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Undergraduate

TASTING THE RAINBOW: ONE DYE AT A TIME

Alvin Huang

Have a quick look at your food. Is it in a wrapper, in a can, or in a bag? Has it been processed or was it picked from a tree or vine? What are the ingredients on the label? One thing most people take for granted is the color of their food. An apple is red, salmon is pink, and butter is yellow. These are immutable facts that are never going to change. However, food dyes have been a staple in the food industry in the United States for well over a century. The use of artificial food coloring goes back to the late nineteenth century, but government regulation did not come about until the early twentieth century. Subsequent government oversight was enacted in response to the growing concern over the use of food coloring. Today, only certain dyes are allowed under the Food and Drug Administration, which faces an ongoing challenge regarding the regulation of food dyes.

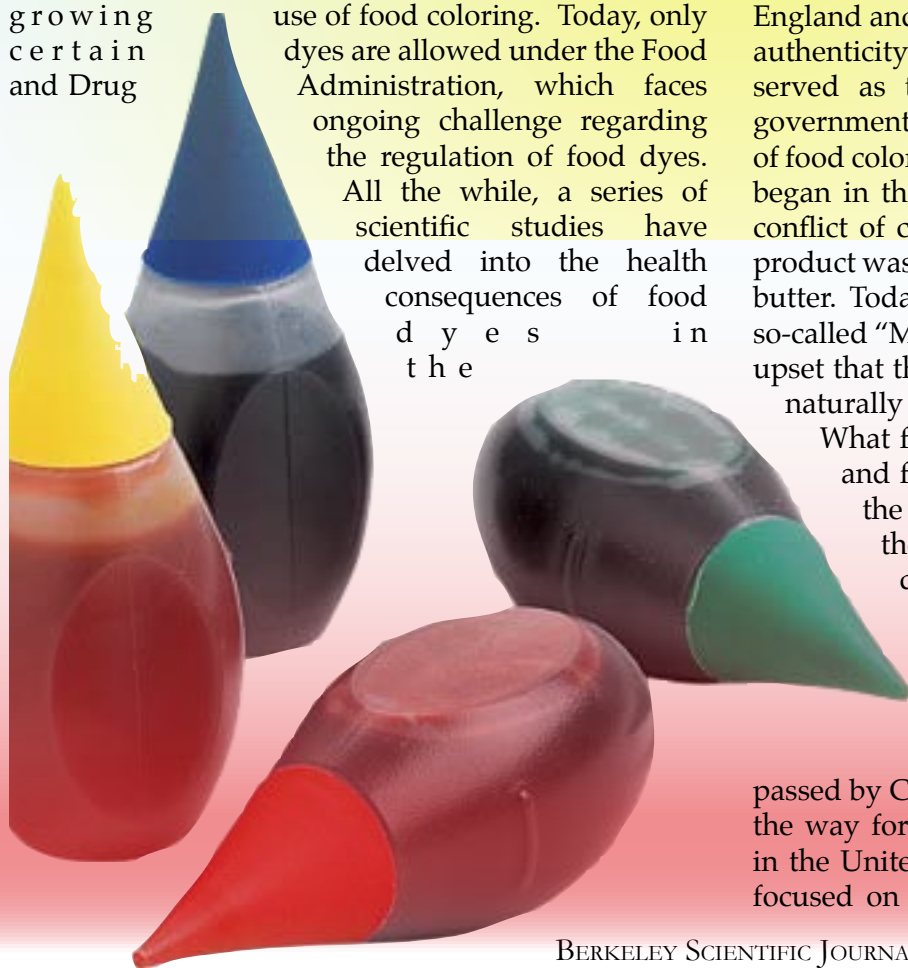
All the while, a series of scientific studies have delved into the health consequences of food dyes in the

food we eat. Food coloring is often forgotten in the larger scheme of one's diet and health concerns, but it remains a factor nonetheless which deserves attention and proper knowledge.

Food coloring has been a part of human food for centuries, though its regulation is more recent. Early records indicate that the Egyptians used food coloring in their drugs as early as 1500 BC. Later records show that the French enacted edicts preventing the coloring of butter and bread during the Renaissance to ensure that the products were not disguised as something else. More modern examples include the coloring of coffee and tea in early nineteenth century England and the subsequent concern for verifying the authenticity of the coffee and tea. This controversy served as the catalyst for beginnings of modern government regulation over food dyes. Modern uses of food coloring and its regulation in the United States began in the late nineteenth century over a curious conflict of coagulated fats. During this time, a new product was created that challenged the dominance of butter. Today, this product is called margarine. In this so-called "Margarine War", the dairy industry became upset that the margarine manufacturers colored their naturally white product yellow to imitate butter.

