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Consumption of Sweet Foods and Tantrums: Can Biochemical Mechanisms Explain Emotional Dysregulation in Toddlers?

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ABSTRACT
Temper tantrums in toddlers are generally explained by psychological factors, while the role of biochemical mechanisms has not yet been extensively studied. This study aims to analyze the biochemical mechanisms underlying the relationship between the consumption of sugary foods and emotional dysregulation in toddlers. The study employed a qualitative descriptive approach through a literature review, analyzing scientific articles and reputable references on glucose metabolism, neurotransmitters, neurobiology, and emotional regulation. The analysis was conducted using content analysis to develop a conceptual synthesis of sucrose digestion, insulin regulation, adenosine triphosphate (ATP) production, dopamine and serotonin synthesis, and changes in gene expression through epigenetic mechanisms. The results of the study indicate that excessive sugar consumption has the potential to trigger fluctuations in blood glucose that disrupt neuronal energy homeostasis and neurotransmitter balance, thereby increasing susceptibility to emotional dysregulation. However, this relationship cannot yet be deemed causal, as it is also influenced by psychological and environmental factors. These findings underscore the importance of a multidisciplinary approach to understanding tantrums in toddlers and provide a foundation for future experimental research.

***Keywords**: Toddlers; Emotional dysregulation; Sugar; Biochemical; Temper tantrum.*

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INTRODUCTION

Temper tantrums are a common form of emotional behavior in young children, particularly among toddlers aged 12-48 months (Lestari et al., 2021). This behavior is characterized by emotional outbursts such as crying, screaming, thrashing about, hitting, or throwing objects in response to the child's frustration or inability to express their desires and regulate their emotions (Agustini, 2025). Although tantrums are part of the normal developmental process, excessive frequency and intensity of tantrums may indicate an emotional regulation disorder. According to Paulus et al. (2021), the causes of tantrums are related to the immature development of the nervous system in toddlers, particularly the prefrontal cortex which plays a role in self-control and the limbic system, which functions as the center for emotional processing. Therefore, toddlers are a particularly vulnerable age group prone to emotional instability when exposed to various environmental stimuli.

Changes in the consumption patterns of modern society have made high-sugar foods and beverages increasingly accessible to children. Various types of sweet foods, such as candy, chocolate, sweetened beverages, and processed foods with high sugar content, have become part of daily consumption patterns (Karimanudin et al., 2025). This situation is a cause for concern because several studies have reported a link between excessive sugar consumption and various behavioral changes, such as increased impulsivity, hyperactivity, irritability, and difficulty controlling emotions (Del-Ponte et al., 2019). Although this relationship remains a subject of debate, various scientific findings suggest that fluctuations in blood glucose levels following the consumption of sugary foods may potentially affect brain functions involved in emotional regulation (Novitasari et al., 2025). Therefore, nutritional factors are an important aspect to consider, in addition to psychological and environmental factors, when explaining the occurrence of tantrums in children.

Studies on the causes of tantrums have primarily focused on psychological aspects, such as parenting styles, social-emotional development, the family environment, and children's communication skills (Lailiyah et al., 2023; Subagja & Catya, 2024). While this approach can explain various external factors influencing a child's behavior, it does not fully elucidate the biological mechanisms occurring within the body after a child consumes sugary foods. In fact, various studies in the fields of neurobiology and biochemistry, such as those by He et al. (2025) indicate that the body's metabolic state is closely linked to nervous system function, neuronal activity, and the production of neurotransmitters involved in emotional regulation. In other words, the relationship between the consumption of sweet foods and tantrums can be understood not only as a behavioral phenomenon but also as a consequence of physiological changes occurring at the cellular and molecular levels.

This article aims to critically examine the relationship between the consumption of sugary foods and the occurrence of tantrums in toddlers through an analysis of biochemical mechanisms, including sucrose digestion, insulin regulation, ATP production, the synthesis of the neurotransmitters dopamine and serotonin, the role of epinephrine, and the involvement of epigenetic gene expression. Thus, this study is expected to provide a more holistic understanding of the relationship between dietary patterns and emotional regulation in early childhood.

