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Review Article

Natural Colorants: A Perfect Substitute of Synthetic Colorants

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ABSTRACT

Nowadays due to increasing demand of the food colors various companies are using food colorants to make their food more merchandisable and marketable. Various types of colorants are available in the market as coloring agents which are commonly used in food industries, some known synthetic colorants include brilliant blue, indigo carmine, citrus red, fast green, erythrosine, and allura red. The main food bio-colorants are carotenoids, flavonoids, anthocyanins, chlorophyll, etc. There has been a rising safety concern and health implications of the use of food colorants s in human diets. Consumer demand for natural colors is enhanced as awareness about various toxic traits of synthetic food colors come to be known. This article examines the concerns related to the over usage of synthetic colors that can cause harmful effects on health such as allergy, hypersensitivity, and even cancerous growth. Furthermore, we have emphasized on using natural colorants in food industry as not only have coloring properties, they have also been found to possess number of pharmacological properties such as anti mutagenic, anti-inflammatory and anti-neoplastic, and anti-arthritic effects.

Key words: Chemistry, Food colors, Food industry, Natural colorants, Synthetic colorants.

1. INTRODUCTION

Color is the main feature of any food item as it enhances the appeal and acceptability of food recently more and more attention has been paid to the determination of synthetic and organic colorants which are widely used to color food or medicines [1]. The visual aspect plays a key role in the selection of food products by modern consumers [2]. This is due to consumers who always links food with other qualities such as ripeness and freshness. Color additives or colorants are used to make food more appealing and even it always people to identify products on site. Synthetic food colors are available in different shades and they are mostly preferred in food industries. However, there are many reports related to toxicity associated with these colorants [3]. The over usage of these colorants causes pollution [4], disturbs the ecological balance, and causes health hazards to humans [5]. Nature gives a number of compounds which are adequate for food coloring such as the water soluble anthocyanin, beta lains as well as oil soluble carotine oils and chlorophyll. Countless number of plants are used for colorants extraction and are classified as medicinal and some of these have recently been shown to possess remarkable antimicrobial activity, anti-inflammatory, anti-carcinogenic, etc. However, substituting synthetic colors with natural colorants presence a challenge because the color and stability of plant pigments are dependent on various factors such as structure and concentration of the pigment, light intensity, metals, ph, temperature, enzymes, oxygen, sugars [6], flexibility during processing, and long lasting effect. The natural colorants are eco-friendly, harmonized with nature, obtained from renewable sources, and their method of preparation involves minimum possibility of chemical reactions and they are bio disposable [7]. The present review describes the detailed information about basic chemistry of the major pigments and their curative traits found in naturally occurring colorants yielding plants, which are helpful to further development of pharmaceutical expressions.

2. SYNTHETIC COLORANTS: WELL-BEING AND CLIMATE

Colorants are natural mixtures with trademark tones. The compounds owe these characteristic colors due to their ability to absorb light in the visible spectrum (400–700 nm) [8]. Have at least one chromophore (color-bearing group),have a conjugated system, that is, a structure with alternating double and single bonds, and exhibit resonance of electrons, which is a stabilizing force in organic compounds. Their role is to shift the color of the colorants and influence their solubility. Examples of such group include hydroxyl, carboxylic acid, sulfonic acid, and amino groups [9]. Figure 1 depicts some of the synthetic colorants used in food industry.

2.1. Some Examples of Synthesis Food Colorants

Brilliant blue (Blue #1): disodium;2-[[4-[ethyl-[(3-sulfonatophenyl)methyl]amino]phenyl]-[4-[ethyl-[(3-sulfonatophenyl)methyl]azaniumylidene]cyclohexa-2,5-dien-1-ylidene]methyl]benzenesulfonate. This is a commonly used coloring agent however it causes DNA damage and hence poses high risk to humans [10], thus promotion of natural coloring substances is needed and recommended [11].

