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KEEPING FOOD SAFE: TACKLING THE HEALTH RISKS OF PHTHALATES AND AZO DYES

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ABSTRACT

Phthalates and azo dyes, prevalent in food products due to their use in packaging, processing equipment, and as additives, pose significant health risks. Phthalates can migrate into food, disrupting endocrine function, causing reproductive and developmental toxicity, and potentially leading to cancer. Azo dyes, used to enhance food appearance, can trigger allergenic reactions, genotoxic effects, and impact gut microbiota. Regulatory bodies like the Food and Drug administration (FDA) and European Food Safety Authority (EFSA) have established guidelines to mitigate these risks, although regional differences in regulations exist. Advances in analytical methods, such as chromatographic and spectroscopic techniques, have improved the detection of these substances, supporting compliance and contamination monitoring. Mitigation strategies involve adopting safer alternatives, implementing best practices, and enhancing regulatory frameworks. Consumer awareness and education on reading food labels and making informed dietary choices are crucial in reducing exposure. Continuous research is necessary to address emerging concerns, understand long-term effects, and develop innovative detection technologies. A coordinated effort among industry, regulators, and consumers is essential to ensure food safety, protect public health, and foster trust in the food supply chain. This comprehensive review highlights the importance of addressing phthalates and azo dyes in food to promote a safer and healthier environment for all.[1][2]

KEYWORDS: Phthalates, azo dyes, food contamination, endocrine disruption, food safety, toxicology, analytical detection methods.

1. INTRODUCTION

Phthalates and azo dyes are chemical compounds widely used in various industries, including food production. Phthalates, a group of plasticizers, are commonly found in food packaging materials, processing equipment, and even some food products due to their migration from packaging. They are used to increase the flexibility, transparency, and durability of plastics. However, phthalates are known to disrupt endocrine functions, potentially leading to reproductive, developmental, and metabolic health issues. As the usage of plastic is increased day-by-day, the phthalate migration increased food supply chain and raised significant concerns about long-term exposure and cumulative health effects. Phthalates, used in food packaging and processing, can leach into food items, leading to chronic exposure. These compounds are known endocrine disruptors, which can interfere with hormonal functions and cause reproductive, developmental, and metabolic disorders.[3]

Azo dyes, synthetic colorants extensively used in food, textiles, and cosmetics, are valued for their vibrant colors and stability. In the food industry, they enhance the visual appeal of products, influencing consumer preferences. Despite their benefits, some azo dyes can degrade into aromatic amines, which are potentially carcinogenic and have been linked to allergic reactions and hyperactivity, particularly in children. Regulatory bodies in various countries have set permissible limits and banned certain azo dyes due to these health risks. Additionally, certain azo dyes have been linked to allergic reactions and behavioural issues, especially in children.[4]

The objectives of this review article are to comprehensively examine the presence of phthalates and azo dyes in food products, identify their sources, and elucidate the pathways of exposure. The review will also assess current regulatory standards and detection methods.

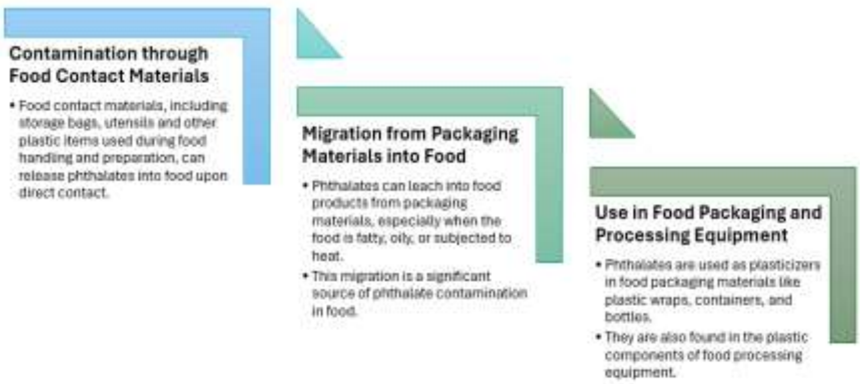

Figure 1: Sources of Phthalates in Food.[1][2]

Figure 2: Sources of Phthalates in Food.[1][2]

Permitted Levels of phthalates

Phthalates, used in plastics, have strict limits due to health risks. In many regulated countries, toys and childcare articles limit of any phthalates present in that material permitted up to 0.1% by weight. Food contact materials also have regulated phthalate levels, varying by region.

