FOOD PRODUCT DESIGN
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Maintaining Color Stability

By Elaine Knehr, Contributing Editor

The color of a food or beverage often determines whether the consumer accepts or rejects the product. Adding color to foods can encourage acceptance by offsetting color loss caused by exposure to light, temperature extremes and/or moisture; correcting natural color variation; enhancing naturally weak colors; providing a colorful identity to products that would otherwise have little color (e.g., gelatins); and supplying a fun look to kid-oriented beverages and candies.

Added food colors can be temperamental, influenced by factors like the product matrix and processing and/or storage conditions. Keeping attractive hues from turning into ho-hum or dingy shades requires a blend of food science, ingredient technology and packaging.

Color categories

Food and beverage designers can choose from a wide array of synthetic and natural colorants to give their products the expected appearance. FDA regulates color additives, which are classified as either certified or exempt from certification.

Certified colors are synthetic organic compounds that have been assigned an FD&C number. Color additives certifiable for foods and beverages are FD&C Blue No. 1, FD&C Blue No. 2, FD&C Green No. 3, FD&C Red No. 3, FD&C Red No. 40, FD&C Yellow No. 5 and FD&C Yellow No. 6. A sample of each batch must be submitted to FDA for analysis and certification. Color suppliers provide these synthetic colors as water-soluble dyes and water-insoluble lakes. Lakes, formed by extending dyes on an aluminum hydrate substrate, color by dispersion and are useful in products containing fats and oils, or in products with insufficient moisture to dissolve dyes.

Color additives exempt from certification consist of what are called natural and nature-identical colors. Natural colors are derived from natural sources like vegetables, minerals and animals. They include carotenoids (yellow to red), anthocyanins (red, purple, blue), caramel color (light yellow to dark brown), turmeric (yellow), annatto (yellow to reddish orange) and carmine/cochineal (pink, red, magenta). Nature-identical colors are produced by chemical synthesis and are considered chemically and functionally identical to the same colorant found in nature. Neither of these terms, however, have any legal standing in the United States. The list of approved colors can be found in Title 21 of the *Code of Federal Regulations,* Part 73, Subpart A: “Color additives exempt from batch certification.”

Even with this comprehensive palette, achieving the desired color in foods and beverages is not a simple task. “The end-product color should be thought about early in the product-development process,” states Owen Parker, vice president, R&D, D.D. Williamson & Co., Inc., Louisville, KY. “Once a product is formulated, it might be difficult to achieve a specific color.”

Environmental elements

Every food and beverage reflects a unique blend of ingredients, chemical attributes (e.g., acidity), processing conditions and packaging. Colorants vary in their ability to function within these diverse elements.

pH. At certain pH levels, some colorants degrade or shift to a different, less-stable color. Most synthetic dyes have good low-pH stability; however, Red No. 3 will precipitate at a pH less than 4.0. “Lakes are stable at a pH between 4.0 to 8.0, but outside that range, a lake’s substrate typically breaks down, releasing the dye and causing color migration,” says Karen Brimmer, application development manager, Sensient Colors, Inc., St. Louis. “In the natural colors, annatto will precipitate at a pH less than 4.0, and carmine breaks down at a pH less than 3.5; however, these colorants can be used in acidic applications by modifying their form. For instance, an annatto emulsion resists precipitation at low pH.” The anthocyanins are most stable and supply red hues at pH less than 3.8, while at higher pH levels, the color is either lost or shifts to unstable blue and/or purplish tones.

Natural colors with good pH stability include caramel color (pH 3 to 10), the carotenoids (pH 2 to 8) and turmeric (pH 2.5 to 8). “Some caramel colors change color strength as the pH increases. However, the color is stable and consistent at a given pH,” says Dave Tuescher, technical director, Sethness Products Company, Clinton, IA.

Candy made with a panned sugar coating demonstrates how the pH of a product can impact color choice. Sugar inversion, which several factors—including low pH—might induce, can cause improper coating crystallization, producing a rough surface. “To prevent sugar inversion, the pH of the colored syrup typically should not go below 4.5,” says Byron Madkins, director food and beverage development and applications, Chr. Hansen, Inc., Milwaukee. “If a natural red color is desired, carmine, for example, would be a better choice than most anthocyanins, since they are most stable at low pH.”