Indigo carmine (Blue #2): Indi Indigo carmine, or 5,5′-indigodisulfonic acid sodium salt, is an organic salt obtained from indigo by aromatic sulfonation, which renders the compound soluble in aqueous state. It is accepted for use as a food colorant in the U.S and E.U [12]. Blue #

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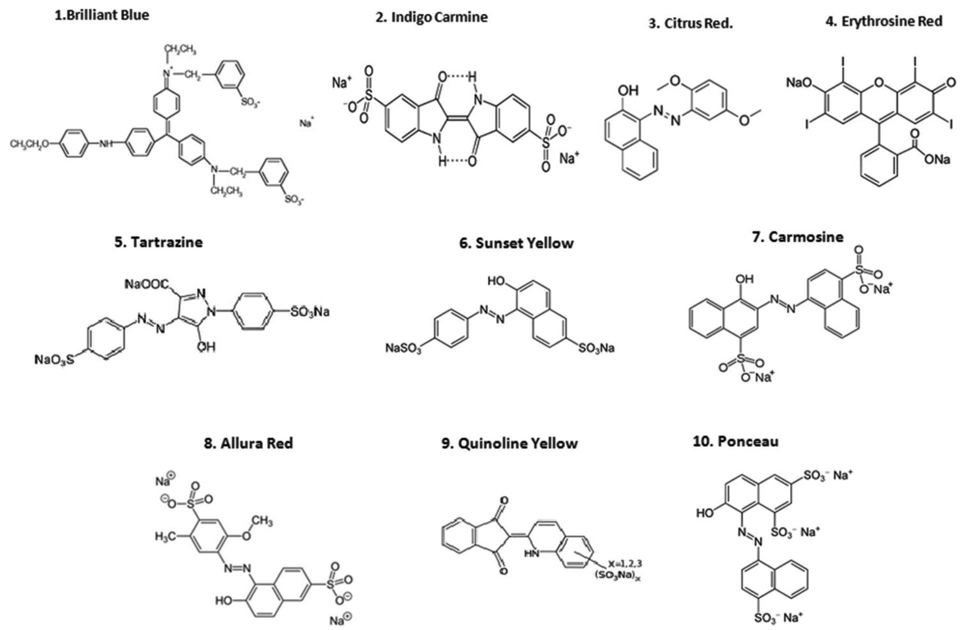

Figure 1: Chemical structures of some popular synthetic food colourants.

2 used in candies, beverages, pet foods, etc., and was linked to brain tumors majorly.

Citrus red #2: 1-(2,5-Dimethoxy-phenylazo)-naphthalen-2-ol. Citrus Red 2 is record by the International Agency for Research on Cancer as a group 2B carcinogen, a substance "possibly carcinogenic to humans" [13]. This colorants is used on peel as well as in the manufacturing of orange juice.

Erythrosine red #3: 2-(6-Hydroxy-2,4,5,7-tetraiodo-3-oxo-xanthen-9-yl)benzoic Found in Cocktail, canned fruits, salads, confections, dairy products, and snack foods. Banned for use in cosmetics and external drug, but not food and ingested drugs in the U.S [14]. Erythrosine exerts cytotoxic and cytostatic effects on human peripheral blood cells [15], and induces endotoxic and mutagenic effects in HepG2 cells [16]. Long-term erythrosine usage influences childhood behavior [17], thyroid function [18], and results in inhibition of drug-metabolizing enzymes [19] and mitochondrial respiration [20].

Tartrazine (E102) FD&C Orange no. 5: Trisodium (4E)-5-oxo-1-(4-sulfonatophenyl)-4-[(4-sulfonatophenyl)hydrazono]-3-pyrazolecarboxylate. Tartrazine provides a lemon color when used in foods, drugs, and cosmetics. For food, it is used to color confections, cereals, snack foods, beverages, condiments, baked goods, powdered mixes, gelatine products, etc., [37] causes hyperactivity, asthma, skin rashes, and migraine and headaches [21].

Sunset Yellow (E110)* Yellow FCF Orange Yellow S: Disodium 6-hydroxy-5-[(4-sulfophenyl)azo]-2-naphthalenesulfonate. Broadly used in almost every type of food preparation such as sweets, jams, soft drinks, candies, ice cream, canned juice, sauces, and pickles [36]. Avoid in allergies and asthma because with other colorants it can cause allergic or pseudo-allergic reaction [39]. Cancer – DNA damage and rise in cancerous cell in animals. Growth retardation and severe weight loss in animals [22].

Carmosine: disodium 4-hydroxy-2-[(E)-(4-sulfonato-1-naphthyl) diazenyl]naphthalene-1-sulfonate. It is used for the purposes where the food is treated at high temperature after fermentation. It causes DNA damage and tumors in animals [23].

Allura red (E129) FD&C Red: disodium 6-hydroxy-5-((2-methoxy-5-methyl-4-sulfophenyl)azo)-2-naphthalenesulfonate. Allura red is used in cereal, beverages, gelatins, puddings, dairy products, frozen treats, powder mixes, icings, and jellies, spices [40]. Causes may worsen or induce asthma, rhinitis (including hay fever), or urticarial (hives) [24].

