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**MANUSCRIPT**

# Adverse Effects of Red 40 in PepsiCo Products on Neurodevelopmental Health in Low-Income Hispanic Communities Near the Texas-Mexico Border

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Received: July 3, 2024

Accepted for publication: January 24, 2025

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## Introduction

This literature review examines the potential adverse effects of Red 40, a synthetic food color widely used in PepsiCo products, on neurodevelopmental health within low-income Hispanic communities residing near the Texas-Mexico border. The review focuses on the intersection of food consumption patterns, environmental exposures, and health disparities within this vulnerable population. While direct research linking Red 40 consumption in PepsiCo products to neurodevelopmental issues in this specific demographic is limited, this review synthesizes existing research on Red 40's potential effects, the dietary habits of the target population, and the broader context of health inequalities along the US-Mexico border.

## Red 40 and Potential Neurodevelopmental Effects

Several studies have raised concerns about the potential adverse effects of Red 40 (Allura Red AC) on behavior and neurodevelopment, primarily in children.<sup>1</sup> Dietary exposure to Red 40 in children, based on data from the 2015-2016 National Health and Nutrition Examination Survey (NHANES), frequently exceeded acceptable daily intakes (ADIs) established by the FDA and WHO. This suggests a potential for widespread exposure, particularly among children, who consume high levels of Red 40 through juice drinks, soft drinks, icings, and ice cream cones.<sup>1</sup> However, the study did not directly assess neurodevelopmental outcomes, only focusing on the extent of exposure.<sup>1</sup> Further research is needed to establish a clear causal link between Red 40 exposure and specific neurodevelopmental problems.<sup>1</sup> Additional research using comprehensive approaches, such as those employed in zebrafish embryo studies examining the effects of various smoke dyes including Red 9 (similar chemical structure to Red 40), could offer valuable insights into potential mechanisms of toxicity.<sup>2</sup> Perkins et al. found that Disperse Red 9 impaired

behavior at all concentrations tested in zebrafish embryos, suggesting potential neurotoxicity.<sup>2</sup> However, extrapolating these findings to humans requires caution due to species differences in metabolism and response to chemicals.<sup>2</sup>

### **Dietary Habits and Food Insecurity in Border Colonias**

Low-income Hispanic communities along the US-Mexico border, often referred to as "colonias," face significant challenges related to food access and nutrition.<sup>3</sup> The high rates of poverty, food insecurity, and obesity within these communities. Limited access to affordable, healthy foods, coupled with the pervasive marketing of less healthy options, contributes to poor dietary habits.<sup>3-4</sup> The prevalence of ultra-processed foods (UPFs), which often contain high levels of added sugars, fats, and artificial additives like Red 40, is a significant concern.<sup>5-6</sup> The link between UPF consumption and obesity, a factor known to increase the risk of several neurodevelopmental problems.<sup>5</sup> The global spread of UPFs and their potential to compromise health at various levels, including cognitive and mental health.<sup>6</sup> The high consumption of sugar-sweetened beverages, often containing Red 40, is another factor contributing to poor dietary quality in these communities.<sup>7-8</sup> The lack of clear front-of-package labeling regarding added sugar content, making it difficult for consumers to make informed choices.<sup>7</sup> The association between NSS soft drink consumption (which may or may not contain Red 40) and lower socioeconomic status in Greek children, suggesting a similar pattern could exist in the studied communities.<sup>8</sup> Stein and Chakraborty further demonstrate the disproportionate presence of fast-food outlets near neighborhoods with larger proportions of racial/ethnic minorities, even after accounting for socioeconomic factors.<sup>4</sup> This unequal access to healthy food options exacerbates existing health disparities.

### **Health Disparities and Neurodevelopmental Outcomes**

The confluence of factors with limited access to healthy food, high consumption of UPFs containing Red 40, and existing socioeconomic inequalities create a complex interplay that can negatively impact neurodevelopmental outcomes in low-income Hispanic communities near the Texas-Mexico border.<sup>9-10</sup> The Hispanic Health Paradox, where Hispanics in the US have longer lifespans despite facing numerous health disparities, including higher rates of food insecurity.<sup>9</sup> However, this paradox doesn't negate the significant health challenges faced by this population, including potential neurodevelopmental risks related to diet and environmental factors.<sup>9</sup> The additional disadvantages faced by Hispanic and Latino cancer survivors, which includes limited access to equitable treatment options and sociodemographic adversities.<sup>10</sup> These inequalities are frequently rooted in disparate social determinants of health, including limited access to healthy and affordable food and barriers to community health/exercise opportunities.<sup>10</sup> While not directly related to Red 40, this emphasizes the broader context of health inequities that may exacerbate the impact of dietary exposures on neurodevelopmental outcomes.<sup>10</sup> Furthermore, the impact of air pollution, another prevalent environmental risk factor in these areas, on children's mental health needs further investigation.<sup>11</sup> Finding in the associations between air pollution exposure and behavioral/developmental disorders, anxiety, and eating disorders in rural children, highlighting the importance of considering multiple environmental stressors.<sup>11</sup> The potential cumulative effect of these factors, including dietary exposures to Red 40, on neurodevelopment requires further study.

