A SYSTEMATIC REVIEW ON ARTIFICIAL FOOD ADDITIVES: HOW DO E-NUMBERS AFFECT HUMAN BEHAVIOUR?

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https://doi.org/10.5281/zenodo.20378594

Abstract: The E numbers are shorthand for additive names and are derived from the international numbering developed for the European Union. Many people are concerned about the long-term effects of consuming E numbers and especially the effect they could have on children. Although E numbers do go through lengthy testing processes before being unleashed on the unsuspecting members of the public, sometimes certain numbers do have a negative effect on consumers.

The aim of this study is to raise awareness about synthetic food additives which have negative impact on human health and apprise parents about the additives in snacks that cause mental disorders and severe health problems in children. We have collected data about these food additives and analyzed investigations carried out to investigate negative side effects of E-numbers and came up with the solutions for the problem. We have also made a list of E-numbers to avoid, in what certain foods these can be found and alternative safe foods.

Background of the study: Today, you can find food additives in any kind of food. They are added as sweeteners, emulsifiers, colorants, etc. E-numbers are just codes for food additives. These code numbers can be created for any substances that fit the following three descriptions: substances that are not normally consumed as food itself; substances that are intentionally added to food for technological purposes during manufacturing, processing, preparing, treating, packaging, transporting and/or storing the food to achieve the end product you find in the store; substances that may or may not have any nutritional value. Although, there are dangerous additives, not all of them are bad for your health. For example, E300 is Vitamin C (boosts immune system) or E440 is Pectin (soluble fiber which binds substances in the intestines and adds bulk to the stools. However, there are plenty of those which cause significant harm to our organism. For example, E210 is Benzoic acid (can cause cancer) or E239 is Urotropin (can cause urinary track irritations and allergic reactions). Researches show that various and individual psychological, *biological*, and environmental risk factors can influence brain structure and function and contribute to the development of mental health disorders. The Key Clinic's article written by Lily Barton says research suggests that certain dietary factors, including food additives, might influence ADHD symptoms in some individuals. In particular, some E numbers, the codes assigned to food additives in the European Union, have been implicated in exacerbating ADHD symptoms. Nearly 1 in 5 children ages 3 to 17 (21%) had ever

been diagnosed with a mental, emotional, or behavioral health condition (2021) and numbers are increasing. Can the food they are eating be the reason for these statistics?

Thematic review of literature

1. **Connections between food additives and Psychiatric disorders**

2. Psychiatric Times's article about connections between food additives and osychiatric disorder (2024) says that an increasing number of studies suggested that ingestion of specific food additives can disrupt neurotransmitters and the hippocampus and induce neuroinflammation and gut microbiota dysbiosis, leading to anxiety and depression. Consumption of sweeteners widely used in the food industry has been connected to a variety of mental health issues and conditions in research. Results of a study based on 18,838 participants found a positive correlation between the consumption of non-nutritive sweeteners and major depression in both men and women. Another study involving 227 college students showed a potential link between reduced artificial sweetener intake and lower stress levels. Use of the natural sweetener sucrose and the nonnutritive sweetener aspartame may have negative effects on mental health—however, the nonnutritive sweeteners saccharin and stevioside have shown potential for attenuating depression in mice. This suggests that different nonnutritive sweeteners may have varying effects. Animal studies have also reported effects of preservatives on mental disorders. For example, exposing zebrafish embryos to methylparaben temporarily increased cortisol levels, reduced AChE activity, induced anxietylike behaviors, and decreased exploratory behavior in a dose-dependent way. Similarly, sodium benzoate given at a dose below the US Food and Drug Administration (FDA) safety limit induced delayed hatching, oxidative stress, and anxiety-like behaviors in zebrafish larvae. In a rat model, sodium benzoate consumption induced anxiety and motor impairment. Other food additives, such as emulsifiers and flavoring agents, may also have negative effects on mental health. For example, administration of 2 emulsifiers—carboxymethylcellulose and polysorbate 80—altered gut microbiota and the expression of anxiety-related neuropeptides in a sex-dependent manner, leading to anxiety-like behaviors in male mice and reduced social behaviors in female mice.

