Permissible Synthetic Food Dyes in India*

Jyoti Mittal

Since prehistoric times, people have been fascinated with colors. From cave paintings to the latest gadgets, color has been a constant companion of humans. Coloring materials aka 'dyes' aren't just for fabrics but have been added to various types of food to enhance their appeal. Evidently, this coloring chemicals have their origin in natural products, which later expanded to the huge market of artificial food dyes. Artificial food colorings have been in the controversy for many years and scrutinized for being possibly linked to cancer, allergies and hyperactivity. Globally, natural as well as artificial dyes are being cautiously researched and regulated by the food safety authorities. In India, the Prevention of Food Adulteration Act, 1954 (now called the Food Safety and Standards Act, 2006), has been implemented for the quality assurance of various types of foods and food products, and only eight dyes have been suggested edible, but within prescribed limits. The present article explores the history and journey of these captivating materials which have been brightening our world for more than 3500 years, along with a detailed overview of their physical and chemical properties, and the usage and toxicity of the eight permissible food dyes in India.

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Keywords
Food dye, synthetic dye, toxicity, food safety and standards act.

Food provides nutritional support and energy to the living organisms. To make food tender and palatable, natural edible resources are usually processed, and their shelf life is enhanced. Sight and appearance of food trigger neurons in the hypothalamus and this plays a crucial role in its consumption [1]. Visuals of the dish can act as an appetite stimulator or depressor and can lead to delight or dejection. Thus the visual appeal of a food product is the primary indicator of its perceived quality rather than its taste,

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touch, or smell and is correlated with the sense 'sight' or color [2]. Whether we realize it or not, the color of the food product makes it cynosure and has similar effects as the kaleidoscope of colors surrounding us. These colors have the gift to affect our emotions and sway our moods in a way that even costly gadgets can't do. Do you observe, a pink-colored room makes a patient calm or red gathers immediate attention being an emotionally-intense color? Red color also epitomes contradictory emotions, like patriotism and anarchy, love and hatred, compassion and war, and many others [3]. Color choice can magnetize and attract a target audience or alienate them.

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The latest researches on color psychology explain the meaning of colors, their role in our lives, their impact on our body and mind, and how to use them to derive maximum benefit. As far as food products are concerned, their colors play a vital role in the choice of the consumer. Colors green, brown and red are more generally acceptable than blue, purple and black. Indeed millions of years ago, when our ancestors were hunting for food, blue, purple and black were considered 'warning signs' of potentially lethal foods. It is also well known that blue color is observed to be an appetite depressant and is rarely used. Thus there is a large array of emotional responses that are associated with colors. Some of these are evident by vague arguments. It is often said, colors are only a perception of an individual and not real. Your own feelings about colors can be very personal. Meanings of colors may have something to do with your choices, past experiences or culture. For instance, while the color white is often used in many Western countries to represent purity and innocence, it is seen as a symbol of mourning in many eastern European countries [3].

Color theory suggests that red, blue and yellow are called primary colors and act as basic building blocks. Mixing these three in equal proportions will give us black while mixing any two will give us secondary colors – orange, green and violet. Mixing secondary colors in different proportions creates millions of colors, each with a unique name, meaning and impact [4]. In chemistry, the chemical added to impart or change the color of a substance is called a dye, which forms a chemical bond with the substrate. Dyes are often considered in reference to clothes, wool, paper or leather, but digestible colors have always been employed in food or drink products and are known as 'food dyes', 'food additives' or 'edible dyes'. Archaeological findings show that color has been in existence since 1500 BC. Earlier colors were derived from leaves, vegetables, fruits, and seeds. For example, extract from black glutinous rice and sesame seeds were used for getting black color; gardenia fruit and turmeric extracts for yellow; beetroot, radish and red cabbage for red and so on. These natural colors were not only meant for coloring but they also possess several biochemical properties [5].