According to Aminah Lewis, food technologist, Colorcon, West Point, PA, “Synthetic colors are often used for panning, since it is easier to get a stable, uniform color than with natural colorants.”

Ascorbic acid. Some synthetic colors, such as Red No. 40 and Yellow Nos. 5 and 6, contain an azo-linkage, two nitrogen atoms with a double bond in between. Ascorbic acid can break this bond, causing the color to fade. “When ascorbic acid interacts with anthocyanins, browning and color loss often occur,” says Thanyaporn Siriwoharn, Ph.D., product development manager, RFI Ingredients, Blauvelt, NY. On the plus side, ascorbic acid is an oxygen scavenger and helps prevent the fading of colors like carmine and beta carotene.

Brimmer notes that ascorbic acid is mainly an issue in beverages, especially those fortified with vitamin C. Solutions include using encapsulated ascorbic acid or natural colorants— generally others besides the anthocyanins, since ascorbic acid tends to degrade anthocyanins.

However, some increased-stability anthocyanins options exist. “We have developed an anthocyanin with better stability in the presence of ascorbic acid,” says Nathalie Pauleau-Larrey, colors engineer, David Michael Europe, Bourg-Les-Valence, France. “Stability is improved by intermolecular co-pigmentation in which the anthocyanin pigment is protected by other components naturally present in the extract, like phenolic acids.”

Heat. Both synthetic and natural colors generally have good heat stability, in particular Red No. 3, Blue No. 1, Blue No. 2, caramel color, turmeric and carmine. Exceptions include Red No. 40 and some of the anthocyanins, which are not retort-stable. A color’s ability to withstand heat is dependent on end-product processing conditions, specifically the temperature, time and point of color addition. “While Red No. 40 breaks down under prolonged exposure to heat, it is often used in products with less-severe heat treatment, like cookies and extruded cereals,” says Brimmer.

Light. All colors, both synthetic and natural, will eventually fade if exposed to sufficient light. Colorants especially susceptible to light include Red No. 3 and turmeric, while annatto, carmine and some anthocyanins have moderate to good light stability. "Caramel colors have good light stability, plus they absorb UV light, which helps to prevent the degradation of UV-sensitive ingredients in a product, like some nutraceuticals," says Tuescher.

Approaches to minimizing light degradation include color encapsulation or emulsions, packaging materials with UV barriers, and shelf-life management. "While the color turmeric can fade in days or weeks in the presence of light, an encapsulated form of turmeric can have a shelf life of a year or more," says Madkins. Red No. 3, often required to achieve shades of hot pink and purple not possible with Red No. 40, is widely used in products like cereals and candies that are packaged in opaque metalized films or other lightinhibiting materials. Anthocyanins are often used in clear-pack beverages with a short turnaround time, as consumers will likely drink the product before noticeable fading or color change occurs.

Oxygen. Colorants like carmine, carotenoids and paprika can fade in the presence of oxygen. Antioxidants like ascorbic acid or tocopherols can improve the shelf life of the color itself and help maintain the desired shade in the end product. For instance, the ascorbic acid in a beverage protects some colors by scavenging residual oxygen.

"Natural rosemary extract has antioxidant properties and is sometimes used to improve the oxidative stability of carotenoids," says Pauleau-Larrey.

Matrix maneuvers

Effective colorants not only supply consistent hues, they also disperse evenly in a product without bleeding or precipitating out over time. Color stability can be affected by the moisture, protein or fat content of the end product. Some colorants are naturally more stable in certain product matrices, plus pigments can be prepared in a variety of forms that ensure uniform and stable dispersion in diverse applications.

While moisture is key to the consistent dispersion of water-soluble colors in food systems like beverages and fruit fillings, available water can have a detrimental effect on the color stability of some products. For example, a multilayered dessert made with water-soluble colorants might experience color migration between the layers. "Lakes are commonly used to prevent color migration in higher-moisture systems, plus they are useful in dry mixes like snack seasonings, or if there is insufficient moisture to dissolve water-soluble colors, such as cookie fillings," notes Brimmer. "Blue No. 2 is not stable in the liquid form or in products with high water activity; however, it works well in products with low water activity, like confections and cereals." Beet color will degrade with moisture—as well as heat—and is not recommended for beverages and fruit fillings. It is an effective colorant in products like dry beverage mixes and frozen novelties.