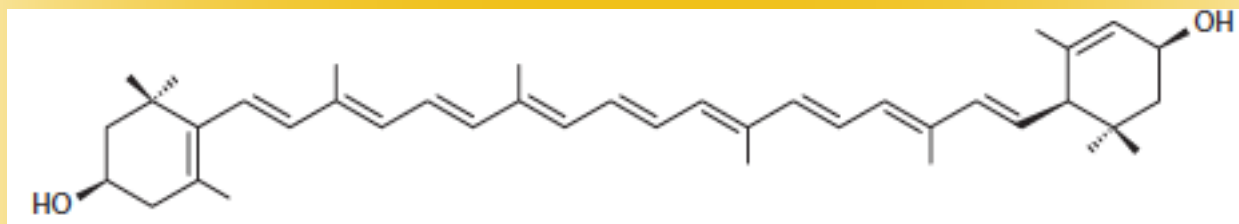
What followed afterwards were a series of back and forth attacks and advertisements between the two sides to convince consumers to buy their respective products. Eventually, the dairy industry petitioned Congress to pass legislation restricting the manufacture and coloring of margarine in the 1880s.

The margarine industry tried to fight back via the Supreme Court, but they could do nothing as the legislation passed by Congress was upheld. This incident paved the way for government regulation of food coloring in the United States. The first major legislation that focused on food regulation was the Pure Food and



Drug Act of 1906, which gave the United States Department of Agriculture the power to regulate the use of poisonous coloring dyes and additional dyes used to mask an inferior quality product. Though the act did not mandate that all food manufacturers must have the Department of Agriculture test their food products for illegal dyes, it brought the issue of food safety to the public eye. Later, Congress increased government regulation of food dyes in the Food, Drug, and Cosmetic Act of 1938. In this law, Congress formalized the definition of food dyes, categorized all food dyes by their legality, and created the modern nomenclature system of food dyes. However, this proved insufficient in preventing trace amounts of poisonous substances from being used in dyes and more legislation was passed. Modern government regulation of food dyes come from the Color Additives Amendments to the Food, Drug, and Cosmetic Act

cheaper and the dyes can be engineered to be more potent and last longer than their natural counterparts. Red dyes are synthesized from anthocyanins and betacyanins. Anthocyanins are a group of compounds whose pigments are range from intense red to dark purple and whose color is mostly determined by pH levels. Anthocyanins are degraded by light and heat and are soluble in both water and alcohol. As a result, anthocyanins are very popular for use in juices, wines, and other alcoholic drinks. Betacyanins also have a red color, but it is at an optimum red at pH 6-7, which makes it great for coloring milk and dairy-based desserts. Yellow and orange dyes are primarily synthesized from carotenoids, but also come from annatto and saffron. Carotenoids are the most abundant natural pigments, which are primarily found in plant tissues and contain beneficial antioxidant properties. These carotenoids are usually found in our foods in



Distinguishing between cis and trans is a matter of the positions of the molecules in a compound. Cis is latin for “on the same side,” and describes molecules with functional groups in the same direction. Trans, or “on the other side,” describes functional groups lying in opposite directions. If focusing on the middle most carbon-carbon bond and taking the long carbon chains to be the functional groups, we can see that this double bond is in trans formation.

of 1938 in 1960. This new amendment gave the Food and Drug Administration complete regulatory powers over all artificial and natural food dyes, including determining legal dyes, their production, uses, labeling, and certification. Modern regulation of food dyes has certainly come a long way from the early days of adulterated coffee, margarine wars, and poisonous additives in coloring dyes (Burrows, 2009).

Current government regulations restrict only a certain group of dyes for coloring food, but this group has many applications in the food industry. Under the Color Additives Amendment of 1960, only a total of nine color additives are allowed in food products. These nine dyes 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, FD&C Yellow No. 6, Citrus Red No. 2, and Orange B. These dyes are used in a wide range of products from juices and teas to flour and brownies to chocolate and cereal (Harp, 2012).