METHODS OF RESEARCH

This study employs a descriptive qualitative approach through library research. Library research is a type of research in which both primary and secondary empirical data sources are derived from books, documents, journals, or other literature (Cahyono, 2021). The data analyzed were derived from secondary sources, including scientific articles and research findings that examine the relationship between sugar consumption, biochemical mechanisms, and emotional regulation in children. The primary focus of this analysis is to examine the biochemical pathways from sucrose digestion to their impact on neuronal function and emotional behavior in children. The author used content analysis to construct a systematic scientific narrative regarding the interrelationships among the biochemical molecules, organs, enzymes, and neurotransmitters involved in this process. This study is descriptive-exploratory in nature, with the aim of systematically explaining the biochemical mechanisms underlying the relationship between the consumption of sugary foods and the occurrence of tantrums in toddlers.

RESULT AND DISCUSSION

Biochemical Molecules Involved

Molecules and biochemical mediators involved in the relationship between the consumption of sweet foods and emotional regulation include glucose, insulin, adenosine triphosphate (ATP), dopamine, serotonin, and epinephrine (Myers et al., 2021; Scherer et al., 2021). Glucose is the primary product of sucrose hydrolysis and serves as the main energy source for neurons in the brain (Peng et al., 2021). The glucose produced is then absorbed into the bloodstream, thereby stimulating insulin secretion by pancreatic β-cells. The pancreas has two main functions: the exocrine function, which produces digestive enzymes, and the endocrine function, which produces hormones such as insulin and glucagon to regulate blood glucose homeostasis. Insulin facilitates the uptake of glucose into insulin-sensitive tissues, primarily skeletal muscle and adipose tissue, via the glucose transporter type 4 (GLUT4). Glucose that has entered the cells is then utilized as an energy source or stored in the form of glycogen. Glucose that has entered the cells is subsequently metabolized through various cellular metabolic pathways to produce energy in the form of ATP (Petersen & Shulman, 2022; Scherer et al., 2021).

Inside the cell, glucose is metabolized through glycolysis in the cytosol, followed by pyruvate oxidation, the citric acid cycle (Krebs cycle), and oxidative phosphorylation in the mitochondria to produce adenosine triphosphate (ATP). ATP is the primary energy source required by neurons to maintain membrane potential, support synaptic transmission, and facilitate the synthesis and release of neurotransmitters (Peng et al., 2021; Attwell & Laughlin, 2001). The two main neurotransmitters involved in emotion regulation are dopamine and serotonin. Dopamine is primarily synthesized by dopaminergic neurons in the ventral tegmental area (VTA) and the substantia nigra, and plays a role in the reward system, motivation, and behavioral reinforcement. Meanwhile, serotonin is primarily synthesized by serotonergic neurons in the raphe nuclei of the brainstem and plays a role in maintaining mood stability, impulse control, and emotional regulation (Björklund & Dunnett, 2022; Ren et al., 2024). In addition, epinephrine (adrenaline), a hormone secreted by the adrenal medulla, is released as part of a counterregulatory response when blood glucose levels decrease. Excessive sugar consumption can cause a rapid increase in blood glucose levels, followed by a decrease in glucose levels due to the insulin response. These fluctuations in glucose levels have the potential to affect neuronal energy homeostasis as well as the synthesis and release of neurotransmitters, while simultaneously stimulating the release of epinephrine to maintain blood glucose levels within the normal range (Petersen & Shulman, 2022; Cryer, 2021). Overall, glucose, insulin, ATP, dopamine, serotonin, and epinephrine form an integrated biochemical pathway. Disruptions in this pathway may affect emotional regulation and increase susceptibility to temper tantrums in toddlers (Liu & Bohórquez, 2022; Petersen & Shulman, 2022).

Biochemical Processes in the Digestive System

The biochemical process of digesting sweet foods begins immediately after the food enters the oral cavity. At this stage, the salivary enzyme α-amylase begins to hydrolyze starch into maltose, maltotriose, and dextrin (Zhang et al., 2022). Next, in the stomach, carbohydrate digestion occurs primarily mechanically through agitation, while amylase activity is reduced due to acidic conditions. Digestion is then completed in the small intestine, where the enzyme sucrase hydrolyzes sucrose into glucose and fructose, which are ready to be absorbed by intestinal enterocytes (Petersen & Shulman, 2022; Ferraris & de Oliveira, 2023). Glucose is subsequently absorbed by intestinal epithelial cells via the sodium-glucose cotransporter 1 (SGLT1), which utilizes the sodium gradient maintained by the Na^+/K^+-ATPase pump, allowing glucose to enter the cell even against the concentration gradient. Once inside the enterocytes, glucose is transported into the bloodstream via glucose transporter 2 (GLUT2) through a facilitated diffusion mechanism, which subsequently increases blood glucose levels (Koepsell, 2020).

