Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol.13 , (2024)
https://www.jneonatalsurg.com

OPEN ACCESS

Hidden Risks: The Biological Cost of food Preservatives and its impact on Early Life

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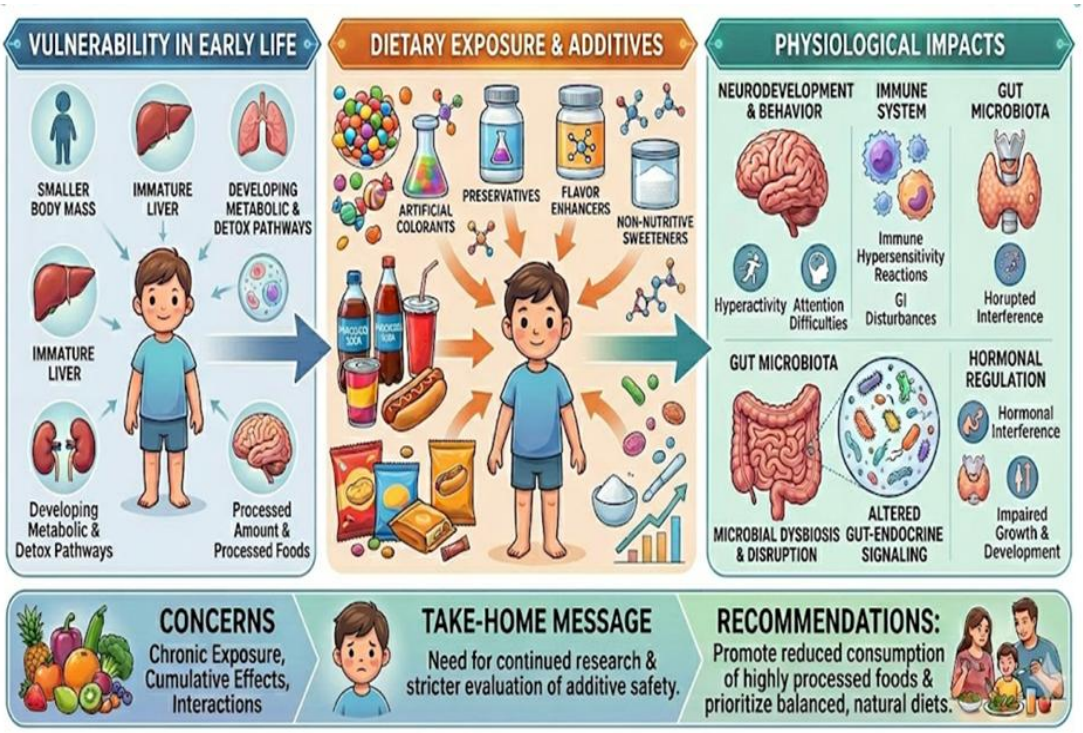
Cite this paper as: Anas Yassin Ahmed ; Hamada Hamdallah ; Aya Sh. Metwally (2024) Hidden Risks: The Biological Cost of food Preservatives and its impact on Early Life..Journal of Neonatal Surgery, 13, 2354-2361

Received: 15-03-2024; Reversed: 27-4-2024; Accepted: 26-5-2024; Published: 22-6-2024

ABSTRACT

GRAPHICAL ABSTRACT

Food additives present in processed products can significantly raise health concerns for infants and children, who are particularly more vulnerable due to their still-developing bodies and immune systems. It is crucial to be aware of these additives, as they can impact overall immunity and development. This review article aimed to examine the biological effects of food additives on young individuals.



In conclusion:
Food additives play a significant role in modern food systems, their potential biological costs in early life warrant careful consideration.

Keywords: *Food Additives; Preservatives, Artificial Colorants, Childhood, Flavor Enhancers, Non-Nutritive Sweeteners*

INTRODUCTION

Food additives in infant diets risk serious health issues due to widespread use and poor regulations. Outdated safety assessments fail to account for interactions that may increase risks for neurodevelopmental disorders and immune dysfunction **(1,2)**.

Food additives are substances intentionally added to food to improve its quality, safety, shelf life, or sensory appeal. They can be natural, like salt or vinegar, or synthetic, such as certain artificial colorings and preservatives. In modern food systems, additives play a crucial role in ensuring that products remain stable during storage and transportation, especially in packaged and processed foods **(3,4)**.