Permitted Levels of azo dyes

The use of azo dyes in food products varies across regions, with specific dyes and maximum permitted levels defined by regulatory authorities. In the European Union (EU), common approved dyes include Tartrazine (E102), Sunset Yellow FCF (E110), Carmoisine (E122), Ponceau 4R (E124), and Allura Red AC (E129), with maximum levels ranging from 10 to 500 mg/kg, and warning labels required for certain dyes due to potential hyperactivity in children. In the United States (US), only FD&C Yellow No. 5 (Tartrazine), FD&C Red No. 40 (Allura Red), and FD&C Yellow No. 6 (Sunset Yellow) are allowed at levels between 10 to 300 mg/kg, with no requirement for warning labels. Canada, Australia/New Zealand, Japan, China, and India approve similar dyes, generally with permitted levels between 10 to 300 mg/kg, although India allows levels up to 200 mg/kg for specific dyes. None of these countries, aside from the EU, mandate warning labels for azo dyes in food products.

2. Exposure of phthalates and azo dyes

Phthalates and azo dyes enter the human body primarily through dietary exposure, either by direct ingestion of contaminated food and beverages or indirect contact with food materials. Phthalates can migrate from packaging materials, such as plastic wraps and containers, into the food they hold. Similarly, azo dyes are intentionally added to food products to enhance their colour, leading to direct consumption. Indirect exposure occurs when food comes into contact with materials containing these chemicals, such as plastic utensils or packaging. Both direct and indirect dietary exposure routes are significant in assessing public health risks.[3]

Non-dietary exposure to phthalates and azo dyes is generally less impactful than dietary exposure but can occur through inhalation and dermal absorption. Phthalates may be inhaled from indoor air contaminated by vaporized chemicals, particularly in areas with phthalate-containing materials. Dermal absorption occurs through contact with personal care products or cleaning agents containing phthalates. Similarly, non-dietary exposure to azo dyes is rare but can occur through inhalation of airborne particles in manufacturing environments or skin contact with textiles or cosmetics. Although these non-dietary pathways are less pronounced, they still contribute to the overall exposure risk, emphasizing the need for comprehensive safety measures in both dietary and non-dietary contexts.[4]

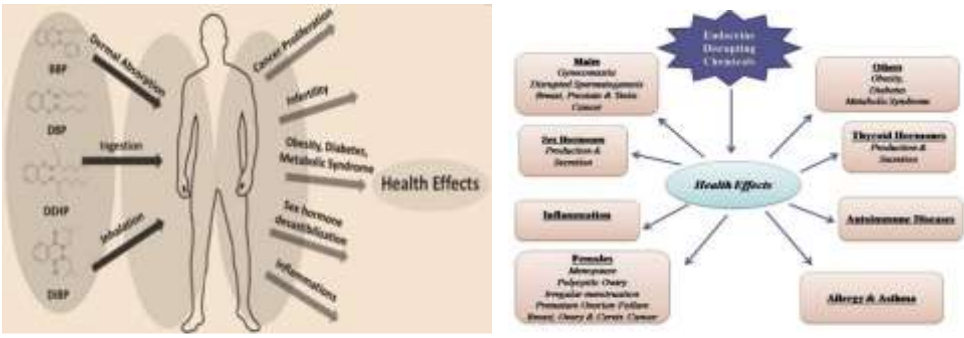

Figure 3: Effects of Phthalates on Human Body.[13][14]

3. Health risks and toxicological effects of azo dyes

1. **Allergenic and Hypersensitivity Reactions:** Azo dyes can trigger allergic reactions and hypersensitivity, particularly in sensitive individuals. Symptoms may include skin rashes, itching, and respiratory issues.[15]
2. **Genotoxicity and Carcinogenic Potential:** Some azo dyes can degrade into aromatic amines, which are known to be genotoxic and carcinogenic. This degradation poses a risk for mutations and cancer development.
3. **Impact on Gut Microbiota and Other Health Effects:** Azo dyes may affect gut microbiota, potentially leading to imbalances that can influence overall health. Other health effects can include behavioural changes and potential links to hyperactivity, particularly in children.[16]