The biochemical aspects of food dyes are integral to how they function and why certain dyes project certain colors. Most modern dyes are artificially synthesized in a laboratory because it is

the form of beta-carotene, an orange-colored chemical that is generally extracted from carrot oil. Annatto yields a yellow-orange color that is due to having a shorter chain of carbons compared to carotenoids and is used more often in baking. However, addition of heat can cause annatto to convert between its cis and trans conformations, which may alter the yellow-orange hue into a reddish pink color. Saffron gives off a bright yellow color due to the crocin pigment and is produced through water or ethanol extraction from fruits. Green and blue coloring dyes are made from chlorophyll and iridoid pigments, respectively. Chlorophyll is soluble in lipids and can react with copper and zinc ions to produce a light-stable green color. Iridoid pigments produce a blue color through the chemical removal of glucose and addition of amino acids to a chemical compound called aglycone genipin. Brown coloring dyes are primarily obtained through caramel. The brown color is created through the absorption of various wavelengths across the visible light spectrum and is generally acquired by heating sugars. Caramel-colored compounds are soluble in water, though they remain stable in alcohol. For these

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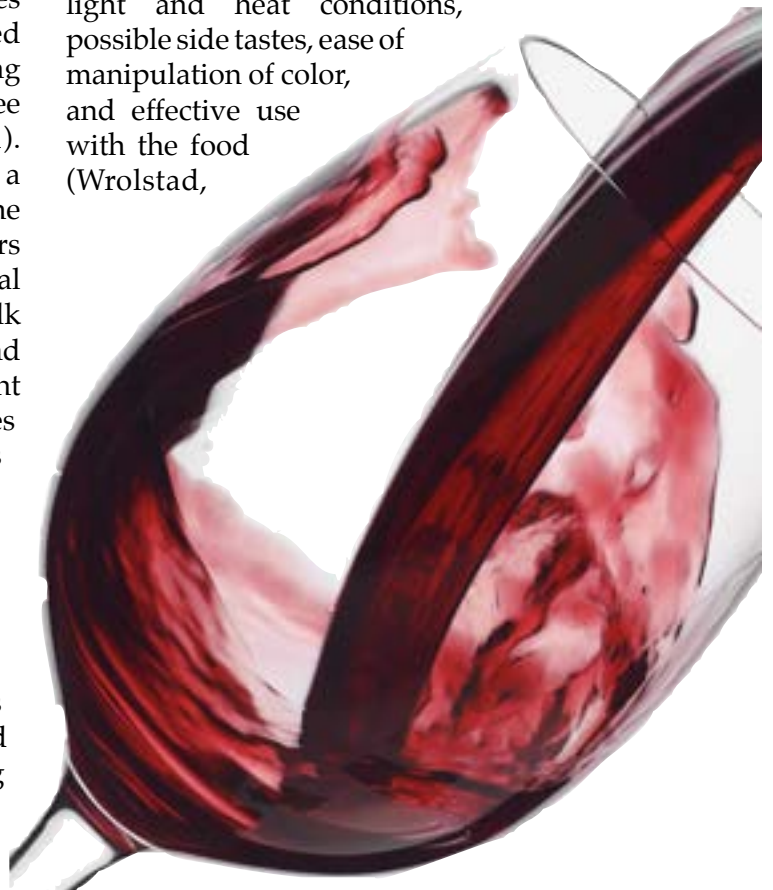
reasons, caramel coloring is widely used in alcoholic beverages and soft drinks. Lastly, black and white dyes are synthesized through various concentrations of other color dyes. Black colors are created with highly concentrated dyes that absorb almost all the light that hits it and allows little to none to bounce back. White colors function in the opposite manner and reflects back all visible light. White coloring dyes can be obtained through titanium oxide, which is used in many desserts and baked goods. These few coloring dyes all determine the various colors consumers see when they go out to purchase food (Wrolstad, 2011).

One application of food dyes is found in a recent patent filed for food coloring in cereal. The patent designs a type of cereal that changes colors upon contact with milk (Farinella, 2005). The original cereal corn starch is coated with one color, but the milk medium will dissolve the outer coat to reveal a second coat of a different color (Farinella, 2005). This patent is a small reminder how prolific the use of food dyes is to our food industry and the ubiquity of food dyes in almost all of our foods. Furthermore, this patent shows how food coloring is used to attract consumers to purchase certain food products, a correlation which has been demonstrated in other studies.