The early stages of life, extending from fetal development to adolescence, represent a particularly susceptible period during which dietary choices and exposure to chemicals can significantly influence long-term health outcomes. A growing body of research increasingly associates food additives and contaminants found in processed and ultra-processed foods with various metabolic, immune, and neurodevelopmental consequences in children **(1-5)**.

Emerging evidence suggests that certain additives may influence neurodevelopment and behavior, contributing to conditions such as hyperactivity and attention difficulties. Additionally, some compounds are associated with immune hypersensitivity reactions, gastrointestinal disturbances, and alterations in gut microbiota composition. Disruption of the intestinal microbiome during critical developmental windows may have long-term consequences for metabolic health and immune function **(4-6)**.

Furthermore, growing research indicates that specific additives could interfere with hormonal regulation, potentially affecting growth and development. Although regulatory agencies establish safety limits for individual additives, concerns remain regarding chronic exposure, cumulative effects, and the interaction of multiple additives within the diet **(3,7)**. This highlights the need for continued research and stricter evaluation of additive safety, particularly in relation to vulnerable populations.

Historical Context of Chemical Food Additives

The American Pure Food and Drug Act of 1906 sparked regulation of food processing. It was the first American law to prevent the use of dangerous chemicals and adulterants of food. Subsequent laws have been passed to make standards for the modern day food industry. The early 20th century began regulation aimed at maintaining standards in manufacturing for the health of consumers to prevent impure foods from entering the market. Regarding food safety, global food processing settings have engaged in the proper choice of industrial standards with such regulations as Codex, being the collection of standards and guidelines set by the World Health Organization, and the Food and Agriculture Organization. These regulations promote health through food safety standards **(8-11)**.

In respect to food fortification to enhance health and nutrition, countries have been establishing regulations to make sure the nutrients are being standardized and are being consumed per daily nutritional goals. This serves as another type of regulation crucial for maintaining public health from diseases and disorders resulting in the consumption of malnourished diets. The introduction of vitamin fortification was met with a large amount of scepticism where the safety and necessity of synthetic vitamins would be questioned. However, after nearly a century of vitamin fortification, its importance purely for human health is recognized **(10-12)**.

In Egypt, traditional diets were low in nutrient density which has led to malnourished staple diets in diverse developing countries. Staple diets which are not nutrient dense is an escalating global problem that Egypt is no stranger to. While developing countries face the similar challenge of the decreasing nutrient density of staple diets, Egypt is facing the rise of covered synthetic additives in traditional food products. There has been a major setback in health policy efforts to assure food safety standards and formulations **(13,14)**.

The types of food additives used in Egypt are broadly similar to those used in other countries, but there are some differences in usage patterns, regulation, and common food products **(Table 1)**. Prompt actions are required to reform food safety management and regulations in Egypt to build a national health infrastructure. Assistance from international health organizations can be beneficial for the nation to adapt industrial food processing into mass agricultural food production. Egypt can also learn from the regulations seen globally through the growing Codex standards to not only promote health through food safety but to also boost the economic growth of the country **(13-15)**.

In addition, the shortage of food nutrients is not only limited to Egypt but is seen globally where international organizations like Codex are acting by assisting countries, specifically developing countries on establishing their own. Thus, Egypt may receive assistance all while maintaining safety regulations on food products to improve health where they are lacking **(16)**.

