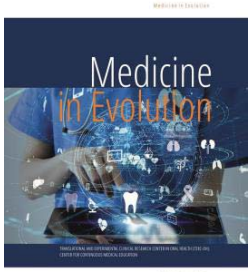
Variation in Salivary pH Based on Sugar Consumption



Lucian Floare[1], Delia Abrudan-Luca[1], Ioan-Alexandru Simerea[1], Ramona Dumitrescu[1,2], Octavia Balean[1,2], Vanessa Bolchis[1,2], Jojic Alina Arabela[3]

[1]*Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania, Faculty of Dentistry, Clinic of Preventive, Community Dentistry and Oral Health; Translational and Experimental Clinical Research Centre in Oral Health, Department of Preventive, Community Dentistry and Oral Health*
[2]*"Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania, Faculty of Dentistry, Clinic of Preventive, Community Dentistry and Oral Health*
[3]*"Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania, Faculty of Pharmacy, Discipline of Pharmacology-Pharmacotherapy*

Correspondence to:
Name: Delia Abrudan-Luca
E-mail address: delia.abrudan-luca@umft.ro

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Abstract

This research investigates the impact of sugar consumption on salivary pH, highlighting its implications for oral health. 1.Background/Objectives: The study aimed to analyze the effects of excessive sugar intake, a key factor in the development of dental conditions. 2. Methods: The study involved 45 students aged 20–23 years. Saliva samples were collected at four intervals: before sugar intake, immediately after, 30 minutes later, and one hour post-consumption. Samples were obtained via drainage, and pH was measured using indicator strips. 3. Results: The data revealed a significant drop in salivary pH immediately after sugar consumption, decreasing from an initial pH of 7 to 5.5. Partial recovery was observed, with pH reaching 6.5 after one hour. This temporary acidification of the oral environment confirms the link between sugar intake and an increased risk of dental caries. 4. Conclusion: The study emphasizes the importance of maintaining optimal salivary pH to prevent enamel demineralization and support natural remineralization. It also underscores the need for public education to reduce sugar consumption and adopt effective oral hygiene practices. This research contributes to understanding the dietary impact on oral health and suggests preventive measures to lower the incidence of dental issues.

Keywords: pH, saliva, acid, diatery, oral health, sugar consumption, caries, oral enviroment

INTRODUCTION

In recent decades, oral health has increasingly been recognized as a significant public health issue, heavily influenced by dietary behaviors, particularly the excessive consumption of sugar. Sugars have been identified as a primary risk factor for the development of dental caries and periodontal diseases, which are among the most prevalent non-communicable diseases worldwide [1]. These conditions contribute significantly to the global burden of oral health problems, affecting individuals' overall well-being, quality of life, and healthcare systems. As such, addressing sugar consumption is critical in mitigating oral health risks and promoting long-term health outcomes.