An increase in blood glucose levels after consuming sweet foods stimulates pancreatic β-cells to secrete insulin. When simple sugars are consumed in excess, a rapid rise in glucose levels can be followed by a strong insulin response, causing blood glucose levels to drop rapidly. In some individuals, this condition can lead to relative hypoglycemia a state in which the body exhibits a hypoglycemic response due to a sharp drop in glucose levels, even though blood glucose concentrations may not necessarily be below the normal range (Altuntaş, 2019; Kwan et al., 2022). This condition has the potential to affect the function of neurons nerve cells that play a role in transmitting impulses and regulating various brain activities, including emotional regulation. Neurons rely heavily on glucose as their primary energy source to produce adenosine triphosphate (ATP), which is necessary to maintain nerve cell function, as well as on oxygen and amino acid precursors, such as tryptophan and tyrosine, to support neurotransmitter synthesis. Fluctuations in blood glucose levels can affect neuronal energy homeostasis, thereby disrupting the availability of ATP needed to maintain nerve cell function. This condition has the potential to affect neurotransmitter synthesis and release, which in turn can disrupt emotional regulation (Peng et al., 2021; Fernstrom, 2013). In toddlers, these changes may increase vulnerability to excessive emotional responses, including temper tantrums, because emotional regulation mechanisms have not yet fully developed (Gee, 2016).

The Role of Enzymes in Biochemical Processes

Enzymes play specific roles at each stage of this biochemical process. In the digestive system, the process begins in the oral cavity, where salivary amylase produced by the salivary glands begins to break down complex carbohydrates into maltose, while also contributing to blood glucose homeostasis following carbohydrate consumption. The breakdown of carbohydrates then continues more intensively in the small intestine, where disaccharidases such as sucrase-isomaltase hydrolyze sucrose into glucose and fructose as the final stage of carbohydrate digestion before absorption by the intestinal epithelium (Gericke et al., 2016). Unlike digestive enzymes that act extracellularly, metabolic enzymes function within cells to regulate energy pathways and neurotransmitters. Hexokinase, for example, catalyzes the phosphorylation of glucose to form glucose-6-phosphate, the first step and the rate-limiting step of glycolysis (Roberts & Miyamoto, 2014). Furthermore, tyrosine hydroxylase is the rate-limiting enzyme in catecholamine biosynthesis, utilizing the cofactors tetrahydrobiopterin and molecular oxygen to convert tyrosine into L-DOPA, a precursor of dopamine (Daubner et al., 2011). Similarly, tryptophan hydroxylase acts as the rate-limiting enzyme in serotonin biosynthesis and requires the reduced pteridine cofactor, molecular oxygen, and non-heme iron to function optimally.

These findings suggest that excessive sugar consumption may affect the activity of these enzymes through glycemic instability, whereby consumption of foods with a high glycemic index produces a momentary euphoria due to a rapid spike in glucose levels, but is generally followed by a sharp drop (crash) that negatively impacts mood and mental function (Arshad, et al., 2025). Glucose itself is an essential substrate for ATP production in the brain as well as a precursor for neurotransmitter synthesis; thus, fluctuations in its availability directly affect neurotransmitter production and neuronal transmission (Dienel, 2019). It is this metabolic instability that is mechanistically thought to reduce the efficiency of tyrosine hydroxylase and tryptophan hydroxylase, resulting in suboptimal synthesis of dopamine and serotonin and contributing to emotional dysregulation in toddlers, which can clinically manifest as tantrum episodes (Arshad, et al., 2025).

The Role of DNA in Biochemical Processes

DNA serves as the primary regulator of the entire biochemical process, as it stores the genetic information necessary to produce various functional proteins, including enzymes, hormones, and receptors involved in glucose metabolism and neurotransmitter synthesis (Patel et al., 2023). In addition to encoding metabolic enzymes, DNA also encodes neurotransmitter receptors, proteins on the surface of neurons that function to receive chemical signals including dopamine receptors (DRs), whose expression is also influenced by gene methylation patterns. In this context, it is important to understand that dopamine as a neurotransmitter and dopamine receptors as signal-receiving proteins are two distinct components that functionally interact within the nervous system (Blum et al., 2024).