Presently, an astonishing amount of the foods we eat is processed. To prolong the shelf life of food, additives and colors are added, which make them safe and appealing. About 70% of the diet of the average U.S. resident is from processed foods, which is about forty times more than what is used in India [6]. Examples of typical ultra-processed foods are soft drinks, sweet or salty packaged snacks, confectionery, mass-produced packaged bread, buns, biscuits and cakes, poultry, fish and other preserved meat products, instant soups and noodles, industrialized desserts, and packed pizzas, pies and other dishes and meals [7].

Natural colors are safe and sometimes even possess some medicinal qualities. On the other hand, synthetic colors, produced from coal and petroleum, could be harmful. So why use artificial colors? The foremost reason is cost. Synthetic colors can be mass-produced at a much lower cost than natural colors. In addition, the availability of materials to produce natural colors is limited and season dependent. The stability of the color, fastness, vibrancy, hues, and shades desired in the present world cannot be met with natural colors alone. In the past 60 years, the amount of artificial dyes used in food around the world has increased five-fold. Color additives are used in food for many reasons. The addition of color in the food increases its attractiveness, make it look fresh and mask its original color. It also counterbalances the color loss that happens due to exposure to light, air, temperature,

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moisture, storage conditions, etc. Giving an identity to colorless food products can also be the reason for adding color to food [8].

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History reveals that in ancient times, natural colors extracted from vegetables and mineral sources were used to color foods, drugs, and cosmetics. Smoke and aloe extract were used to improve the color and flavor of wines [9], butter, jams, pickles. Nevertheless, large number of inorganic chemicals, like mercury sulphide, red lead, white lead, yellow lead chromate, verdigris (chemical mixture of copper salts of acetate, carbonate, chloride, formate, hydroxide, and sulphate), copper sulphate (blue vitriol or bluestone) and Scheele's green (copper arsenite), etc. were also extensively used as colorants in ancient times [11]. For example, candies were given beautiful vibrant appearance by adding copper sulfate, lead chromate, and mercury sulfide [10]. To enhance the color of tea, cayenne pepper and curry powders, copper carbonate, lead oxide, and mercury sulfide were used, while chalk was added to enhance the whiteness of bread. This adulteration of food products gave rise to strict legislations, like the 1396 French act against the coloring of butter, the 1574 French law against coloring to pastries, and the 1531 German law that provided for the burning of anyone accused of using saffron as a color [12].

In the year 1856, a real breakthrough happened, which is a classic case of serendipity. A teenager, William Henry Perkin, was experimenting at his makeshift laboratory to synthesize malaria medicine 'quinine' from nitrogen-containing chemicals obtained from coal tar as an alternative for the established method of extracting it from the bark of cinchona tree. While cleaning a beaker he noticed that diluting the dark purple sludge with alcohol left a bright purple stain on the glass. He called it Mauveine and filed for a patent. In mid-1800, Mauveine was the only synthetic color on the fabric. It was the first mass-produced dye, which was cheap and commercially available. This opened the doors of a new color industry, and beautiful magenta, fuchsia, violet, blue and green synthetic colors were born from the coal tar in the laboratory. Food industries leveraged this opportunity by replacing toxic minerals and naturally derived products by organic-based synthetic dyes as food colorants [12].

This abrupt change in food colorants posed potential health problems because the safety of these organic coal tar derivatives had not been investigated. H W Wiley [13], who is known as "the father of the pure food and drugs act", brought a law in the United States of America on food safety in 1906, and shipping of meat and meat products containing synthetics dyes, chemicals, or ingredients unfit for human consumption was banned. In other countries also concerns over food safety led to numerous regulations. Interestingly, earlier the procedure was of 'negative listing' meaning the substances were not allowed for use but in the 20th century, a principle called 'positive listing' has been implemented. It implies that substances meant for human consumption have been tested for their safety and that they have to meet specified purity criteria prior to their approval by the corresponding authorities [14].