A key factor in preserving oral health is the maintenance of an optimal salivary pH. The importance of salivary pH in maintaining oral health lies in its ability to regulate the acid-base balance within the oral cavity. Recognizing the importance of saliva as a diagnostic fluid, the New York Academy of Sciences sponsored a pivotal conference on this topic in 1992. During the event, participants highlighted the critical need for advancing highly sensitive and specific assays to accurately measure and understand salivary variations associated with drug therapy, substance abuse, endocrine function, systemic and oral diseases, genetic abnormalities, nutritional status, and age-related changes. This conference significantly contributed to raising awareness of the potential of saliva-based diagnostics. Since then, ongoing research has led to the development of more refined salivary assays, enhancing our understanding of the intricate relationship between oral health and overall well-being [2]. When salivary pH is within the optimal range (6.2–7.6), saliva exerts a buffering effect that helps neutralize acids produced as a result of consuming foods and beverages, particularly those containing sugars. Saliva plays a crucial role in neutralizing acids in the oral cavity, protecting tooth enamel from demineralization, and supporting the remineralization process [3]. However, frequent and excessive intake of sugar-laden foods and beverages disrupts this balance, leading to a persistent drop in salivary pH. Acidic conditions in the oral environment create a favorable for the environment growth and activity of acidogenic and aciduric bacteria, which metabolize sugars into organic acids. This microbial activity accelerates the demineralization of enamel, increasing the risk of dental caries and other periodontal complications over time. Understanding the dynamic relationship between sugar consumption, salivary pH, and oral health is fundamental for devising effective preventive strategies. Prior research links sugar intake to salivary pH reduction, with studies highlighting the acidifying effects of sugary beverages and foods [2]. Numerous studies have investigated the factors influencing salivary pH, including dietary habits, sugar consumption, and microbial activity within the oral cavity. Recent studies have examined how salivary pH varies among individuals with different caries risk levels following the consumption of organic sugars, such as sucrose, and non-organic sugars, like maltitol. These findings highlight the distinct acidogenic potential of these sugars and their impact on caries risk. Such research provides valuable insights into the complex relationship between dietary sugars and oral health, underscoring the need to understand how different types of sugars influence the oral environment [4]. In addition to research examining salivary pH changes in individuals with varying caries risk after consuming organic and non-organic sugars, other studies further emphasize the complex interplay between dietary sugars, salivary pH, and oral health [5]. For instance, investigations have explored how sugar-rich diets interact with salivary proteins, shedding light on their role in dental plaque formation and its impact on oral health. These findings contribute to a broader understanding of the mechanisms linking sugar consumption to oral disease development [6].

Aim and objectives

This study investigates salivary pH fluctuations in response to sugar consumption, focusing on changes observed before, immediately after, and at specific intervals following exposure. This sugar consumption pattern is strongly associated with oral health challenges, underscoring the vital connection between sugar intake, salivary pH dynamics, and the overall condition of the oral cavity. By examining these physiological changes, the study aims to deepen understanding of the processes linking dietary habits to oral health outcomes.

MATERIAL AND METHODS

This cross-sectional study was conducted between October and November 2023 in Clinic of Preventive, Community Dentistry and Oral Health. The study included volunteers who provided informed consent after disclosing information about their health status, medication use, and smoking habits. The participants were second- and third-year students from the University of Medicine and Pharmacy "Victor Babeş" Timişoara, enrolled in the oral health discipline. The research was conducted during laboratory sessions as part of their academic activities. This study was approved by the Ethics Committee of the "Victor Babeş" University of Medicine and Pharmacy, Timişoara, Romania (No 34/2018). The research was conducted in accordance with the Declaration of Helsinki (1975) and its subsequent amendments, with written informed consent obtained from all participants prior to data collection.

The study was conducted with students enrolled in the "Oral Health" course, a mandatory component of the fifth-year curriculum at the Faculty of Dental Medicine Timisoara. Attendance for this course is compulsory, as it is required for eligibility to sit for the final examination. Out of the 110 students initially enrolled, 80 met the participation criteria. The final study included 45 students, comprising 19 males and 26 females aged between 20 and 23 years, with a mean age of 22. Exclusions were made for one participant with diabetes, two who declined participation by not signing the informed consent form, and one who violated the rules by eating an hour before saliva sample collection. Thus, the final sample consisted of 45 participants who adhered to all inclusion criteria and the study protocol.

Inclusion and exclusion criteria for the study were based on participants' consent to join and their adherence to the established guidelines. Participants were required to sign informed consent forms and comply with specific preparatory conditions, including abstaining from food consumption for at least two hours prior to saliva sample collection, refraining from oral hygiene practices such as toothbrushing, and, for smokers, avoiding smoking for one hour before the procedure. A general health questionnaire, designed by the College of Dental Physicians of Romania and widely used in dental offices across the country, was completed by participants. This questionnaire collected personal information, including age, gender, residence, general health status, and smoking habits (smoker or non-smoker). Additional data recorded during sample collection included medication use, smoking duration for smokers, and the number of cigarettes smoked daily. Individuals who did not comply with these requirements, refused to sign the consent forms, or failed to complete the questionnaire were excluded from the study. These measures ensured that the collected data were both reliable and relevant to the research objectives.