Some high-moisture applications might require an oil-soluble color to achieve the desired hue. A uniform dispersion can be attained by modifying the color form. "Beta carotene, which is naturally oil-soluble, can be made into a microemulsion that disperses evenly in water," says Siriwoharn. "In a beverage, the microemulsion provides a clear, natural yellow color that will not separate and form a ring at the top."

Product designers also need to remember that proteins have different colloidal charges, notes Parker. "If a caramel color has a charge opposite the protein in the system, it may form a precipitate," he says. "To prevent this, caramel colors are available with different charges for specific applications." For example, soft drinks generally carry negatively charged particles due to tannins derived from plant material, root, bark, etc. Using a negatively charged caramel color prevents the formation of a haze, which can occur when tannins react with a positively charged caramel.

The water-soluble form of annatto is especially suited to coloring cheese and is often chosen for dairy-based products. “Annatto is unique in that, during cheese manufacturing, it inherently binds to the protein in the curd and does not wash away with the whey like other water-soluble colors,” says Madkins.

Achieving uniformly colored, fat-based systems frequently requires modifying the form of the color. Many colorants are naturally water-soluble, including synthetic dyes and various natural colors, which are usually extracted from an aqueous environment. Oil-soluble and/or oil-dispersible options include synthetic lakes; carmine (the lake form of cochineal); naturally oil-soluble colors like annatto, carotene and paprika; and emulsions of water-soluble colors.

Ironing out metal issues

Metal ions, added to fortify a food or beverage, or possibly present in trace amounts in an unpurified water source, can degrade some colorants. For instance, iron reduces azo dyes like Red No. 40, and Yellow Nos. 5 and 6, while calcium ions can form insoluble complexes with annatto and carmine. Solutions include choosing a metal-resistant color, effective water filtration and possibly the use of chelating agents, such as EDTA.

“Anthocyanins like sweet potato and red cabbage have good resistance to metals and can be used to provide a stable, natural red color to a fortified beverage,” says Madkins.

A matter of microbes

Microbial growth presents another risk to end-product color stability. In certain situations, microorganisms will reduce some azo dyes like Red No. 40, resulting in color loss. “This might occur if a consumer uses old milk to prepare a product,” explains Brimmer. “For example, a dry pudding mix might use Blue 1,Yellow 5 and 6, and Red 40 to produce a chocolate shade. If made with milk near the expiration date, Red 40 might degrade during refrigeration of the prepared pudding, resulting in a green-colored product. To ensure the targeted end color, Red No. 40 could be replaced with Red No. 3, carmine or beet juice.”

In applications that use a sugar syrup, Lewis notes, “The level of sugar in the syrup generally retards the growth of most microbes due to high osmotic pressure; however, in rare cases, microbial metabolites may cause a change in pH, which may affect some natural colors, such as anthocyanins.”

Improving stability

Encapsulation is a useful means of protecting colorants from degradation and preventing premature color development. Microencapsulating a pigment in a matrix suitable for a given application improves the stability of the color both in bulk and in food formulations while ensuring end-product functionality. “Encapsulated natural colors have better heat, light and pH stability, which allows the use of natural colors in applications where they typically could not have been successfully used,” notes Madkins.

Advantages of encapsulated colors include longer color shelf life, improved stability over a wider pH range and the prevention of color hydration in the package.

Brimmer notes that encapsulation can help avert premature color development during storage while delivering the intended color upon preparation, such as in a powdered drink mix.

Exploring the box of colors

Some colorants enjoy widespread use in Europe and other countries, but are not permitted, or have limited use, in the United States. Lutein, which is not approved in the United States, is a naturally oil-soluble, bright-yellow color with good heat and pH stability. The marigold extract is used in products like baked goods and beverages. Sodium copper chlorophyllin, a natural green watersoluble pigment with limited heat and pH stability, is approved for use in the United States only in citrus-based dry beverage mixes (not exceeding 0.2% of the dry mix).

It is often said that we “eat with our eyes,” deriving more enjoyment from foods that meet our color expectations. With the wide array of available colorants, products can be designed that deliver and maintain a fresh, high quality appearance.

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