Quinoline Yellow (E104): Sodium 2-(1,3-dioxoindan-2-yl) quinolinedisulfonate. Typical implementation for quinoline yellow include beverages, confectionery, meat, bakery, dairy fats, seafood, snacks, dry mixes and seasonings, fruit preparation, and convenient food [36]. It causes Asthma, rashes and hyperactivity. It's carcinogen in animals, infect bladder and liver which causes cancer [25].

Ponceau 4R (E124): Conchineal: Trisodium (8Z)-7-oxo-8-[(4-sulfonatonaphthalen-1-yl)hydrazinylidene]naphthalene-1,3-disulfonate. Colorants used in a range of alcoholic and nonalcoholic beverages, and a variety of foodstuffs including confectionary, desserts, cheeses, meats, preserved fruits, and sauces [39]. Causes Cancer - DNA damage and melanoma in animals. Can produce bad reactions in asthmatics [26]. More recently studies carried out by the Center for Science in the Public Interest (CSPI), on food colorants revealed that [27]. Some of the most commonly used food colorants may be linked to numerous forms of cancer.

CSPI reported in their 58-page report, ― Food Colorants: A Rainbow of Risks CSPI revealed that nine of the food colorants currently acclaim for use in the United States are linked to health issues ranging from cancer and hyperactivity to allergy-like reactions, and these results were from studies conducted by the chemical industries.

Similarly in placebo-controlled study conducted in 2007 and published in The Lancet journal [28], the work evaluated the effects of common food colorants found in many soft drinks, fruit juices, and in salad. The results showed that colorants studied caused some children to be more uncontrolled and distractible. As a support to the findings in the Lancet, a research work reported in the Annals of Allergy [29] revealed that 73% children who were suffering from ADHD responded favorably to a diet which artificial colors have been omit. The Lancet study found that E-numbered food colorants cause as much damage to the children's brains as lead in gasoline, leading to significant reduction in their IQ. At the wake of these findings, the British Food Standards Agency (FSA) issued advisory warning to parents to limit their children's intake of food additives. FSA also advised the food industry to voluntarily remove the six food colorants named in the study back in

2009, and replace them with natural alternatives if possible. UK food colorants on which the FSA has called for a voluntary ban include: Tartrazine, Quinoline Yellow, Sunset Yellow, Carmoisine, Ponceau 4R, and Allura Red [30]. However, FDA has approved nine artificial food dyes for use, three food dyes are most commonly used, Red No. 40, Yellow No. 5, and Yellow and Blue No., Green No. And Orange B if used in appropriate amount.

Over time, brighter colored foods were deemed more "natural" than duller colored foods. Unfortunately, this is not the case at all. The issue is that food colorants have negative effects on our environment and health. During production, approximately 10–15% of food colorants are discharged as effluents into the environment [30]. Effluent is liquid waste that is sent to a river or the sea. An example of this can be seen in food colorants factories in China. The river water becomes contaminated with the food colorants discharged from these factories. When farmers try to use the river water to farm, the soil becomes toxic with the chemical waste [31]. Many plants and fish that live in the area surrounding the factory also die because they cannot survive the chemical contaminants that stain the water. According to IntechOpen have reported, "From an environmental perspective, the discharge of colorants effluents from colorants manufacturing or consuming units into the water bodies poses potential threats to the quality of water and induces serious health problems to human, plants, and animal life in particular and aquatic biota in general" [32]. Some colorants are shown to have high mutagenic potential. The mutagenic potential of any colorants is done through the Ames test initially followed by texting on cell lines. Proper genotoxic analysis can help in determining mutagenic as well as the carcinogenic potential of colorants stuff. For azo colorants, a superior modification of Ames test i.e. Prival test is done while performing toxicity analysis [31]. Human exposure to various colorants has shown to increase cancer incidences as well as many other acute and chronic medical conditions. According to various investigations, it is now proven that certain metabolites formed from these organic compounds have high carcinogenic potential [33]. Therefore, it becomes essential to treat water discharged after processing of the fabric. Techniques such as adsorption, filtration, and ozonation should be employed in treating wastewater. Recently many studies indicate the use of micro-organism for the treatment of wastewater specifically used for increasing the yield of degradation. According to a study acetoclastic methanogenic bacteria under anaerobic conditions can be used against azo colorants [34]. Apart from these many studies show the use of different bacteria for oil or effluent degradation. The employment of these organisms is mainly due to its low cost, less maintenance, ease of handling, and better results. Furthermore, apart from treating wastewater, due to the increasing demand for water in these industries, reusing treated water can help meeting the supply as well as the demand. Water quality can be increased by adding secondary and tertiary treatment plans [35-40].