The study utilized the draining method to collect unstimulated whole saliva, a widely accepted approach for such samples due to its simplicity and high acceptability. Saliva was collected until a volume of 2 to 3 mL was reached in sterile tubes, adhering strictly to clinical protocols to ensure reliable results. To minimize the influence of circadian rhythms on salivary biochemical composition, sample collection was standardized between 8:00 and 10:00

AM. Participants were instructed to abstain from consuming food or beverages (except water), performing oral hygiene procedures, or smoking for a minimum of two hours prior to collection, with smokers refraining from smoking within one hour. Additionally, participants avoided medication use for at least eight hours to prevent any drug-related effects on salivary secretion. The collection took place in a relaxed classroom and examination setting, with participants seated, their heads slightly tilted downward, and facial and lip movements minimized after a 5-minute adaptation period. The research consisted of four stages: before the sugar consumtion, immediately after, 30 minutes post-consumtion, and one hour post-consumtion. Saliva samples were promptly analyzed using pH indicator strips (Qualigens, Glaxo India Ltd., Mumbai, India) by immersing them in the saliva and comparing the resulting color change to a standard color chart provided by the manufacturer. While these strips offer convenience and cost-effectiveness, their precision is lower compared to pH electrodes, as they measure pH in increments of 0.5 rather than two decimal points. Materials used in the study included collection cups, salivary pH indicator strips, a color chart, and 100g of Milka milk chocolate (Mondelez International), which served as the stimulus. The chocolate contained sugar, salt, cocoa butter, skimmed milk powder, cocoa mass, whey powder, milk fat, and an emulsifier. This composition was integral to assessing its effects on salivary pH. The normal salivary pH range of 6.5 to 7.4 provided a baseline for comparison, ensuring a consistent framework for evaluating pH changes throughout the study. Strict adherence to collection protocols ensured the accuracy and reliability of the results.

The study was conducted in four distinct stages to evaluate salivary pH fluctuations in response to a sugar stimulus. In the first stage, salivary pH was measured without any external stimulants to establish baseline values. Volunteers recorded salivary pH within the normal physiological range of 6 to 7, serving as a reference point for subsequent stages. In the second stage, participants were given a 4.2g cube of milk chocolate, which they chewed for three minutes to ensure uniform exposure of the oral cavity to the stimulus. Immediately after chewing, saliva samples were collected using sterile collection cups, and the pH was measured. A noticeable decrease in salivary pH was observed at this stage, with values ranging between 5 and 6, reflecting the acidogenic impact of the chocolate. The third stage involved collecting saliva samples 30 minutes after the participants consumed the chocolate. During this phase, salivary pH values varied among participants. For some individuals, the pH remained unchanged from the second stage, while others experienced either a further decrease or a slight increase in pH, indicating variability in the oral cavity's buffering capacity and individual salivary responses. In the fourth and final stage, saliva was collected one hour after consuming the chocolate. At this point, salivary pH values returned to their initial baseline levels recorded in the first stage, demonstrating the oral cavity's ability to recover and stabilize its pH over time. Throughout all stages, salivary pH was determined using pH indicator strips, which were immersed in the saliva samples and compared against a color chart to estimate pH values. While this method provided a convenient and cost-effective means of measuring pH, its precision was limited compared to more advanced tools such as pH meters. Strict adherence to collection protocols ensured reliable results, and the study design allowed for a comprehensive analysis of salivary pH dynamics following sugar exposure.