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The legislation that dealt with food safety in India for a very long time is called the 'Prevention of Food Adulteration Act, 1954' (PFA) [15]. Later, the government of India merged all the older laws related to food, fruit, meat, vegetable, edible oil, milk, etc., into one act for food safety namely the 'Food Safety and Standards Act' (FSSA), 2006 [16]. This act recognizes eight coal tar dyes as safe for use in foods and cosmetics. As far as the usage of food dyes in other countries is concerned, authorities allow only 7 dyes in the United States of America, 8 in Canada, and 15 in several European countries (*Table* 1) [17]. According to the Indian PFA/FSSA, eight synthetic dyes which are allowed to be used as red, yellow, blue and green colors in food are – Brilliant Blue FCF (Blue 1), Indigo Carmine (Blue 2), Fast Green FCF (Green 3), Tartrazine (Yellow 5), Sunset Yellow FCF (Yellow 6), Erythrosine (Red 3), Carmoisine (Red 10) and Ponceau 4R (Red 18). The PFA also prescribes the specificity of these synthetic colors in food items, their maximum permissible limits, and instructions on harmful impurities [18]. Detailing about their general and chemical names, synonyms, color index numbers, E-number, and physical properties like color, molecular weight, sol-

Property	Dye							
	Brilliant Blue FCF	Indigo Carmine	Fast Green FCF	Tartrazine	Sunset Yellow FCF	Erythrosine	Carmoisine	Ponceau 4R
FD&C Name	Blue 1	Blue 2	Green 3	Yellow 5	Yellow 6	Red 3	Red 10	Red 18
Synonyms	Cosmetic Blue LakeModrKysela 9, Intracid Pure Blue	Acid Blue W Carmine Blue Indigo DisulphonateIndigo	Aizen Solid Green FCF 1724 Green	Acid Yellow 23, Filter Yellow, Food Yellow # 4	Orange Yellow S	Acid Red 51 Food Red 14C.I. Food Colour No. Red 14	Azorubine Acid red 14 Brilliant Crimson Red	Cochineal Red A, C.I. Acid Red 18, Brilliant Scarlet 3R New Coccine
Class	Triaryl Methane	Indigoid	Triaryl Methane	Mono Azo	Mono Azo	Xanthene	Mono Azo	Mono Azo
Chemical Formula	$C_{37}H_{34}O_9N_2S_3Na_2$	$C_{16}H_8O_8N_2S_2Na_2$	$C_{37}H_{34}N_2O_{10}S_3Na_2$	$C_{16}H_9N_4Na_3O_9S_2$	$C_{16}H_{10}N_2Na_2O_7S_2$	$C_{20}H_6I_4Na_2O_5.H_2O$	$C_{20}H_{12}N_2Na_2O_7S_2$	$C_{20}H_{11}N_2Na_3O_{10}S_3$
I.U.P.A.C Name	Bis{4-(N-ethyl-N-3-sulfophenylmethyl) aminophenyl}-2-sulfophenyl methylium disodium salt	3,3'-dioxo-2,2'-bis-indolyden-5,5'-disulfonic acid disodium salt	(4,4_–bis–(N–(ethyl–3–sulphobenzyl)–amino–2–sulpho –4–hydroxy–fuchsonium, disodium salt),	Trisodium-5-hydroxy–1-(4-sulfonatophenyl)-4-(4-sulfonato phenylazo)-H-pyrazole-3-carboxylate	Disodium 6-hydroxy-5-[(4-sulfophenyl)azo]-2-naphthalenesulfonate	Disodium 2-(2,4,5,7-tetraiodo-3-oxido-6-oxoxanthen-9-y1) benzoate monohydrate	Disodium 4-hydroxy-3-(4-sulfonato-1-nephthyl azo)-naphthalene sulfonate	Trisodium (8*Z*)-7-oxo-8-[(4-sulfonatonaphthalen-1-yl)hydrazinylidene] naphthalene-1,3-disulfonate
Molecular Weight	792.84	466.36	808.85	534.4	452.36	897.88	502.42	604.46
Color	Blue	Dark Blue	Dark Green	Yellow	Orange	Pink	Red to Maroon	strawberry red
C.A.S. No.	223-339-8	860-22-0	2353–45–9	1934-21-0	2783-94-0	16423-68-0	3567-69-9	2611-82-7
C.I. No.	42090	73015	42053	19140	15985	45430	14720	16255
E-Number	E-133	E-132	E-143	E-102	E-110	E-127	E-122	E-124
λ_{max}	630 nm	610 nm	622 nm	426 nm	480 nm	526 nm	508 nm	505 nm
Solubilityin water	Soluble	Soluble (15 g/l)	Soluble	Soluble (140 g/l)	Soluble	Soluble(120 g/l)	Soluble (120 g/l)	Soluble (100 g/l)
Melting Point	No Sharp Point	390°–392°C.	209°C	> 300 °C (Decomposes at 250 °C)	300 °C	No sharp point	No sharp point	No sharp point
Density	0.20 – 0.70	0.80	No information	1.85 – 1.95	No information	0.80	No information	No information
Permitted Usage	Food, Ingested Drugs, Externally Applied Drugs	Foods, and Ingested Drugs	Food, Drugs, Personal Care Products, and	Foods, Drugs, and cosmetics	Foods, Drugs, and cosmetics	Foods, Drugs and Cosmetics	Foods,Beverages, Externally applied drugs, and	Foods, Drugs and Cosmetics