Table (1): The approved common additives in processed foods worldwide

Common Food additives	***Role & Characters***
Preservatives	Prevent spoilage and extend shelf life Examples: sodium benzoate, nitrates, sulfites.
Color Additives	Improve or restore food color Include Natural (turmeric, beetroot) and artificial dyes as Brilliant Blue (E133), Tartrazine (E102), Sunset Yellow (E110), Carmoisine (E122), Allura Red (E129), and Brilliant Blue (E133).
3. Sweeteners	Provide sweetness with less or no sugar Examples: aspartame, saccharin, stevia
4. Flavor Enhancers	Enhance taste and aroma and used globally although risks. Example: monosodium glutamate (MSG)
5. **Emulsifiers**	Help mix ingredients like oil and water. Examples: lecithin, mono- and diglycerides.
6. Stabilizers and Thickeners	Improve texture and consistency Examples: gelatin, pectin, carrageenan Used in dairy, desserts, and sauces
7.**Nutritional Additives (Fortification)**	Add vitamins and minerals to improve nutrition Examples: vitamin D in milk, iodine in salt Promoted globally by the World Health Organization.
8. Antioxidants	Prevent oxidation (rancidity and color changes) Examples: ascorbic acid (vitamin C), BHA, BHT Approved for use within safe limits worldwide
9. Acidity Regulators	Control or maintain pH levels in food to improve flavor and preservation Examples: citric acid, lactic acid
10. Raising Agents (Leavening Agents)	Help baked goods rise, and widely approved for bakery products Examples: baking soda, baking powder

Classification of food preservations Methods

Food preservation is the process of treating and handling food to slow down spoilage and inhibits the growth of bacteria to maintain the food quality and shelf life. Preservation of food is done in several ways depending on the variety of the food or the type of food. The methods used for food preservation can be classified into categories based on certain criteria **(17,18)**.

Food preservation methods are applied to ensure long-term storage, reducing waste and food. They can be classified into physical, chemical, biological, and modern technological methods **(Figure 1)**, each serving different roles in maintaining food quality and shelf life.

These methods are a blend of the various traditional preservation methods. While these days, they are used mainly as a method of food preservation, they are not the only set of methods to preserve food. They also lower the amount of waste discarded and improves the standard of living in several ways **(18-20)**.