Statistical analysis was conducted using SPSS v23 (Statistical Package for Social Sciences, IBM, Chicago, IL, USA). Descriptive statistics, including mean and standard deviation, were used to summarize salivary pH values across the four stages of the study. The normality of data distribution was assessed using the Shapiro-Wilk test. Differences in mean salivary pH between the stages were evaluated using a paired t-test for normally distributed data. For all analyses, a significance threshold of $p < 0.05$ was applied to determine

statistically significant differences. This simplified approach ensured the results were analyzed effectively while adhering to the study's methodological constraints.

RESULTS

The study was conducted on 45 participants (16 males and 29 females) aged between 20 and 23 years, with a mean age of 22.0 years (±0.75). All participants were enrolled in the "Oral Health" course at the Faculty of Dental Medicine, UMF "Victor Babeş," Timişoara, Romania. Participants were from both urban and rural residential backgrounds, reflecting a diverse demographic profile relevant to the study's objectives. Of the 45 participants, 22 (48.9%) were smokers, with the number of cigarettes smoked per day ranging from 2 to 20. Among the smokers, the majority reported smoking traditional cigarettes, while a smaller proportion used electronic cigarettes. The remaining 23 participants (51.1%) were non-smokers. All participants were healthy, with no acute or chronic oral conditions, and complied with the study's inclusion criteria by refraining from food, beverage, or oral hygiene practices for at least two hours prior to saliva collection.

Baseline salivary pH values, measured before sugar consumption, ranged from 6.5 to 7.0, with an average of 6.75 (±0.2), providing a consistent reference point for subsequent measurements. In Stage 1, prior to any stimulus, the salivary pH values were predominantly at the higher end of the range, indicating a stable starting condition. Stage 2, immediately after consuming 4.2g of milk chocolate, showed a marked decrease in pH, with values ranging from 5.0 to 6.0 and a mean of 5.5 (±0.5), reflecting a rapid acidification of the oral environment due to sugar exposure. In Stage 3, 30 minutes' post-consumption, pH values showed partial recovery, clustering between 6.0 and 6.5, with reduced variability compared to the previous stage. By Stage 4, one hour after consumption, salivary pH had largely returned to baseline levels, with many participants recording values close to 7.0. Across all stages, salivary pH values fluctuated within a range of 5.0 to 7.0, with most measurements falling between 6.0 and 7.0. These findings highlight the dynamic response of salivary pH to sugar intake, characterized by an initial drop followed by gradual recovery, maintaining a near-neutral to slightly acidic balance throughout the process (Figure 1).

Figure 1. ph Values across stages

The data reveals that the initial average pH values for participants are the same for both men and women, each measuring 6.75. This consistency suggests that no significant differences existed between the gender groups at the start of the study regarding their average pH levels. The overall average pH value of 6.75 further highlights this equilibrium across the two groups. This finding establishes a uniform baseline for the experiment, facilitating a more equitable comparative analysis of future variations.

Saliva samples were collected 30 and 60 minutes after sugar consumption to observe pH fluctuations.

Table 1. Salivary pH values after chocolate consumption

Time	Initial Average pH
30 minutes	5,7
60 minutes	6,5

The average salivary pH values measured before sugar consumption were 7 (±0.5). After consuming chocolate, the average salivary pH values decreased to 5.5 (±0.5), indicating a significant acidification of the oral environment. The significant decrease in salivary pH immediately after sugar consumption (from 7.0 to 5.5) indicates a rapid acidification of the oral environment, which may promote the development of dental caries. The partial recovery of pH at 60 minutes suggests that saliva begins to neutralize the acidity, but fails to fully return to the initial value within the one-hour period (Figure 2).

Figure 2. Dynamic Changes in Salivary pH Across Four Stages of the Study

In Stage 1, the mean pH value was 6.81, with a small standard error of 0.0398, indicating a low margin of sampling error. The median and mode were both 7, reflecting a slight tendency toward higher pH levels. Variability among the measurements was minimal, as indicated by a standard deviation of 0.2673 and a sample variance of 0.0715. The distribution was slightly left-tailed, with a skewness of -0.9834, and nearly flat, with a kurtosis value of -0.1032. The pH values ranged from 6 to 7, suggesting limited variability.