4. Regulations for phthalates and azo dyes

The FDA regulates phthalates through its oversight of food contact materials rather than setting specific permissible limits for phthalates in food itself. The focus is on ensuring that food contact materials, such as packaging, do not release phthalates at levels that pose significant health risks. EFSA has set specific migration limits for phthalates from food contact materials, with detailed guidelines on permissible levels to minimize consumer exposure. EFSA provides comprehensive risk assessments and recommendations for reducing phthalate exposure through food packaging and processing materials. Codex Alimentarius and JECFA provide general guidelines and recommendations for food safety but do not set specific limits for phthalates. Their focus is more on overall safety standards for food contact materials and the management of potential contaminants.

The FDA has a list of approved azo dyes with specific permissible levels for each dye in food products. Some azo dyes are banned due to safety concerns, such as potential carcinogenicity or adverse health effects. The FDA requires clear labelling of foods containing azo dyes and imposes limits to ensure safety. EFSA has set strict regulations on the use of azo dyes in food, including maximum allowable levels and specific conditions for their use. Certain azo dyes are banned or heavily restricted based on safety evaluations and health risks. EFSA's guidelines aim to protect consumer health by controlling dye concentrations and ensuring proper labelling. Codex Alimentarius sets international standards for the use of azo dyes in food, including permissible levels and usage conditions.[10] [24]

5. Methods for Assessing Exposure Levels and Health Risks

Phthalates

➢ **Exposure Assessment**

- Dietary Surveys and Food Sampling: Analysing food samples for phthalate residues helps estimate dietary exposure. Surveys collect data on food consumption patterns and measure phthalate levels in foods to assess average intake.
- Migration Testing: Testing of food contact materials (e.g., packaging and processing equipment) to determine the extent of phthalate migration into food products. This helps evaluate potential exposure from packaging.
- Biomonitoring: Measuring phthalate metabolites in biological samples (e.g., urine, blood) to assess actual exposure levels and correlate them with dietary intake.

➢ **Health Risk Assessment**

- Toxicological Studies: Conducting studies on the effects of phthalates in animal models and cell cultures to understand their potential health impacts, including endocrine disruption, reproductive toxicity, and carcinogenicity.

- Risk Modelling: Using exposure data and toxicological information to model potential health risks and establish safe exposure limits. Risk assessment involves calculating margins of safety and comparing exposure levels to established health-based guidelines.

Azo Dyes

➢ **Exposure Assessment**

- Food Analysis: Testing food products for the presence and concentration of azo dyes to estimate dietary exposure. Analysing product labels and food composition data helps identify potential sources of exposure.
- Environmental Monitoring: Assessing environmental contamination, such as residues in water and soil, to understand indirect exposure pathways. This can provide insight into potential sources of azo dyes in the food supply.

➢ **Health Risk Assessment**

- Genotoxicity and Carcinogenicity Studies: Conducting laboratory studies to evaluate the potential for azo dyes to cause genetic mutations and cancer. This includes in vivo and in vitro tests to assess carcinogenic risk.
- Risk Characterization: Integrating exposure data with toxicological findings to characterize health risks. This involves comparing actual exposure levels with acceptable daily intake (ADI) values and assessing potential health outcomes based on scientific evidence.

ANALYTICAL METHODS FOR DETECTION

Techniques for Detecting Phthalates and Azo Dyes in Food Products[28]

1. Chromatographic Methods

- Gas Chromatography-Mass Spectrometry (GC-MS): GC-MS is widely used for detecting and quantifying phthalates in food products. The sample is first vaporized and separated in a gas chromatograph, then detected and quantified using mass spectrometry. This method is highly sensitive and specific, making it suitable for trace-level detection of phthalates.
- High-Performance Liquid Chromatography (HPLC): HPLC is employed to separate, identify, and quantify azo dyes in food samples. The sample is dissolved in a liquid and passed through a chromatographic column, with detection often performed using UV or

fluorescence detectors. HPLC is effective for analysing complex mixtures and provides accurate results for azo dye concentrations.

2. **Spectroscopic Methods**

- UV-Visible spectroscopy is used to detect azo dyes based on their characteristic absorption of ultraviolet or visible light. This method is valuable for analysing dye concentrations and is often coupled with chromatographic techniques for enhanced specificity.
- Fourier-Transform Infrared Spectroscopy (FTIR) is utilized to identify phthalates and azo dyes based on their molecular vibrations and functional groups. FTIR provides qualitative data and can be used for confirming the presence of specific phthalates or dyes in complex food matrices.