3. Food additives, essential nutrients and neurodevelopmental behavioural disorders in children.

A systematic review carried out by PubMed Central suggests that changing lifestyles in Canadian homes has led to demand for foods with long shelf lives that are cosmetically appealing, palatable, easy to prepare and to consume. Food additives, especially preservatives and artificial colours as well as suboptimal intake of essential nutrients, have been linked to hyperactive behaviours and poor attention in a subgroup of children. One challenge associated with the increasingly hectic Canadian family lifestyle is providing children with palatable food options that are easy to prepare and to consume. The food industry has responded seemingly effectively to this challenge by offering foods with long shelf lives, cosmetic appeal and palatability to children by using Health Canada-approved preservatives, food colourings and flavourings. Although these food additives undergo rigorous testing for efficacy and safety, questions are being asked regarding their potential effects on the health and behaviour of children. In the 1970s, the Feingold diet was introduced following suggestions that hyperactive behaviour demonstrated by children may be managed by eliminating artificial food colours, artificial flavours, naturally occurring salicylates and the preservative butylated hydroxytoluene.

Studies from the 1970s and 1980s cautiously supporting the behavioural benefits of diets free from synthetic food dyes and additives were counteracted by negative ones. Small study numbers and inconsistent methodologies noted discrepancies between parental observations and other objective assessments. However,clinical and epidemiological evidence supports a potential role of food additives and essential nutrients in NDBD in children as modifiable risk factors for certain symptoms and behaviours.

4. How foods impact behaviours

An article published by Dartmouth Health says that Diet significantly influences children's behavior; highly processed foods containing added sugars, unhealthy fats, artificial dyes, and additives can negatively impact mood and behavior. Processed foods cause rapid spikes followed by crashes in blood sugar, triggering stress hormones that can lead to irritability, anxiety, and anger, sometimes described as "hanger" in toddlers or adults. Frequent sugar intake and artificial colors have been linked to increased hyperactivity, temper tantrums, and behaviors resembling ADHD symptoms. Ultra-processed foods can contribute to long-term cognitive deficits, poor memory, and increased risk of mental health disorders due to neuroinflammation and disruption of brain development. Replacing processed snacks with whole foods rich in protein, fruits, and vegetables can help stabilize blood sugar levels and improve behavior over time.

5. Ultra-processed foods and mental health in children and adolescents

In article that lists evidences from systematic review on the relationship between ultra-processed foods and mental health in children and adolescents shows that UPFs have become increasingly prevalent not only in adult diets but also among children and adolescents, while the consumption of unprocessed or minimally processed foods has declined.. Evidence from population-based studies indicates that UPFs contribute a substantial proportion of daily energy intake from an early age. In the United Kingdom, consumption of UPFs at the age of seven accounts for approximately 59.4% of total energy intake. Similarly, in the United States, UPFs contribute approximately 66.2% and 66.4% of total energy intake among children and adolescents, respectively.

High consumption of UPFs has been consistently associated with adverse health outcomes and an increased risk of non-communicable diseases in both adults and children. Research suggests that UPFs negatively affect glycemic response alter gut microbiota composition, reduce overall dietary nutritional quality and are associated with higher prevalence of obesity, hypertension, cardiovascular diseases and metabolic syndrome. Importantly, the impact of UPFs extends beyond physical health and may also influence mental health outcomes. The World Health Organization (WHO) defines mental health as a state of well-being in which individuals realize their abilities, can cope with the normal stresses of life, work productively and contribute to their community.

6. Link between hyperactivity in children and certain food additives

A study by researchers at the University of Southampton has shown evidence of increased levels of hyperactivity in young children consuming mixtures of some artificial food colours and the preservative sodium benzoate.

The possibility of food colours and preservatives affecting children's behaviour has long been an unresolved question for parents. This significant new research by a team from the University of Southampton's Schools of Psychology and Medicine provides a clear demonstration that changes in behaviour can be detected in three-year-old and eight-year-old children. The children's families were asked to put them on a diet free from the additives used in the study. Over a six-week period the children were then given a drink each day which either contained one of two mixtures of food colours and benzoate preservative, or just fruit juice – with all the drinks looking and tasting identical. The research team used a combination of reports on the children's behaviour from teachers and parents, together with recordings of the children's behaviour in the classroom made by an observer, and, for the older children, a computer-based test of attention. None of the participants – teachers, parents, the observer, or the children – knew which drink each child was taking at any one time.

