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A REVIEW ON ARTIFICIAL COLORANTS IN SOFT DRINK HEALTH COMPLICATIONS AND REGULATIONS

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Abstract:

Colour additives, as with other consumables, contain natural or artificial colours to produce the desired colour, and to potentially retain the natural colour of soft drink in processed or stored formats; artificial colours are usually more cost effective and more stable than natural colours thus favouring their use. Now, many people are using artificial colours for aesthetic appeal and flavour for soft drinks. There are regulations, standards, and acceptable daily intake (ADI) levels of food safety established for artificial dyes to protect the consumer, as they may be toxic, and especially in high dosage amounts. More specifically dye agents are limited to use in soft drink for specific reasons: either aesthetics, or shelf life. We must first consider the risks, and any possible health effects of food dye agents when we ingest them in food, if there are health outcomes at all, though. The only way we will be able to complete this determination is to accumulate sufficient evidence of either identifying food dye agents in food products, or measuring the levels of consumption of food dye agents, or both, when identified in food products.

INTRODUCTION

Artificial colorants have become staples in the food and beverage industry, particularly with soft drinks, as they provide greater aesthetic appeal, not only visually attractive to consumers (Smith & Johnson, 2020). Their bright colors add aesthetic quality while also changing consumer perceptions of a drink with respect to taste, freshness, and overall value. Food colorants are commonly synthetic dyes, that are man-made and include the widely used azo dyes such as Sunset Yellow FCF, Allura Red AC, and Atrazine due to their low cost, color stability, and water solubility (Martinez &

Lopez, 2016). In addition to having the properties above, synthetic dyes can be used in, both carbonated and noncarbonated beverages. The risks of using synthetic dyes in certain products or for certain individuals have led to widespread study of these additives and increased regulation on the product (Lee & Kim, 2019; Sharma & Kumar, 2017). There is research to suggest synthetic dyes to lead allergic reactions, behavioral changes, such as hyperactivity in children, an increase in toxicity and neurotoxicity with long term exposure or regular consumption, and/or mutagenic or



carcinogenic potential (Patel & Shah, 2018). Even though regulatory agencies assess these dyes as safe based on Acceptable Daily Intake (ADI) levels, the ongoing research challenges the safety of long-term exposure, especially cumulative exposure, in vulnerable, at risk populations (Patel & Shah, 2018; WHO, 2022). The International Agency for Research on Cancer (IARC) has placed food additives, including synthetic dyes, under cancer risk group 2B (possible human carcinogen) or group 3 (not classifiable as to carcinogenic), according to their potential (IARC, 2017). Thus, in response to popular consumer concern, regulatory agencies, such as EFSA and WHO, have both re-evaluated food additives and food use levels, created new safety guidelines, labeling laws, and changes to acceptable laws for synthetic food colorings (EFSA, 2015; WHO, 2022) (1-4).

MAINSECTION TYPES AND CHARACTERISTICS OF ARTIFICIAL COLORANTS IN SOFT DRINKS:

The soft drink industry uses artificial colorants widely to create aesthetically pleasing goods that draw customers and guarantee brand awareness. These artificial dyes are azo dyes (Allura Red AC, tartrazine), anthraquinone dyes, and others that are distinguished by their vivid, strong hues and resistance to extreme processing conditions including heat, light, and acidity. Their chemical structures are stable after pasteurization and storage, and they are highly soluble in water. These substances' durability varies, though, and elements including pH, metal ion concentration, and light exposure can cause deterioration that compromises colour quality and safety. Longer shelf life and a constant product look are made possible by ongoing improvements in dye chemistry that increase artificial colorants' photo stability and resilience to environmental influences.

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TOXICOLOGICAL EVALUATION AND HEALTH IMPLICATIONS:

The possible toxicological consequences seen in investigations on humans and animals raise serious concerns about the safety of artificial colorants. In sensitive people, like those with asthma or aspirin sensitivity, a number of colours have been linked to allergic responses. Since several azo dyes have been controversially related to behavioural consequences including hyperactivity in children, some countries have taken regulatory action. Patel and Shah compiled the data pointing to potential carcinogenic and mutagenesis effects at high exposure levels or over an extended period. This being said, additional study is still needed in cumulative exposure from multiple sources. The IARC's classification of food additives emphasizes the necessity of constant toxicological evaluation and a comprehensive assessment of carcinogenic potential.