3. NATURAL FOOD COLORANTS: HEALTH AND BENEFITS

They are derived from the natural elements that are pigmented for instance the beta carotene pigment is widely distributed amongst various organic colored fruits and vegetables in results to the pigment that can be extracted from the same. They are derived from seeds, vegetables, fruits flowers and insects etc. Natural colorants (Figure 2) are most commonly used as given as below:

- Carotenoids: These are large class of pigments that can be extracted from plants, algae and photosynthetic bacteria. They are the naturally appealing colorants and their antioxidative and anti-cancer potential are well known. It is also used as the natural preservative in the food industry. Vitamin A is integrated from carotenoids of natural fruits and vegetables. It is vital source for vision immune system and growth. Carotenoid offer red, yellow, and orange color to the products [40]
- Beta – Carotene: These when used as a color at provides yellow to orange color shades. Beta carotene is the most abundant carotenoid and is naturally found in carrots and mangos. It is high grade antioxidant [41]
- Anthocyanins: They are probably the most spectacular of plant pigment, as they are responsible for most of the red, purple and blue pigment of flowers, fruits and vegetables. They are water soluble vacuolar pigments and have color according to the ph of the vacuole. Under acidic condition it gives Red pigment, in the intermediate ph condition it gives Purple/blue pigment and in alkaline condition it gives Yellow/Green pigment [42]
- Turmeric: The turmeric is first boiled in water, dried and then it is ground in deep orange –yellow powder. It cleanses the whole body especially liver, including fighting cancer cells. It is used to support digestion and to treat fever, injection, and inflammation; it

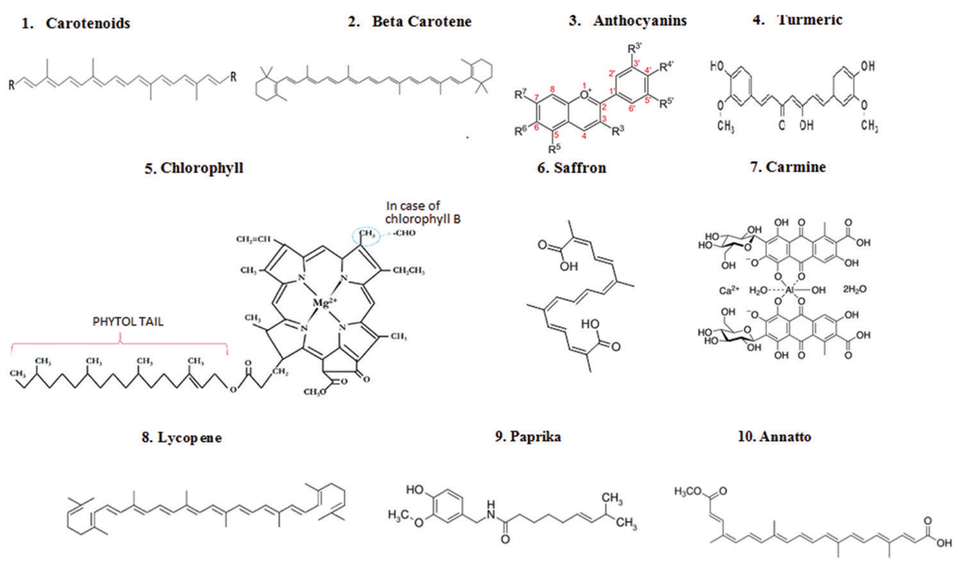

Figure 2: Chemical structure of some popular natural food colorants.

has powerful anti-inflammatory effect and very strong antioxidant. It is also used to color butter, cheese, yogurt, etc. It is used as an herbal medicine for rheumatoid arthritis, chronic anterior uveitis, conjunctivitis, skin cancer, small pox, chicken pox, etc. [43]