Professor of Psychology, Jim Stevenson , who led the research, comments: "We now have clear evidence that mixtures of certain food colours and benzoate preservative can adversely influence the behaviour of children. There is some previous evidence that some children with behavioural disorders could benefit from the removal of certain food colours from their diet. We have now shown that for a large group of children in the general population, consumption of certain mixtures of artificial food colours and benzoate preservative can influence their hyperactive behaviour.

Critical analysis

The reviewed literature suggests that E-numbers, particularly artificial colours, preservatives, and sweeteners, may influence children's behaviour, especially in relation to hyperactivity, attention, and emotional regulation. However, while some evidence supports this connection, the overall findings remain mixed and not entirely conclusive. A key strength of the literature is the presence of **controlled human studies**, such as the Southampton study, which demonstrated that mixtures of artificial food colours and sodium benzoate can increase hyperactive behaviour in children. The use of a double-blind design, combining parental, teacher, and observational assessments, strengthens the reliability of these findings. This suggests that certain E-numbers may have a measurable, short-term impact on behaviour in the general child population. Similarly, broader research indicates that **diets high in processed foods containing additives** are associated with irritability, anxiety, and attention difficulties. These behavioural effects are often explained through biological mechanisms, including blood sugar fluctuations, neuroinflammation, and disruptions in neurotransmitter function. Such mechanisms provide a plausible explanation for how E-numbers could influence mood and behaviour. However, the evidence is not entirely consistent. Earlier studies, including those examining the Feingold diet, produced conflicting results. These inconsistencies are partly due to **methodological weaknesses**, such as small sample sizes, lack of standardization, and reliance on subjective parental reports. As a result, it remains unclear whether E-numbers affect all children equally or only a **sensitive subgroup**, such as those with pre-existing behavioural conditions like ADHD. Additionally, some of the supporting evidence comes from **animal studies**, which, while useful for identifying mechanisms, cannot fully represent human behaviour. This limits the strength of conclusions about long-term psychological effects in

children. Importantly, the literature also suggests that **not all E-numbers have the same impact**. While certain artificial colours and preservatives are linked to hyperactivity, other additives may have minimal or even neutral effects. This indicates that the issue is more complex than simply labeling all additives as harmful. In conclusion, E-numbers appear to have a **potential influence on children's behaviour**, particularly in increasing hyperactivity and attention problems in some individuals.It is most accurate to conclude that certain E-numbers may negatively affect behaviour in **susceptible children**, rather than all children, highlighting the need for further well-controlled research.

Synthesis of findings

The literature shows that E-numbers, especially artificial colours, preservatives, and some sweeteners, can negatively affect children's behaviour. The most common effects include **increased hyperactivity, poor attention, irritability, and mood changes**. Several studies found that mixtures of additives, such as food colours and sodium benzoate, can make children more hyperactive. Other research suggests that E-numbers may affect the brain by disrupting neurotransmitters, increasing inflammation, and altering gut health, which can influence mood and behaviour. Diets high in processed foods with many additives are also linked to behavioural problems. These foods can cause quick changes in blood sugar levels, leading to irritability and difficulty concentrating. Overall, the findings suggest that E-numbers can have **negative effects on children's behaviour**, particularly when consumed in large amounts or in combination.

Research gap

Although existing studies suggest that E-numbers may negatively affect children's behaviour, there is still a lack of **consistent and conclusive evidence**. Many studies rely on small sample sizes, short-term observations, or animal models, which limits their applicability to real-life human behaviour. Additionally, few studies clearly isolate the effects of specific E-numbers, as children usually consume multiple additives at once. There is also limited research on the **long-term effects** of E-numbers and why some children are more sensitive than others. Therefore, more large-scale, well-controlled human studies are needed to better understand how E-numbers affect children's behaviour.

Conclusion

In conclusion, the evidence suggests that E-numbers, particularly artificial colours, preservatives, and sweeteners, can negatively affect children's behaviour. Studies have linked these additives to increased hyperactivity, attention difficulties, and mood changes, possibly due to their impact on brain function, gut health, and blood sugar levels. However, the findings are not entirely consistent, and the effects appear to be stronger in some children than others. Overall, while E-numbers are considered safe in regulated amounts, their potential influence on behaviour highlights the importance of limiting highly processed foods in children's diets and encouraging healthier, more natural alternatives.

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