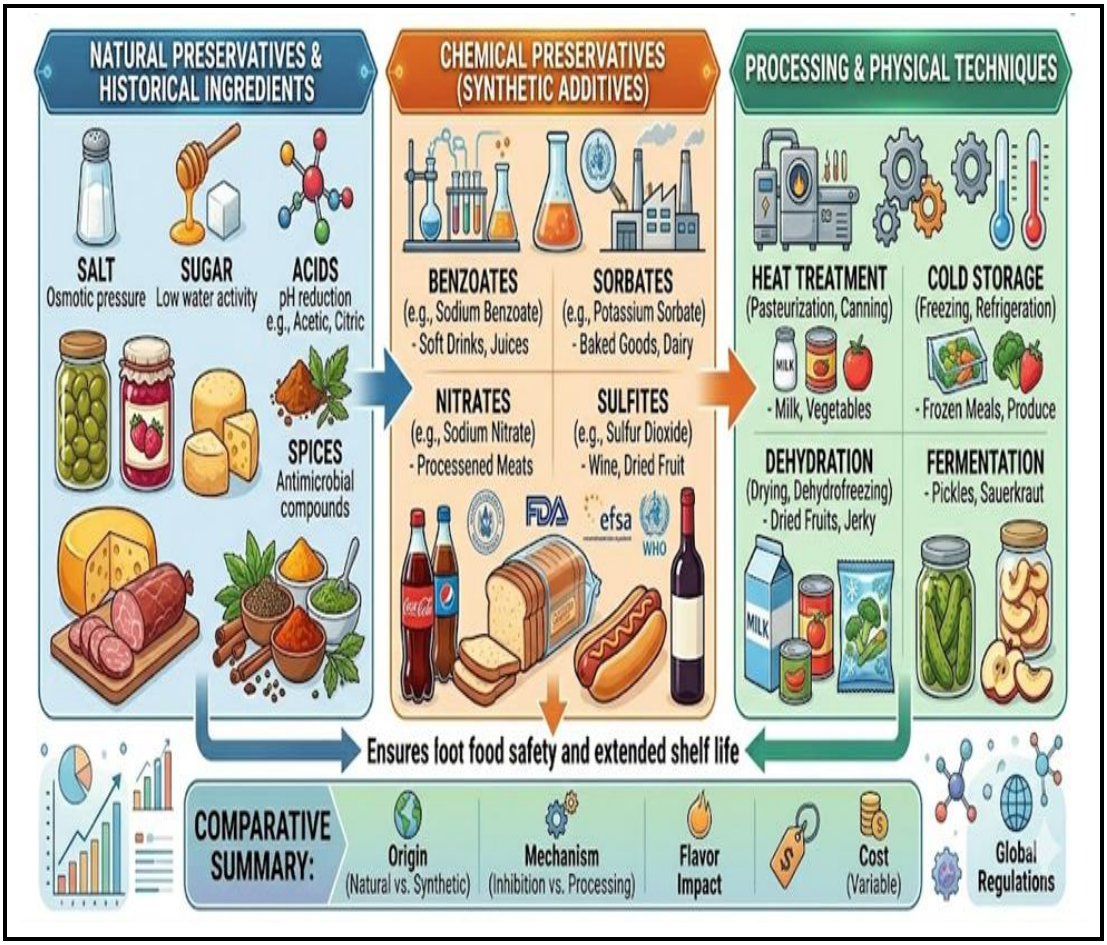


Figure (2): Classification of food preservations Methods used globally

Preservatives are another common fixation. Their job is to prevent spoilage, generally from bacteria or fungus. There are a number of preservatives including: (1) sodium chloride; (2) organic acids such as citric acid and acetic acid (3); sugar (4) natural preservatives such as garlic and spices ;(5) chemical preservatives such as sodium benzoate and potassium sorbate; and (6) use of nitrates and nitrites **(Figure 1)**. Nitrated meats have been made even more common with fast food and processed foods, most common in the U.S. and Europe. The preservatives help extend the shelf life of the products, so they're perfect for pre-processed, mass-produced items that need to last longer in storage and travel **(18,21)**.

Sulfur dioxide (or sulfites) are another commonly used preservative, generally used in dried foods like raisins and figs. Food can also be preserved naturally with methods like drying or fermenting, which are more common in some areas than in others. For example, fermenting foods is a very common preservation method in Egypt and in India. The bacteria from the fermentation process creates lots of flavor and preserves somewhat effectively, making the foods last longer **(22,23)**.

Pharmacological Considerations of Food Additives

The pharmacological dimension of food additives concerns how these substances interact with the body's biological systems following ingestion. Although primarily employed to preserve, color, flavor, or stabilize foods, certain additives can exert physiological and biochemical effects akin to those of drugs when consumed in substantial amounts or over extended durations **(24)**.

When any food is made more convenient to eat by removing any of these above mentioned processes from the process of manufacture, it becomes a higher risk type of food. For instance foods that do not undergo these processes, the greater risk they have of spoilage. Microorganisms, bacteria and fungi can spoil food in various ways. Bacteria metabolize food and emit toxic substances that make food unusable **(25,26)**.

Following ingestion, food additives undergo absorption, distribution, metabolism, and excretion through processes comparable to pharmacokinetics observed with medicines. The liver largely handles detoxification, while the kidneys facilitate elimination. In young children, less mature detoxification mechanisms heightening sensitivity to particular chemicals **(27,28)**.

Some additives may influence the nervous, immune, endocrine, or gastrointestinal systems. For instance, artificial colorants and flavor enhancers such as MSG have been investigated for potential neurological and behavioral effects **(29)**. Preservatives like

nitrites can form nitrosamines, compounds linked to carcinogenic activity under certain conditions **(30)**.

Certain additives may also provoke pharmacological reactions in susceptible individuals, including allergies, asthma exacerbations, headaches, skin irritation, or hyperactivity. Sulfites, for example, can trigger respiratory reactions in some individuals with asthma **(31)**.

Toxicological evaluations are conducted to establish acceptable daily intakes (ADIs) to guarantee safety at regulated exposure levels. Organizations such as the World Health Organization and the Food and Drug Administration assess the pharmacological and toxicological profiles of additives prior to their approval for use in foods **(32,33)**.

Impacts of Food Additives on young Bodies

Young children are at an increased risk of adverse health effects from exposure to food additives that are known to have adverse health effects over the long term. For example, the exposure to chemical additives can lead to oxidative stress, hormonal imbalance, and inflammation, which are all known causes of chronic diseases such as obesity and metabolic disorders. Young children are more susceptible to these adverse health effects because their livers and kidneys are still immature and don't have the ability to process the additives effectively, leading to issues with chemical build-up and processing in their system **(34,35)**.