- Chlorophyll: The chloroplast of algae and plants contains a green pigment called chlorophyll. Due to this plant absorb energy from light, so it can be isolated and used as food color. Chlorophyll may help heal surgical wounds and prevent infections and also shown potential as a cancer treatment. Other possible health benefits are increased energy, hormonal balance, arthritis, fibromyalgia relief, and weight loss [44]
- Saffron: Saffron is a shade of yellow or orange; it is isolated from the flower of plant crocus sativus. It has large amount of medicinal properties including antineuropathic pain effects, anticonvulsant, and antidepressant. Saffron also serves as an antimicrobial, antibacterial, antifungal, antiseptic, anti-inflammatory, and therapeutic effect against cardiovascular diseases. Various *in vitro* and *in vivo* analysis have provided evidence for the use of saffron/ or crocin derivative of saffron as a chemotherapeutic agent against cancer [45]
- Carmine: It is derived from the insect cochineal which produces carminic acid. It gives deep red colors [46]
- Annatto: It is an orange-red spice and food colorant derived from the seeds of the achiote tree. Useful in diabetes, diarrhea, fevers, fluid retention, heartburn, malaria, and hepatitis [48]
- Paprika: It is derived from Peppers. Useful in it has antioxidant properties, can help reduce the risk of cancer and heart disease, improve immunity, and even alleviate gas [49]
- Lycopene: Lycopene is a natural colorant, useful in preventing heart disease; "hardening of the arteries" (atherosclerosis); and cancer of the prostate, breast, lung, bladder, ovaries, colon, and pancreas.

3.1. Benefits of Natural Food Coloring

As natural food colors are extracted or processed entirely from ingredients such as vegetables, tubers, and fruits which are available in nature. Because of the extracts from the natural ingredients, they also contain certain vitamins, minerals such as antioxidants, anti-inflammatory, and anti-cancer. Other health benefits of natural colorants include enhancement of immune system function protection from sun burn and inhibition of development of certain type of cancer. A flavored and brightly colored seed of manilkara probate has been showed to have both antioxidant and hepatoprotective activities. They also get antibacterial, laxative, diuretic and antiseptic properties such as myrobalan fruits, turmeric, manjistha root, Arjuna (*Terminalia arjuna*) bark, and safflower florets have curative properties and have been used in various traditional medicinal. Natural colorants are healthy as well as eco-friendly, biodegradable, and renewable.

Natural dyes tend to get degraded in certain conditions. Chlorophylls are highly sensitive to heat, light, oxygen, acids and enzymes, leading to their prompt degradation and color change. They are stable in alkaline pH between 7 and 9. It is unstable in acidic pH. When exposed to light or heat, the cell membrane of the plant degenerate releasing acids which decrease the pH as shown in Figure 3. The same situation applies on anthocyanin and beta-carotene. The color stability of anthocyanins is affected not only by the structural features, but also by the pH, temperature, light, presence of co-pigments, enzymes, oxygen, and sugars. In a high acidic media, the red flavylium cation is the only predominating equilibrium species.

Residual matter left after extraction of colorants can be used as manure. They also act as U.V. protector. Natural colorants possess healing properties by absorption of medicinal compounds through the skin so they are skin friendly [47]. By looking at these attributes of natural colorants, we can draw the inference that they could be a best substitute of synthetic colorants.