## Research Gaps and Future Directions

This review highlights significant research gaps regarding the specific impact of Red 40 in PepsiCo products on neurodevelopmental health in low-income Hispanic communities along the Texas-Mexico border. Further research is needed to:

*Establish a direct causal link:* Studies are needed to directly assess the relationship between Red 40 consumption (specifically from PepsiCo products) and neurodevelopmental outcomes within this specific population. This requires well-designed epidemiological studies with appropriate control groups and adjustments for confounding factors such as socioeconomic status, overall diet quality, and other environmental exposures.

*Investigate potential mechanisms:* Research is needed to understand the potential biological mechanisms through which Red 40 might affect neurodevelopment. This could involve examining its effects on gut microbiota, immune function, and brain development at a cellular level.<sup>12-13</sup> The gut-brain axis and the influence of diet on neurodevelopment, suggest a potential avenue for investigation.<sup>12</sup> The interplay between diet, microbiota, and brain processes, suggest that whole-dietary approaches should be considered.<sup>13</sup>

*Consider cumulative effects:* Future research should consider the cumulative effects of multiple risk factors, including Red 40 exposure, food insecurity, and environmental pollutants, on neurodevelopmental outcomes. This requires a holistic approach that integrates data on multiple exposures and health outcomes.

*Address methodological limitations:* Many existing studies on Red 40 and neurodevelopment have limitations in terms of study design, sample size, and assessment of neurodevelopmental outcomes. Future studies should employ robust methodologies to minimize bias and increase the generalizability of findings.

*Engage communities:* Research involving border communities should prioritize community engagement and culturally sensitive approaches. This includes working closely with community members to design studies, recruit participants, and disseminate findings. The success of the "Eat Healthy, Be Active" workshops in empowering Mexican American women demonstrates the importance of culturally appropriate interventions with positive changes in healthy eating practices among participants.<sup>14</sup>

## Conclusion

While the evidence linking Red 40 to neurodevelopmental problems remains inconclusive, particularly within low-income Hispanic communities near the Texas-Mexico border, existing research raises significant concerns. The high prevalence of food insecurity, limited access to nutritious food, and widespread consumption of ultra-processed foods (UPFs), including those containing Red 40, contribute to an environment that may pose risks to neurodevelopmental health. Addressing these challenges requires further research using rigorous methodologies and a holistic approach that considers multiple interacting factors.

This review highlights the critical need for comprehensive investigations into the health impacts of food additives and packaging materials, including potential interactions that may influence human health. Studies on artificial food coloring and hyperactivity, though controversial, underscore the importance of continued exploration into the long-term consequences of dietary exposures, particularly in vulnerable populations.

Additionally, emerging evidence suggests that maternal COVID-19 infection during pregnancy, even without vertical transmission, could have long-term implications for fetal development and neurodevelopmental outcomes, including potential cognitive and behavioral issues such as ADHD. The complex interplay of genetic and environmental factors, exemplified by the sex-biasing influence of Ube3a gene overdosage, further emphasizes the multifaceted nature of neurodevelopmental disorders.

Beyond Red 40, the broader context of socioeconomic disparities including food insecurity and environmental exposures which remains a crucial determinant of health outcomes. Addressing these disparities through improved access to healthy food and targeted public health interventions is essential to promoting better neurodevelopmental health in these communities. Evidence from related health concerns, such as chronic kidney disease and cardiometabolic diseases, reinforces the need to consider social determinants of health in designing effective interventions.

Furthermore, lessons from agricultural systems in teaching kitchens suggest that collaborative, community-based approaches can address diet-related chronic diseases and improve food systems. Policy-driven solutions informed by U.S. food policy initiatives offer potential strategies to enhance dietary quality and reduce health disparities. Insights from international studies on toxic trace elements in food highlight the importance of monitoring environmental contaminants and their potential health impacts.

The review also points to the potential of bio-based packaging materials and natural food preservatives as sustainable solutions to reduce exposure to harmful chemicals. Advances in dietary interventions, such as targeted probiotic delivery, highlight the promise of emerging technologies in enhancing public health outcomes.

Finally, addressing health disparities requires a comprehensive approach that includes educational interventions, behavioral modifications, and policy reforms. Programs focusing on nutrition, such as school-based family asthma educational initiatives and dietary interventions for ADHD management, provide valuable models for future efforts. Understanding the relationships between diet, environmental exposures, and health outcomes will be crucial in shaping effective, evidence-based strategies to mitigate risks and promote well-being in underserved communities.

In conclusion, tackling the complex interplay of food additives, environmental exposures, and social determinants of health requires a multidisciplinary approach. Future research should prioritize the unique needs of low-income Hispanic populations and develop culturally tailored interventions that address both immediate dietary concerns and broader systemic inequities.

**Acknowledgements:**

Nori Zapata, MSN, RN, Senior Vice President of Education and Career Development, Vanessa Vera, MS, Senior Manager of High School and Community Outreach, Anisa Mirza, Intern Program Coordinator.

**Funding:**

Funded by DHR Health High School and Community Outreach; DHR Health; South Texas Independent School District.

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