberry juice to color strawberry ice cream pink. If beet juice is used to tint strawberry ice cream pink, it must be listed as a color additive. The term "natural color" is not permitted on the label.

Since the enactment of the Nutrition Labeling and Education Act in 1993, all certified food colors must be labeled by specific name, e.g., "Red 40" or "Blue 1 Lake" or "Yellow 5."

Safety

Color manufacturers must prove to FDA that all coloring used in the U.S. is safe. FDA publishes a "positive list" of safe colors, which includes every compound that can be used. This is the opposite of what is done in some countries—publishing a "negative list," which allows use of all color compounds except those specifically listed as prohibited. The lists of certified and exempt colors are found in Sections 73 and 74, respectively, of Chapter 21 of the *Code of Federal Regulations* (CFR, 2004c, d). Even though the uses of color additives are highly regulated for each country's domestic and export food supplies, the color regulations of most countries will follow those of the three major world markets: the U.S., the European Union, and Japan. All three markets have a positive list for the color additives that are permitted for use, and the colors that are permitted in each market vary considerably. The positive lists in the EU and Japan each contain far more colors than does FDA's positive list. All of the commonly used FDA-exempt color additives are on the positive lists in both the EU and Japan.

That a color is listed in the CFR is not engraved in stone, but is subject to re-review as additional scientific data are developed and sensitive populations exposed. The Adverse Reaction Monitoring System tracks potential public health hazards from the exposure to foods and drugs and has been instrumental in tracking color additive issues (FDA, 1992). By 1986, sufficient reports had been received linking FD&C Yellow 5 (tartrazine) with allergic reactions that FDA required that Yellow 5 be listed on the label, so that sensitive individuals could avoid foods that included the chemical (AAP, 1985). Now all synthetic, certified colors must be listed individually on every food label. The vibrant red color FD&C Red 3 was linked to thyroid tumors in laboratory animals, and although it is still on the permitted list of certified colors, many manufacturers have voluntarily ceased using it.

The FD&C Act provides exemptions for some substances from the definition of a food additive if they meet prescribed conditions and are deemed "Generally Recognized As Safe" (GRAS). The GRAS process puts the determination of safety and safe use concentrations in the hands of external experts convened by the interested food ingredient or finished food manufacturer or a scientific or trade association (e.g., the Flavor and Extract Manufacturers Association does this with regard to flavoring substances).

The majority of recent food ingredients have traversed the GRAS affirmation route, but color additives are specifically prohibited from being determined GRAS outside of the FDA petition process. Therefore, all food colorings must go through a pre-market review and approval by FDA to be included on the positive list.

A food ingredient found to be GRAS for one technological function, e.g., as an antioxidant or acidulant, might also be the subject of a color additive petition if it has the capability or potential to also impart color. And vice versa, if an approved certified or exempt color is found through research and testing to also serve a useful function, e.g., as an antioxidant or acidulant, it may also be the subject of an external GRAS affirmation as a food ingredient for this non-color function.

Trends

Anticipating the direction of color addition to foods and beverages is virtually impossible. Like flavors, colors are used at very low concentrations and are often easily replaced at the final stages of formulation; therefore, they tend to be "tweaked" from test market to test market and from season to season. Bright, vivid, and unusual colors are entering the snack, dessert, and beverage segments aimed at children and young adults looking for fun, excitement, and "extreme" flavor. These strong and/or unusual colors are also used with innovative or exotic flavor blends.

Muted and pastel colors are popular in the spring and summer and as a relaxing change of pace. Exempt colors are used in the fast-growing functional, natural, organic, and vegetarian markets, even though they are often synthetically derived, extracted, or preserved. Food technologists willing to experiment and apply this ever-more-interesting palette of color choices to these and other product segments will always have opportunities to create a signature look.

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Avoiding the Sudan Debacle

During the winter of 2005, food coloring became a "red hot topic" in several corners of the world, most notably in the United Kingdom and China. Sudan "scarlet" dye, previously banned as carcinogenic, had found its way into colorings mixed with curry and chili spices from India and the Far East. In the UK, more than 580 different food products were found to have demonstrable levels of Sudan, resulting in a massive recall and destruction of the affected products.

The recall encompassed not only chili powders, oils, and sauces but also curry powder and Worcestershire sauces—and the multitude of prepared foods and meals that contained those ingredients, such as sausages, chicken tikka masala, vegetable casserole, mustard, and sweet sauces.

In the UK, concentrated chili powder was contaminated with up to 80 ppm of Sudan, and the most egregiously contaminated Worcestershire sauces 3 ppm.

The incidence has been referred to in the European trade press as the "Sudan Debacle," as there is no clear understanding of the cause, and thus solution.

It was unclear whether the contamination was solely from old stocks of chili powder that had entered commerce prior to the EU ban or whether new stocks of chili and/or curry powder without sufficient certification or testing were the culprit.

The "ripple-effect"—others will start to look for Sudan colors—from this primarily UK problem would imply that there are likely to be other ingredient suppliers, and therefore manufacturers, who will discover the presence of disallowed color ingredients. A subsequent story has indicated that Sudan-contaminated chili oils have been discovered in Canada.

The only action a food company can take to prevent such occurrences is to apply the same scrutiny regarding the source and quality of minor ingredients, such as color additives, as is taken for the major food ingredients.