Children are also more susceptible to the adverse health effects of additives due to gut microbiome disruption. This can lead to these children becoming sensitive to certain food additives. Allergic reactions in childhood can lead not only to allergies in adulthood but also to chronic diseases such as asthma and hyperactivity **(37)**.

Young children and especially infants are more sensitive to the effects of food additives than adults. The organs, immune system, and metabolic processes of young children are still developing, and so additives can interfere with their healthy development as the following:

(i) Adverse effect on immature detoxification systems

Infants and young children have immature detoxification systems because their livers and kidneys have not fully developed. As a result, the preservatives in foods have a greater potential to create problems because they remain in the bloodstream longer and are more likely to have toxic effects. Young children are also likely to be adversely affected by preservatives because their bodies have lower production of certain enzymes, especially if they have an underlying genetic disorder that is exacerbated by a diet high in preservatives **(38)**.

In fact, the oxidative stress caused by chemicals that would otherwise have been broken down by a properly functioning liver can lead to many health problems **(39)**.

(ii) Interference with gut microbiome

The influence of food preservatives on early life is closely tied to their effects on the developing gut microbiome in infants and young children. During this crucial period, the digestive system is being colonized by beneficial bacteria that support digestion, nutrient absorption, and immune function. However, certain preservatives particularly those with antimicrobial properties can inadvertently reduce or alter these beneficial microbial populations, disrupting the gut's natural balance **(40)**.

This disruption, often termed dysbiosis, can have significant implications for early development. Healthy gut microbiome helps educate the immune system to differentiate between harmful and harmless substances. When this process is perturbed, children may become more vulnerable to infections, allergies, and inflammatory conditions. Additionally, an unhealthy gut environment can impair digestion and diminish the body's capacity to absorb essential nutrients essential for growth **(41)**.

In the long term, early disruption of the gut microbiome may influence overall health beyond childhood. Evidence indicates that changes in microbial diversity during early life can be associated with elevated risks of conditions such as obesity, metabolic disorders, and damaged immunity **(42)**.

(iii) Undesirable controls on brain development and behavior

Preservatives may also affect brain development and behavior. Some studies indicate associations between certain food additives and hyperactivity, attention difficulties, or behavioral alterations in children. Given that the brain undergoes rapid growth in early life, exposure to compounds that disrupt neurotransmitter function or neural signaling could yield enduring developmental consequences **(43)**.

(iv)Negative impact on hormonal and general metabolic effects

Certain preservatives are suspected to function as endocrine disruptors, potentially interfering with hormone signaling. This could influence growth trajectories, metabolic processes, and energy balance, possibly elevating the risk of obesity or metabolic disorders as the child matures **(44)**. Additionally, early and repeated exposure to preservatives may heighten the likelihood of chronic health conditions over time. By affecting immune function, metabolism, and cellular health during a critical developmental period, these additives could contribute to the long-term emergence of conditions such as asthma, food

sensitivities, or other non-communicable diseases **(45)**.

In summary, Food preservatives and additives serve a crucial function in preserving food safety, preventing spoilage, and extending shelf life. Nevertheless, excessive or prolonged exposure to certain synthetic additives may elicit biological,pharmacological effects, and negative impact on heath particularly in infants and young children whose organs and body systems are still developing.

Conclusions

Food safety not only is important in diseases and health care spending, but it is growing to be an essential aspect towards economic growth.

The pharmacological study of food additives helps scientists understand their effects on human health, determine safe exposure levels, and reduce potential risks associated with long-term consumption.

Children exhibit greater vulnerability due to immature detoxification mechanisms, developing brain function, unstable hormonal balance, and a maturing gut microbiota. Some additives may contribute to digestive disturbances, behavioral alterations, metabolic disorders, allergic reactions, and oxidative stress.

Recommendations

Promoting reduced consumption of highly processed foods and encouraging balanced, natural diets may help mitigate associated health risks in children.

Foods containing food additives are not only unhealthy for children, but they also set a bad precedent for the rest of their lives, making it necessary to limit your diets to only healthy options.

Egypt must learn to segment its market through the establishment of global food safety standards with the enforcement of health regulations.

We encourage you to limit the amount of ultra-processed foods your children consume in their daily diet and to encourage them to eat fresh, healthy meals..

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