REGULATORY FRAMEWORK AND SAFETY STANDARDS:

International regulations governing artificial colorants in soft drinks are strict to safeguard consumers. Certain colorants were thoroughly reevaluated in the 2015 scientific opinion of the EFSA Panel, which included updated toxicological data and exposure evaluations. This occasionally resulted in changes to ADI values or usage limitations. To promote standardization of practices and risk management tactics, the WHO's Food Additives Series acts as a worldwide reference for food safety. Furthermore, colorant concentration limitations, labelling regulations, and periodic safety reviews based on new scientific data are all enforced by national regulatory bodies. Children are among the vulnerable groups that regulatory frameworks take into account since they may be more prone to negative consequences.



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ANALYTICAL DETECTION METHODS:

Strong analytical techniques are necessary to keep an eye on artificial colouring in soft drinks for both quality control and regulatory compliance. Diode array detection (DAD) or mass spectrometry (MS) in conjunction with HPLC allows for the sensitive and specific identification of many dyes in intricate beverage matrices. Even at trace quantities, colorants can be quantified using these chromatographic techniques, which is essential for confirming adherence to legal limitations and identifying unapproved additives. Although they provide quick and affordable screening, spectrophotometric methods, such as UV-Visible spectroscopy, are constrained by interference from beverage ingredients. Innovative techniques are being researched to improve detection speed and lower analysis costs, such as capillary electrophoresis and biosensors (5-8)

CONSUMER PERCEPTION**AWARENESS:**

The growing consumer desire for food additive transparency has affected attitudes and purchase decisions regarding artificial colouring in soft drinks. Research indicates that consumers have health concerns regarding artificial dyes, frequently viewing them as unnatural or potentially hazardous, even when they have been shown to be safe at regulated levels. Consumer education is crucial for bridging the gap between perception and scientific data, according to Gupta and Verma. In order to stay competitive in the market, producers are being pushed toward "clean label" formulas and natural dye substitutes by labelling practices and media coverage, which have a big influence on public opinion.

ENVIRONMENTAL IMPACT OF SYNTHETIC DYES:

Synthetic colours used in soft drinks are produced and discarded, which pollutes the

environment, especially water. The toxicity and persistence of azo dyes in industrial effluents, which are frequently intractable by traditional wastewater treatment techniques, are covered by Kumar and Singh. Ecosystems may be disturbed by these substances' ability to bioaccumulate in aquatic life. The environmental impact emphasizes how urgent it is to embrace natural or biodegradable dyes, enhance waste treatment technology, and optimize dye manufacturing methods. Green chemistry concepts can help reduce the substantial energy and resource consumption found in life cycle studies of synthetic dyes.

ADVANCES IN NATURAL AND ARTIFICIAL COLORANTS:

Researchers are focusing more on natural colorants derived from plant, microbial, and animal sources as safety and sustainability concerns increase. The extraction of stable natural colours for soft drinks, such as betalains, carotenoids, and anthocyanins, has advanced, according to Martínez and López. Although natural colorants have attractive safety profiles, they have drawbacks such as poorer stability, inconsistent batch production, and increased expenses. Co-pigmentation, genetic engineering, and encapsulation are methods to increase the stability of natural dyes. Ahmad and Farooq emphasise initiatives to alter artificial colours chemically in order to lessen toxicity without sacrificing their useful qualities. Combining natural and synthetic colorants in hybrid methods seeks to strike a compromise between consumer acceptance, cost, and safety.

REGULATORY STATUS OF ARTIFICIAL COLORANTS IN BEVERAGES

Artificial colorants used in beverages are subject to strict regulatory oversight by national and international food safety authorities to ensure consumer safety. These



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regulations govern permissible colorants, acceptable daily intakes (ADIs), and labelling requirements.