3. **Sample Preparation and Extraction Techniques**

- Solid-Phase Extraction (SPE) is commonly used to extract phthalates and azo dyes from food samples. It involves passing the sample through a sorbent material that selectively adsorbs the analytes, which are then eluted for analysis. SPE enhances the sensitivity and accuracy of the detection methods.
- Liquid-Liquid Extraction (LLE) is used to separate phthalates and azo dyes from food matrices based on their solubility in different solvents. This technique is effective for concentrating analytes and removing interfering substances before analysis.

Advances in Detection Technology and Their Implications

Advances in chromatographic and spectroscopic technologies, such as ultra-high-performance liquid chromatography (UHPLC) and high-resolution mass spectrometry, have significantly improved the sensitivity and selectivity of detection methods. These advancements allow for the detection of lower concentrations of phthalates and azo dyes, even in complex food matrices. Emerging portable and rapid detection technologies, such as miniaturized GC-MS and handheld spectrometers, are improving the feasibility of on-site testing and real-time monitoring. These innovations enhance the ability to perform quick and accurate assessments of food products in various settings, including production facilities and retail environments.

Combining different analytical techniques, such as coupling HPLC with mass spectrometry or UV-Vis spectroscopy, provides more comprehensive data and improves the accuracy of detection. Multi-technique approaches help in identifying a broader range of phthalates and azo dyes, addressing potential interference, and ensuring reliable results. New extraction techniques, such as microwave-assisted extraction (MAE) and pressurized liquid extraction (PLE), are being developed to improve efficiency and reduce analysis time. These methods offer higher recovery rates and better reproducibility, facilitating more effective analysis of phthalates and azo dyes in food samples.[50]

6. Case Studies and Real-World Examples

➢ Incidents of Contamination and Their Consequences.[43]

- Phthalates in Baby Foods (2011): In 2011, a significant contamination incident occurred in Taiwan, where phthalates were found in a range of food products, including baby foods, sports drinks, and dietary supplements. The contamination originated from the illegal use of DEHP as a clouding agent. The consequences were severe, leading to widespread product recalls, a loss of consumer trust, and serious public health concerns, particularly for infants and children.
- Azo Dyes in Imported Foods (2005): In 2005, the UK faced a major food safety incident when Sudan I, a banned azo dye, was found in a wide range of food products, including sauces, soups, and ready meals. The dye had been illegally added to chili powder, which was then used in various food products. The incident resulted in one of the largest food recalls in the UK, highlighting significant gaps in food safety controls and the need for improved surveillance and enforcement.

➢ Successful Interventions and Regulatory Actions:

- EU Ban on Specific Phthalates (2007): The European Union banned the use of several phthalates, including DEHP, DBP, and BBP, in toys and childcare articles in 2007. This regulatory action was based on comprehensive risk assessments that demonstrated significant health risks associated with these chemicals. The ban has been successful in reducing exposure to these harmful substances, particularly among children.
- FDA's Action on FD&C Red No. 3 (1990): In 1990, the FDA banned the use of FD&C Red No. 3 in cosmetics and externally applied drugs due to its carcinogenic potential. Although the dye is still permitted in some food products, the action marked a significant step in reducing exposure to potentially harmful azo dyes and raised awareness about the importance of stringent safety evaluations for food colorants.