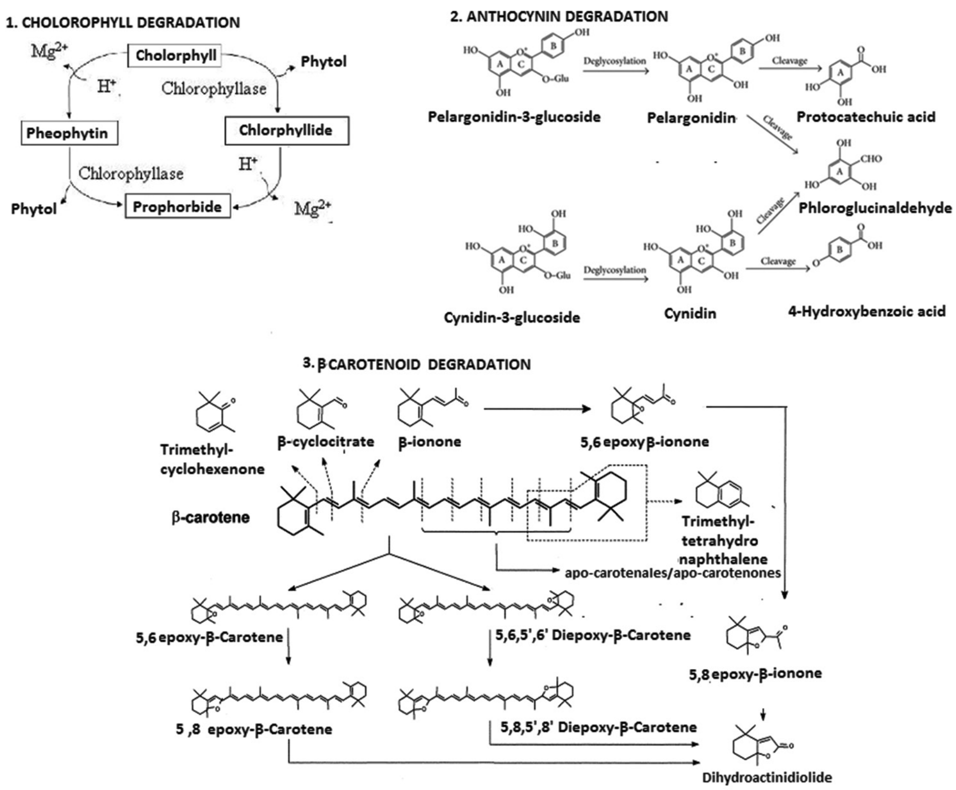

Figure 3: Degradation pathway of some natural colorants.

4. CONCLUSION

The color chemistry of colorants is a vast field that has a great commercial impact. This mini-review covered various aspects involved in colorants chemistry including classification. Colorants stuff is found to have a major impact not only on the environment but also on health. It is quite evident that these synthetic colorants contribute to a large group of organic compounds that are used as coloring agents. Also due to their non-biodegradability and high stability, these compounds pose a threat to the environment as well as to humans. Looking at the beneficial and non-toxic effects of natural colorants it could be considered as a perfect substitute for synthetic colorants.

Natural colorants are exceptionally unsteady with different food preparing conditions. Stabilization of natural colorants is the principle challenge to defeat for their usage as food colorants. Along these lines, more definite examinations and logical examinations are expected to evaluate the genuine potential and accessibility of normal color yielding assets. The food business that creates and produces regular food colorants is developing dramatically because of buyer requests for natural pigments *in lieu* of manufactured colorants Therefore we recommend more research in this direction to combat the inherent limitations and sensitivity of natural colorants to processing conditions and also to understand their properties and utilize them effectively in food industry.