Table 1. Important facts about food dyes used in India.

ubility in water, melting point, density, the maximum wavelength of absorption of light, permitted usage and permissible limits are presented in *Table* 1.

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The point to ponder is that while buying fresh fruits, vegetables or grains, the best possible alternatives are selected, but processed food is purchased without checking the ingredients, let alone their origin or side effects. These items are bought by simply putting faith in the manufacturer. Of course, rules and regulations help in identifying dyes of the safe zone but on many occasions, such regulations are not followed by every manufacturer. Large industries, which produce foodstuff in huge quantities are regularly monitored and are afraid of stringent action by regulatory authorities if caught. But on the other hand, small units operated in the backyards, rarely abide by these measures. Maybe it is unintentional and due to a lack of knowledge and awareness.

Claims have been repeatedly made that artificial dyes cause serious side effects, such as hyperactivity in children as well as cancer and allergies to all. But this topic is highly controversial and contradictory results have been reported by researchers worldwide. Interestingly, some food dyes are banned in some countries and allowed in others. For example, Yellow 5 and Yellow 6 are dyes permitted to be used in Europe, with warning instructions: 'may have an adverse effect on activity and attention in children'. However, the use of both of these dyes is permitted in the USA and India without any warning. In Britain, McDonald's fries have four ingredients, potatoes, vegetable oil, dextrose, and salt. In the U.S., McDonald's fries have more than 15 ingredients, including disodium pyrophosphate, which keeps the fries' from losing color.

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Permission to use a particular food dye goes through extensive testing for its acute/chronic toxicity, carcinogenicity, mutagenicity, reproductive toxicity, absorption in the body, and so on. These tests are performed not only on small rats but also on larger animals like rabbits, dogs, and pigs, whose physiology resembles humans [19, 20]. These time consuming and cumbersome tests then provide the 'Acceptable Daily Intake' (ADI) of the dyes expressed as mg/kg of body weight. ADI indicates the amount of food additive that can be consumed daily throughout life without posing an appreciable risk to consumer health [21]. Furthermore, given the low rate of absorption, harm to human health is unlikely. These tests on determining the maximum allowed dosage and their side effects are only focused on body weight, not on the age of the kid/person. This needs to be mentioned here because children are more fascinated by bright and vivid colors, and food companies to boost the sales especially focus on coloring kid's food with extremely dazzling colors so as to captivate their attention.

Almost 45 years ago, in 1973, Benjamin Feingold presented extensive research to the American Medical Association relating food additives to learning and behavior disorders, which were later linked to Attention Deficit Hyperactivity Disorder (ADHD) [22]. Effects of more than 3,000 different food additives were tested on 1,200 individuals, but his work was not only disproved but also mocked upon. Feingold suggested that a diet free from these additives had a significant decrease in symptoms of hyperactivity, and more than 50% of the people benefitted from it. A large number of studies were performed on detecting the severity of this allegation, out of which three studies done in Southampton University, showed for the first time, conclusively and scientifically, the dark side of these dyes [23–25]. In each of the study, more than 100 children of different age groups were monitored for irritability, restlessness, and sleep disturbance, by elimination and then the resumption of a particular additive.