1. Based on toxicological evidence, the World Health Organization (WHO) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) have carried out thorough assessments of artificial colorants, establishing safety limits and ADIs. Regular updates of their findings can be found in the WHO Food Additives Series.
2. The European Food Safety Authority (EFSA) has re-examined a number of artificial food colouring agents, taking into account their potential for allergenicity, neurotoxicity, and genotoxicity. EFSA requires any food and beverage additives linked to hyperactivity in children (such as the "Southampton Six") to be clearly labelled and places strict restrictions on the use of colorants in EU food and beverages.
3. In accordance with the Federal Food, Drug, and Cosmetic Act, the Food and Drug Administration (FDA) oversees artificial food dyes in the US. Every colorant must

meet identity and purity requirements and have a certification for use. Concerns expressed in other jurisdictions have not stopped some dyes (such as FD&C Red No. 40) from being approved.

4. Although the International Agency for Research on Cancer (IARC) has classified some artificial colorants under its framework for assessing carcinogenicity, not all artificial colours used in beverages have been found to be dangerous to humans. These classifications impact public health and regulatory decisions globally.

5. Countries have quite different regulatory systems; some forbid dyes that are allowed in others. For instance, some azo dyes are illegal in Norway and Austria but permitted in other nations under specific restrictions.

6. Stricter laws and customer preferences are driving a rising movement to switch from synthetic dyes to natural ones. Particularly in the EU and several regions of Asia, there is a strong regulatory push for natural additives.

7. To avoid abuse and guarantee consistent safety across locations, a few studies advocate for strengthening regulatory oversight and harmonizing international standards (91-2).

ANALYTICAL METHODS FOR DETECTING ARTIFICIAL COLORANTS IN SOFT DRINKS

Accurate and reliable detection of artificial colorants in soft drinks is essential for ensuring regulatory compliance and

protecting public health. The most employed methods include

Table 1. High-Performance Liquid Chromatography (HPLC) and Thin-Layer Chromatography (TLC), among others.

Method	Description & Application in Soft Drinks	Advantages



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HPLC (High-Performance Liquid Chromatography)	HPLC is the gold standard for quantifying synthetic colorants in soft drinks. It separates dyes based on polarity and molecular interaction with the column under high pressure. Often coupled with UV or diode array detectors (DAD).	High sensitivity, precision, and suitability for complex soft drink matrices. Can quantify multiple dyes in a single run.
TLC (Thin-Layer Chromatography)	TLC is used for the rapid screening and qualitative analysis of dyes in soft drinks. Samples are spotted on silica-coated plates and developed using solvent systems to visualize dye patterns.	Simple, cost-effective, and quick for preliminary detection; suitable for resource-limited settings.
UV-Vis Spectrophotometry	Frequently used as a complementary method to quantify total dye concentration in soft	Fast and nondestructive; ideal for routine
Method	Description & Application in Soft Drinks	Advantages
	drinks by measuring absorbance at specific wavelengths.	monitoring of known dyes.
LC-MS (Liquid Chromatography–Mass Spectrometry)	An advanced method combining HPLC with mass detection, used for confirmation and trace analysis of artificial dyes.	High specificity; useful for structural confirmation of colorants in beverages.

NATURAL ALTERNATIVES TO ARTIFICIAL COLORANTS IN SOFT DRINKS

Natural colorants have gained popularity as safer and more palatable substitutes for artificial food colors in soft drink

formulations due to the growing health concerns and regulatory limits around these dyes. Customers frequently view these substitutes as healthier because they come from plant, microbial, or mineral sources.



Table 2. Comparison between Artificial Colorants and Natural Colorants in soft drinks

Aspect	Artificial Colorants	Natural Colorants
Source & Composition	Chemically synthesized (e.g., Tartrazine, Allura Red).	Extracted from plants (anthocyanins, turmeric), animals, or minerals.
Stability & Performance	Highly stable to heat, light, and pH; ideal for industrial-scale manufacturing.	Less stable; prone to degradation; may interact with food components.
Health & Safety Concerns	Linked to hyperactivity, allergies, and potential carcinogenicity.	Perceived safer; low toxicity but allergies may occur.
Regulatory Oversight	Strict controls by FDA, EFSA, WHO including ADIs, labelling and safety testing.	GRAS-approved but monitoring increasing to ensure purity and standardization.
Consumer Perception	Declining acceptance due to synthetic origin and health concerns.	Preferred due to “clean label” appeal and natural sourcing.
Nutritional & Environmental Impact	No nutritional benefit; associated with pollution from industrial waste.	May contain health-promoting compounds; viewed as eco-friendly and sustainable.