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REFERENCES

1. K. Duangmal, B. Saicheua, S. Sueeprasan, (2004) ***Roselle Anthocyanins as a Natural Food Colorant and Improvement of Its Colour Stability***. New Delhi: Proceedings of the AIC, p155-158.
2. D. S. Yadav, S. Jaiswal, M. K. Mishra, A. K. Gupta, (2016) Analysis of non-permitted dyes in bakery and dairy products for forensic Consideration, ***International Journal of Development Research***, **6:** 8775-8779.
3. B. A. Cevallos-Casals, L. Cisneros-Zevallos, (2004) Stability of anthocyanin-based aqueous extracts of Andean purple corn and red-fleshed sweet potato compared to synthetic and natural colorants, ***Food Chemistry***, **86(1)**: 69-77.
4. M. Devi, V. N. Ariharan, P. N. Prasad, (2013) Annato, eco-friendly and potential source for natural dyes, ***International Research Journal of Pharmacy***, **4(6):** 106-108.
5. D. Bhardwaj, L. Kumar and N. Bharadvaja, (2020) A review on sources of dyes, sustainable aspects, environmental issues and degradation methods. In: ***India 2020: Environmental Challenges, Policies and Green Technology,*** Mumbai, India.
6. M. J. Scotter, (2011) Emerging and persistent issues with arti¢cial food colours: Natural colour additives as alternatives to synthetic colours in food and drink, ***Journal Quality Assurance and Safety of Crops and Foods***, **3:** 28-39.
7. S. K. Reshmi, K. M. Arvindhan, (2015) The effect of light, temperature, pH on stability of on the stability of betacyanin pigments in *Basella alba* fruits, ***Asian Journal of Pharmaceutical and Clinical Research***, **5(4)**: 107-110.
8. P. Joshi, S. Jain, V. Sharma, P. Kaewkool, M. Van Nguyen, A. Jonsson, J. Prakash, (2011) Acceptability assessment of yellow colour obtained from turmeric in food products and at consumer level, ***Asian Journal of Food and Agro-industry***, **4(1)**: 1-15.
9. Available form: https://www.nyallergy.com/food-coloring-allergy. [Last accessed on 2021 Oct 12].
10. S. N. Okafor, W. Obonga, M. A. Ezeokonkwo, J. Nurudeen, U. Orovwigho, J. Ahiabuike, (2016) Assessment of the health implications of synthetic and natural food Colourants A critical review, ***Pharmaceutical and Biosciences Journal***, **4:** 1.
11. J. F. Borzelleca, K. Depukat, J. B. Hallagan, (1990) Lifetime toxicity/carcinogenicity studies of FD and C Blue No. 1 (brilliant blue FCF) in rats and mice, *Food and Chemical Toxicology*, **28(4)**: 221-234.
12. M. J. Greenhawt, L. L. Baldwin, (2009) Carmine dye and cochineal extract: Hidden allergens no more. ***Annals of Allergy, Asthma and Immunology,*** **103:** 73-75.
13. IARC (2011) ***Agents Classified by the IARC Monographs Archived [2011-10-25] at the Wayback Machine,*** IARC, Lyon, France.
14. Y. Grosse, R. Baan, B. Secretan-Lauby, F. El Ghissassi, V. Bouvard, L. Benbrahim-Tallaa, WHO International Agency for Research on Cancer Monograph Working Group, (2011) Carcinogenicity of chemicals in industrial and consumer products, food contaminants and flavourings, and water chlorination byproducts, ***The Lancet Oncology,*** **12:** 328-329.
15. R. Gupta, S. Ranjan, A.Yadav, B. Verma, K.Malhotra, (2019). Toxic effects of food colorants erythrosine and tartrazine on zebrafish embryo development. ***Current Research in Nutrition and Food Science Journal,*** **7:** 876-885.
16. P. Mpountoukas, A. Pantazaki, E. Kostareli, E., P. Christodoulou, D. Kareli, S. Poliliou, C. Mourelatos, V. Lambropoulou, T. Lialiaris, (2010) Cytogenetic evaluation and DNA interaction studies of the food colorants amaranth, erythrosine and tartrazine, ***Food and Chemical Toxicology,*** **48:** 2934-2944.
17. R. Gupta, S. Ranjan, A. Yadav, B. Verma, K. Malhotra, (2019) Toxic effects of food colorants erythrosine and tartrazine on zebrafish embryo development, ***Current Research in Nutrition and Food Science Journal,*** **7:** 876-885.
18. F. M. D. Chequer, V. de Paula Venâncio, M. de Lourdes Pires Bianchi, L. M. G. Antunes, (2012) Genotoxic and mutagenic effects of erythrosine B, a xanthene food dye, on HepG2 cells, ***Food and Chemical Toxicology,*** **50:** 3447-3451.
19. E. K. Silbergeld, S. M. Anderson, (1982) Artificial food colors and childhood behavior disorders, ***Bulletin of the New York Academy of Medicine,*** **58:** 275.
20. A. S. Jennings, S. L. Schwartz, N. J. Balter, D. Gardner, R. J. Witorsch, (1990) Effects of oral erythrosine (2', 4', 5', 7'-tetraiodofluorescein) on the pituitary-thyroid axis in rats, ***Toxicology and Applied Pharmacology,*** **103:** 549-556.
21. T. Mizutani, (2009) Toxicity of xanthene food dyes by inhibition of human drugmetabolizing enzymes in a noncompetitive manner, ***Journal of Environmental and Public Health,*** **2009:** 953952.
22. F. G. R. Reyes, M. F. C. Valim, A. E. Vercesi, (1996) Effect of organic synthetic food colours on mitochondrial respiration, ***Food Additives and Contaminants,*** **13:** 5-11.
23. R. A. Simon, (2003) Adverse reactions to food additives, ***Current Allergy and Asthma Reports,*** **3:** 62-66.
24. V. Rus, C. Gherman, A. Miclaus, A., Mihalca, C. Nadas (2010). Comparative toxicity of food dyes on liver and kidney in guinea pigs: A histopathological study. ***Annals of the Romanian Society for Cell Biology,*** **15:** 161-165.