Symptoms of ADHD include hyperactivity, low frustration tolerance, impulsivity, and lack of attention. ADHD is a quantitative diagnosis, like hypertension, and the symptoms of some persons, who are near the verge, may aggravate even by small ingestion of these additives. Recent data suggest a small but significant harmful effect of edible dyes on children's behavior that was not previously recognized with diagnosable ADHD. Thus food dyes appear to be more of a public health problem than an ADHD problem [26].

Food safety authorities keep re-evaluating the safety concerns of all synthetic dyes and revising the ADI values according to the available literature and clinical studies. This is important because ADI has several constraints, like intake of one single additive by a healthy person and not in mixture with other additives, change in the eating pattern with the progressing years, etc.

Food safety authorities keep re-evaluating the safety concerns of all synthetic dyes and revising the ADI values according to the available literature and clinical studies. This is important because ADI has several constraints, like intake of one single additive by a healthy person and not in mixture with other additives, change in the eating pattern with the progressing years, different types of diets in countries, and also the allowed additives and dosage in these countries. Importantly, there are new studies demonstrating that children may actually consume more colored foods than expected by the regulatory authorities. For example, in the USA, the amount has risen from 12 mg/capita/day in 1950 to 62 mg/capita/day in 2010 [27]. Further investigations are highly necessary because the usage is not limited to one or two additives in a product. To arrive at the desired taste, color, state, preservation, etc., several additives are being used in combination. For example, a popular brand of fruit-flavored candy, with their tagline as 'taste the rainbow', contains more than 18 ingredients, namely hydrogenated palm kernel oil, sugar, modified corn starch, citric acid, tapioca dextrin, corn starch, carnauba wax, natural and artificial flavors (not revealed, supposed to be a trade secret), artificial food colors (Yellow 6 lake, Red 40 lake, Yellow 5 lake, Blue 2 lake, Yellow 5, Red 40, Yellow 6, Blue 1 lake and Blue 1) and ascorbic acid [28]. Every component, even if explored independently, is suspected to be cause of some health issue, like hydrogenated palm kernel oil can cause colon cancer, high blood pressure and obesity; dextrin and corn starch could be the reason of allergies and so on. Gelling together so many constituents and then heating, molding and preserving them, could cause unimaginable reactions and subsequently effects that is quite hard to imagine [29]. Food authorities makes the listing of ingredients on products mandatory but it doesn't makes it less dangerous, only avoidable for those people who are aware and care to read them. The food industry must be held accountable for the constituents they use and strong impediments are needed to keep these insalubrious components at bay.

The current status of evidence is inconclusive but still noteworthy. It clearly asserts that even if synthetic food colors are not the reason for ADHD in children, it still contributes significantly to pushing them towards it. Throughout the twentieth century, activists have continuously raised their voices against using chemical additives, and consequently, several reputed manufacturers have responded to their demands. For example, Nestle, General Mills, and Kraft Food Group have agreed to phase out artificial colors from their products. This spirit should get into other manufacturers, and our goal should be to eliminate the menace of synthetic dyes from our diet and all the food products. Surely, the shift from synthetics dyes – much simpler, cheaper, brighter, and versatile products – to natural dyes is a big challenge for the food industry, and more serious efforts are required to suggest new cost-effective natural alternatives. If achieved, this will safe-

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guard the tender health of future generations and protect them from unwanted diseases.

Since food adulteration directly affects public health, policymakers must address this issue more seriously, and the use of toxic dyes in the food industry should be treated as a public health hazard. A national campaign is needed to educate children, youth, and their parents to avoid the use of harmful additives and colors and consumption of food with such additives. Law enforcement agencies should play a prominent role, and more stringent action is warranted for the prevention of food adulteration. This is mandatory for building a healthy nation and economy.

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