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Anthocyanins are some of the most widely utilized natural colorants; they are derived from berries, red cabbage, and grapes. They add vibrant shades of red, purple, and blue to fruit-based and fizzy drinks. They are prized not only for their coloring qualities but also for their antioxidant potential. But because anthocyanins are extremely sensitive to pH variations and break down in the presence of heat and light, their shelf life in beverage products may be limited.

Beta-carotene, which is found in sweet potatoes, carrots, and palm oil, gives citrus and tropical drinks their typical orange to yellow hues. In addition to being heat-stable, it has additional nutritional significance as a pro-vitamin A molecule. However, its weak water solubility and crystallization tendency may make emulsifiers necessary in beverage systems.

curcumin The bright yellow substance which comes from turmeric root, is being utilized more and more in herbal and functional drinks. Its antioxidant and anti-inflammatory qualities are well known. Curcumin's limited water solubility and instability in light and alkaline environments make it difficult to formulate, despite its popularity.

Chlorophylls Extracted from green leafy plants, chlorophylls and chlorophyllins provide vegetable-based or detox drinks their green tint. Although these substances are naturally occurring and abundant in antioxidants, heat and acidic conditions, which are prevalent in many soft drink matrices, cause them to lose their colour .

Carmine, the highly stable red pigment carmine, sometimes referred to as cochineal extract, is extracted from cochineal insects. Its exceptional colour retention makes it a popular ingredient in fruit-flavored beverages. Its market appeal is limited, nevertheless, because it is incompatible with vegan or vegetarian products and can trigger allergic reactions in those who are

susceptible.

Spirulina extract, comes from blue-green algae and is a relatively new product on the market for natural coloring. It complements the clean-label movement and offers eye-catching blue or green hues. Despite being natural and high in protein, spirulina is light- and heat-sensitive and may interfere with soft drink flavors.

Lycopene, In order to give beverages a red or pink hue, it is made from tomatoes and watermelon. Additionally, it functions as an antioxidant and may have anti-cancer properties. Nevertheless, the limited pH stability range and difficulties with solubility of lycopene restrict its use .

Paprika extract, extracted from red peppers, and beetroot extract, which comes from beets, are also commonly used. Although it can deteriorate when exposed to light, paprika is widely used and produces reddish-orange hues. Although beetroot extract is valued for its striking red hue and alleged health advantages, it is sensitive to heat and light and may add an earthy flavor that may have an impact on taste acceptance (13).

Overall, even though natural colorants have a lot to offer consumers and may have health advantages, these colorants frequently need processing help (such stabilizers or encapsulation) to get past problems with uniformity and stability in soft drink applications. It is anticipated that their use will increase in line with clean-label requirements, if technological obstacles are successfully removed (14,15).

CONCLUSION

The use of artificial coloring in soft drinks is an example of a complicated interaction between regulatory compliance, customer expectations, health and safety, and usefulness. These artificial dyes, particularly popular azo compounds like Sunset Yellow, Allura Red, and tartrazine, are essential to the soft drink industry



because they provide benefits in terms of color brilliance, stability, and affordability. However, there is growing worry about their toxicological profiles and environmental impact, especially in light of their links to childhood hyperactivity, allergic reactions, and possible carcinogenicity. Despite regulatory guarantees from agencies like the FDA, EFSA, WHO, and JECFA, media coverage and changing consumer perceptions of natural and clean-label products continue to feed public distrust. To protect public health, particularly that of vulnerable groups like children, regulatory regimes are constantly changing in response to new scientific findings. Stricter labeling requirements, updated ADI limits, and increased transparency are just a few examples. Technological developments in analytical detection techniques, especially HPLC and LC-MS, have greatly increased the precision of tracking artificial dyes in intricate beverage matrices, guaranteeing legal compliance and identifying illicit use. Research on pigments produced from plants and algae, such as anthocyanins, beta-carotene, curcumin, and spirulina extract, has expanded in response to the growing demand from consumers for natural alternatives. These natural colorants have technical issues with stability, solubility, and flavor compatibility, despite the fact that they may have positive health effects and increase environmental sustainability. The ultimate goal of soft drink coloring is to strike a balance between market trends, consumer safety, environmental responsibility, and technological viability. The beverage sector is spending more money on bioengineering, encapsulation technologies, and hybrid solutions to improve the performance of natural colors.

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