25. P. Mandal, A. Rai, S. Mishra, A. Tripathi, M. Das, (2018) Mutagens in food. In: ***Mutagenicity: Assays and Applications,*** Academic Press, Cambridge, Massachusetts, p133-160.
26. V. Rus, C. Gherman, A. Miclaus, A. Mihalca, C. Nadas, (2010) Comparative toxicity of food dyes on liver and kidney in guinea pigs: A histopathological study, ***Annals of the Romanian Society for Cell Biology,*** **15:** 161-165.
27. K. T. Chung, (2016) Azo dyes and human health: A review, ***Journal of Environmental Science and Health,*** **34:** 233-261.
28. K. Başak, P. Y. Başak, D. K. Doğuç, F. Aylak, S. Oğuztüzün, B. M. Bozer, F. Gültekin, (2017) Does maternal exposure to artificial food coloring additives increase oxidative stress in the skin of rats? ***Human and Experimental Toxicology,*** **36:** 1023-1030.
29. J. D. A. Burrows, (2009) Palette of our palates: A brief history of food coloring and its regulation. ***Comprehensive Reviews in Food Science and Food Safety,*** **8:** 394-408.
30. D. McCann, A. Barrett, A. Cooper, D. Crumpler, L. Dalen, K. Grimshaw, E. Kitchin, K. Lok, L. Porteous, E. Prince, E. Sonuga-Barke, J. O. Warner, J. Stevenson, (2007) Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: A randomised, double-blinded, placebocontrolled trial. ***Lancet,*** **370:** 1560-1567.
31. M. Boris, F. S. Mandel, (1994) Foods and additives are common causes of the attention deficit hyperactive disorder in children. ***Annals of Allergy,*** **72:** 462-467.
32. M. Oplatowska-Stachowiak, C. T. Elliott, (2017) Food colors: Existing and emerging food safety concerns. ***Critical Reviews in Food Science and Nutrition,*** **57:** 524-548.
33. A. Tkaczyk, K. Mitrowska, A. Posyniak, (2020) Synthetic organic dyes as contaminants of the aquatic environment and their implications for ecosystems: A review. ***Science of the Total Environment,*** **717:** 137222.
34. S. Hussain, N. Khan, S. Gul, S. Khan, H. Khan, (2019) Contamination of water resources by food dyes and its removal technologies. In: ***Water Chemistry,*** IntechOpen, London.
35. K. Hunger, (Ed.), (2007) Industrial Dyes: Chemistry, Properties, Applications, John Wiley and Sons, Hoboken, New Jersey.
36. E. R. Flores, F. Perez, M. De la Torre, (1997) Scale-up of Bacillus thuringiensis fermentation based on oxygen transfer, ***Journal of Fermentation and Bioengineering,*** **83:** 561-564.
37. F. D. Chequer, G. A. R. de Oliveira, E. A. Ferraz, J. C. Cardoso, M. B. Zanoni, D. P. de Oliveira, (2013) Textile dyes: Dyeing process and environmental impact. ***Ecofriendly Textile Dyeing and Finishing,*** **6:** 151-176.
38. V. M. Ghorpade, S. S. Deshpande, D. K. Salunkhe, (1995) ***Food Colors,*** Vol. 4. Marcel Dekker Inc., New York.
39. K. Yamjala, M. S. Nainar, N. R. Ramisetti, (2016) Methods for the analysis of azo dyes employed in food industry a review. ***Food Chemistry,*** **192:** 813-824.
40. K. Dwivedi, G. Kumar, (2015) Genetic damage induced by a food coloring dye (sunset yellow) on meristematic cells of Brassica campestris L, ***Journal of Environmental and Public Health,*** **2015:** 319727.
41. A. Del Olmo, J. Calzada, M. Nuñez, (2017) Benzoic acid and its derivatives as naturally occurring compounds in foods and as additives: Uses, exposure, and controversy, ***Critical Reviews in Food Science and Nutrition,*** **57:** 3084-3103.
42. M. Yusuf, M. Shabbir, F. Mohammad, (2017) Natural colorants: Historical, processing and sustainable prospects. ***Natural Products and Bioprospecting,*** **7:** 123-145.
43. K. Beetul, A. Gopeechund, D. Kaullysing, S. Mattan-Moorgawa, D. Puchooa, R. Bhagooli, (2016) Challenges and opportunities in the present era of marine algal applications. In: N. Thajuddin, D. Dhanasekaran, (Eds.), ***Algae-Organisms for Imminent Biotechnology,*** Mumbai, India, p237-276.
44. O. M. Andersen, M. Jordheim, (2010) Chemistry of flavonoid-based colors in plants. In: ***Comprehensive Natural Products,*** 2nd ed. Elsevier, Oxford, p547-614.
45. T. Pullaiah, (2006) ***Encyclopaedia of World Medicinal Plants,*** Vol. 1. Daya Book, Kolkata, India.
46. P. A. Balch, (2002) ***Prescription for Herbal Healing,*** Penguin, London, United Kingdom.
47. K. Singh, N. Singh (2020) Natural dyes: An emerging ecofriendly solution for textile industries. ***Pollution Research,*** **39:** S87-S94.
48. C. Bisulca, C., Picollo, M., Bacci, D. Kunzelman, (2008) ***UV-Vis-NIR Reflectance Spectroscopy of Red Lakes in Paintings,*** 9th International Conference on NDT of Art, Jerusalem, Israel, p25-30.
49. K. Singh, N. Singh, (2020) Natural dyes: An emerging ecofriendly solution for textile industries, ***Pollution Research,*** **39:** S87-S94.

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