7. Future Directions and Research Needs

- Emerging Concerns and New Findings.
- Microplastic Contamination: Recent studies have raised concerns about the presence of microplastics in the food chain, which can carry phthalates and other harmful chemicals. Understanding the implications of microplastic contamination for food safety and public health is a growing area of research.
- New Synthetic Colorants: The development and use of new synthetic colorants in the food industry pose potential health risks that need to be evaluated. Continuous monitoring and assessment of these substances are essential to ensure food safety.
- Gaps in Current Knowledge and Research Priorities:
- Long-term Health Effects: More research is needed to understand the long-term health effects of chronic exposure to low levels of phthalates and azo dyes, particularly in vulnerable populations such as children and pregnant women.
- Cumulative Exposure: Studies should focus on the cumulative effects of exposure to multiple food additives and contaminants, as real-world exposures often involve a combination of substances that may have synergistic or additive effects on health.
- Innovations in Food Safety and Analytical Methods:
- Advanced Detection Technologies: Innovations in detection technologies, such as biosensors and nanotechnology-based methods, offer the potential for more sensitive, rapid, and cost-effective detection of phthalates and azo dyes in food products.
- Green Chemistry: The development of green chemistry approaches to synthesize safer alternatives to phthalates and azo dyes is an important area of research. This includes designing substances that are non-toxic, biodegradable, and environmentally friendly.
- Comprehensive Risk Assessment Models: Developing more sophisticated risk assessment models that incorporate data on exposure, toxicology, and population health can improve the accuracy and reliability of safety evaluations and regulatory decisions.

CONCLUSION

Phthalates and azo dyes are commonly found in food products due to their extensive use in food packaging, processing equipment, and as direct additives. Phthalates, primarily used as plasticizers, can migrate from packaging materials into food, while azo dyes are synthetic colorants added to enhance the visual appeal of food products. These substances pose significant health concerns due to their potential toxicological effects. Research has shown that phthalates can disrupt endocrine function, leading to reproductive and developmental toxicity, and in some cases, they are considered carcinogenic. Azo dyes, on the other hand, are known to cause allergenic reactions, have genotoxic potential, and can negatively impact gut microbiota.[18]

Regulatory bodies such as the FDA, EFSA, and other international organizations have established guidelines and permissible limits for the use of phthalates and azo dyes in food products. These regulations aim to mitigate the health risks posed by these substances. However, there are differences in regulatory approaches across regions, reflecting varying levels of risk tolerance and scientific evaluation standards. Advances in analytical detection methods, including chromatographic and spectroscopic techniques, have significantly improved the ability to identify and quantify phthalates and azo dyes in food products. Enhanced sample preparation and extraction methods support more accurate and reliable analysis, ensuring that regulatory standards are met, and potential contamination is effectively monitored.[20]

Mitigation strategies are essential to reduce the presence of phthalates and azo dyes in food. The industry can play a crucial role by adopting safer alternatives and implementing best practices to minimize contamination during production. Regulatory bodies can strengthen frameworks and enforcement mechanisms to ensure compliance and encourage the development of safer substances. Consumers also have a vital role to play by making informed dietary choices, reading food labels carefully, and opting for products with natural additives and minimal packaging.[24]

Implications for Food Safety and Public Health.

Ensuring food safety involves addressing the potential hazards posed by phthalates and azo dyes. The health risks associated with these substances highlight the need for a comprehensive approach that includes regulatory measures, industry practices, and consumer awareness. Continuous monitoring and research are crucial to staying ahead of emerging concerns and adapting regulations to reflect the latest scientific findings. Understanding the long-term and cumulative health effects of exposure to these substances is essential for developing effective safety standards and protecting public health.[38]

Public health initiatives should focus on educating consumers about the risks associated with phthalates and azo dyes, promoting safer alternatives, and encouraging transparency in food labelling. By increasing awareness and providing accurate information, consumers can make informed choices that reduce their exposure to harmful substances. Additionally, fostering a collaborative approach between regulatory bodies, industry stakeholders, and research institutions can drive innovation and improve food safety standards.

Final Thoughts and Recommendations

For the industry, investing in research and development of non-toxic alternatives to phthalates and azo dyes is crucial. By adopting safer substitutes and implementing stringent quality control measures, companies can prevent contamination and ensure compliance with safety standards. This proactive approach not only protects consumer health but also builds trust and credibility in the marketplace.[16][19]

Regulators must enhance regulatory frameworks to include updated safety evaluations and enforce stricter limits on harmful substances. Encouraging collaboration between regulatory agencies, industry stakeholders, and research institutions can foster innovation and improve food safety. Providing funding and incentives for research into safer alternatives and new detection technologies can accelerate progress in this area.

Consumers play a pivotal role in ensuring food safety by staying informed about the ingredients in food products and choosing those with natural additives and minimal packaging. Advocating for transparency in food labelling and supporting policies that prioritize public health and safety are essential steps. By making informed choices and reducing consumption of processed foods, consumers can significantly lower their exposure to phthalates and azo dyes.[48][50]

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