Excessive sugar consumption is believed to not only affect metabolic aspects but also influence gene expression through epigenetic mechanisms, as demonstrated by a recent study in children that found an association between a high-sugar diet and DNA methylation patterns in genes related to obesity and metabolism (Patel et al., 2023). One of the underlying mechanisms is a chemical modification known as DNA methylation a process that can alter gene expression levels without changing the structure or nucleotide sequence of the DNA itself and this has also been confirmed in European children who consume high-sugar ultra-processed foods (Llauradó-Pont et al., 2025). These epigenetic changes are thought to influence the brain’s reward system which is closely linked to dopamine pathways thereby amplifying responses to specific stimuli such as sweet foods through the activation of reward circuits involving the dopamine and endorphin systems (Qin et al., 2025).

This condition ultimately has the potential to trigger impulsive behavior in children that is, a tendency to act without mature emotional control as dysfunction in the prefrontal cortex, amygdala, and hypothalamus resulting from excessive sugar exposure is thought to contribute to increased impulsivity (Qin et al., 2025). This occurs because changes in gene expression resulting from these epigenetic mechanisms also influence the production of proteins involved in the neurotransmitter system (Blum et al., 2024), which in turn contributes to instability in emotional regulation that can manifest as tantrums in toddlers.

Effects on Health and Behavior

Excessive sugar consumption has the potential to affect neurological function through fluctuations in blood glucose levels that disrupt the metabolic balance of neurons. This is supported by the findings of Zou et al. (2020), who noted that the drop in glucose levels following an insulin spike reduces ATP production, thereby affecting the synthesis of neurotransmitters such as dopamine and serotonin, which play a role in emotion regulation. As a result, activity in the prefrontal cortex which controls impulses becomes less optimal, while the limbic system becomes more dominant in generating emotional responses (Datta & Arnsten, 2019). This condition can increase children's susceptibility to behaviors such as irritability, difficulty concentrating, and tantrums, particularly in toddlers whose nervous systems are still developing.

Nevertheless, this relationship cannot yet be viewed as a direct cause-and-effect relationship. This is because most studies supporting the link between sugar consumption and behavioral changes are still observational in nature and therefore unable to control for various confounding factors, such as parenting styles, sleep quality, nutritional status, or children's temperament. Therefore, sugar consumption is more accurately positioned as a factor that can exacerbate biological vulnerability to emotional dysregulation in children, rather than as the sole cause of tantrums. An overly simplistic interpretation risks overlooking the complexity of children's neurological and psychosocial development.

Implications for Understanding Children's Behavior

This study shows that tantrum behavior in toddlers needs to be understood through a more integrative approach. Until now, research has largely focused on psychological factors, such as parenting styles and the development of emotional regulation, while biochemical aspects have received relatively little attention. In fact, the mechanisms of glucose metabolism, ATP production, and neurotransmitter balance provide a biological basis for explaining why changes in metabolic conditions can affect a child's ability to regulate their emotions. Thus, biochemical mechanisms can complement rather than replace psychological explanations of tantrum behavior. However, the available evidence is still insufficient to conclude that sugar consumption is the primary cause of emotional dysregulation in toddlers. A child's behavior is the result of the interaction between biological, psychological, and environmental factors that influence one another. Therefore, future research needs to employ both longitudinal and experimental designs to test the causal relationship between changes in glucose metabolism and emotional regulation. Such a multidisciplinary approach is expected to yield a more comprehensive and relevant understanding of the mechanisms underlying tantrums in early childhood.

CONCLUSION

This studies indicates that the consumption of sugary foods has the potential to influence emotional regulation in toddlers through a series of interconnected biochemical mechanisms, ranging from glucose metabolism, insulin regulation, and ATP production to the synthesis of the neurotransmitters dopamine and serotonin, as well as changes in gene expression via epigenetic mechanisms. These findings confirm that tantrum behavior is not only influenced by psychological factors but also has a biological basis that can increase vulnerability to emotional dysregulation. However, the available evidence is insufficient to establish a causal relationship. Therefore, sugar consumption should be viewed as a risk factor that interacts with parenting styles, the environment, and the child's neurological development. The main contribution of this study is to present a conceptual framework that integrates biochemical, neurobiological, and psychological perspectives in explaining the mechanisms of tantrums in toddlers. Moving forward, longitudinal and experimental studies are needed that combine measurements of metabolic biomarkers, neurotransmitters, and psychosocial factors to strengthen the evidence for causality and support the development of evidence-based prevention strategies and nutritional recommendations for toddlers.

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