Commercially, colors are an important aspect in convincing people to purchase certain items. In a study conducted by Mielby et al., investigators tried to determine the effectiveness of colors and complexity among fruits and vegetables in affecting the purchasing decisions of adolescents (age 10-16) and adults (age 16 and above). For this study, the term complexity comprises the size, shapes,

colors, and assortment of fruits and vegetables in the photo. Multiple pictures of fruits and/or vegetables were shown to each group. Each picture varied by the size, color, amount, and commonness of various fruits and vegetables. The participants were asked for their personal characteristics such as age, gender, frequency of eating fruits and vegetables, and how hungry they were at the moment when they ranked a series of photos in the order of how appetizing it appeared to them. The results show that the more complex the photos appeared, the more likely adolescents and adults were to purchase the fruits and vegetables in the photo. The finding indicates a strong correlation between visual stimuli in the form of immediate contrasting colors and preference for said stimuli. Furthermore, the study found that adults are more likely than adolescents to be influenced by the complexity of the photo due to prior exposures to fruits and vegetables. In addition, the study shows that women are far more likely to be influenced by the color complexity than men (Mielby et al., 2012). This study illustrates the subtle effects colors play in the minds of consumers when purchasing food and why the food industry uses dyes in almost all food products.

Modern food dye manufacturers and researchers have recently begun exploring the possibilities of more natural colorants. The most important aspect of food dyes for the food industry, aside from price, is their performance under harsh light and heat conditions, possible side tastes, ease of manipulation of color, and effective use with the food (Wrolstad,



2011). The food industry is currently seeking out new and better ways to obtaining the desired color pigments from natural sources to replace artificial dyes. One such example is the use of the alpine bearberry found in the northern regions of the globe that is both sweet and produces a red-blue color. Research conducted by Linderborg et al., states that the alpine bearberry is an abundant source of anthocyanins and packed with glucose and fructose sugars (2011). Due to these properties, the alpine bearberry may find its uses in red-blue coloring dyes in the near future. Additional sources of natural food dyes may appear in the near future as the food industry becomes less reliant on artificial food colorants.

Research into natural coloring dyes is partially driven by the potential safety hazards posed by artificial food colorants. Numerous conducted studies have indicated some possible adverse health effects from the consumption of food dyes. The most urgent concern regarding the use of coloring dyes in food is the possible connections they may have to attention deficit/hypersensitivity disorder, more commonly referred to as ADHD. In an article by Dr. Barbara Wroblewska, she refers to a study by Dr. Feingold in 1973 that first made the claim that “with the great increase in the use of food additives, there also has emerged considerable scientific data linking food additive intolerance with various physical and mental disorders, particularly with childhood hyperactivity and hypersensitivity” (2009). Dr. Wroblewska states that people have suffered allergic reactions to trace amounts of chemical compounds normally found in food coloring and recent research has indicated food colorants play a role in childhood hypersensitivity. However, she cautions individuals and governments from making any definitive connections between artificial food dyes and ADHD as there is not enough concrete evidence to prove the hypothesis. In addition, an article by the American Academy of Pediatrics indicates that studies on the subject done from 1970 to 2009 have

several objective flaws that may alter the conclusions (Kleinman et al., 2011). The paper claims that the sample sizes were concluded to have been too small, and that the changing definition of what a child with ADHD is contributed to inaccurate results. The lack of conformity among the studies brings into question the reliability of their conclusions and the connection between artificial food colorants and ADHD cannot be adequately established (Kleinman et al., 2011).

Nevertheless, any possible correlation between artificial food colorants and ADHD instigates public outcry and government changes in the regulation of artificial dyes. For example, in the United Kingdom, there have been calls on food manufactures to remove all food dyes from their products (Wroblewska, 2009). However, the United Kingdom, the European Union, and the United States have yet to implement any further government restrictions on food colorants due the fact that no studies have conclusively proven that artificial food dyes cause ADHD (Kleinman et al., 2011). While government action and consumer awareness remain the best course of action to control any possible health effects from food dyes, the causal link between artificial food coloring and ADHD remains to be proven.

Food coloring has been used for hundreds of years and is ubiquitous today in all the food we find on the grocery store shelves. Food manufactures have an assortment of dyes to pick from when coloring their food, ranging from artificially synthesized products to naturally obtained dyes. However, there is strict government oversight into what types of dyes that can be used due to questions of safety and quality of the food product. Food dyes have an enormous range of biochemical properties that influence the way they are made and how they are used in food. In addition, modern-day questions of the adverse health effects from having so much artificial dyes in our food remain unanswered. The history, regulation, and science behind food dyes remain one filled with fascination

“The most urgent concern regarding the use of coloring dyes in food is the possible connections they may have to attention deficit/hypersensitivity disorder, more commonly referred to as ADHD.”

and controversy as they progress into the twenty-first century.

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