In Stage 2, the mean pH decreased to 6.05, accompanied by a higher standard error of 0.0697, signaling increased variability compared to Stage 1. The median and mode, at 6 and 6.5 respectively, were close to the mean. The standard deviation of 0.4674 and sample variance of 0.2184 pointed to greater dispersion of values. A kurtosis of -0.3618 and skewness of -0.7536 indicated a slightly left-skewed and flat distribution. The pH values spanned from 5 to 6.5, with a total of 45 samples and a cumulative sum of 272.5.

Stage 3 showed a slight increase in the mean pH to 6.2, with a moderate standard error of 0.056, indicating a balanced level of variability. Both the median and mode remained at 6, reflecting consistent central tendencies. The standard deviation of 0.3754 and sample variance of 0.1409 highlighted moderate variability. The skewness of 0.1889 suggested a slight right-

tailed distribution, while the kurtosis value of -0.1276 indicated a nearly flat distribution. The pH values ranged from 5.5 to 7, with a total sum of 279 across 45 samples.

In Stage 4, the mean pH increased to 6.73, with a low standard error of 0.0408, indicating precise sampling. The median was 6.5, and the mode was 7, showing a slight tendency toward higher pH levels. Variability was reduced, as evidenced by a standard deviation of 0.2739 and sample variance of 0.075. The kurtosis of -1.0594 and skewness of -0.2972 suggested a flatter and slightly left-skewed distribution. The pH values ranged from 6 to 7, with a total sum of 303 across 45 sample.

DISCUSSIONS

This study provides valuable insights into the impact of dietary sugars on salivary pH dynamics and their broader implications for oral health. The primary objective was to assess the fluctuations in salivary pH across four distinct stages—before sugar intake, immediately after consumption, 30 minutes' post-consumption, and one-hour post-consumption—highlighting the physiological processes underlying these changes. The findings emphasize the importance of understanding the relationship between sugar consumption and salivary pH, a critical factor in maintaining oral health and preventing cariogenic bacterial growth. The results revealed a rapid and significant decrease in salivary pH immediately following the consumption of 4.2g of milk chocolate, followed by a gradual recovery over time. This pattern is consistent with existing literature, which describes a similar acidification of the oral environment after sugar intake, contributing to increased bacterial activity and the risk of dental caries. The study also demonstrated the buffering capacity of saliva, which effectively neutralized the acidic conditions induced by sugar exposure. However, the partial recovery observed within one hour suggests that this process is not immediate, leaving the oral cavity vulnerable to demineralization during the recovery phase. Additionally, the findings highlighted inter-individual variability in salivary pH responses, likely influenced by factors such as smoking habits, dietary patterns, and individual differences in salivary buffering capacity. Despite these variations, the consistency of baseline pH values across participants ensured a reliable framework for comparative analysis.

The findings of this study align with existing literature on the critical role of saliva in maintaining oral health through its buffering capacity, antimicrobial properties, and ability to regulate the oral microbiota [7]. Our research demonstrated a significant decrease in salivary pH following sugar consumption, followed by a gradual recovery, emphasizing saliva's role in counteracting acidification [8]. This aligns with studies highlighting the presence of natural defensive molecules in saliva, such as antimicrobial peptides (AMPs), mucins, and proline-rich proteins (PRPs), which play a key role in neutralizing acidic conditions and preventing dental caries. Moreover, the buffering action of ammonia derived from amino acids such as arginine and lysine, noted in previous studies, complements our findings by explaining saliva's ability to stabilize pH levels post-sugar intake [9,10].

However, this study primarily focused on pH fluctuations, while the literature points to additional salivary factors, including protein concentration, enzymatic activity, and glycoproteins, that contribute to oral health. For instance, the role of defensins and lactoferrin in controlling microbial flora and immunoglobulin A (IgA) in regulating bacterial activity could further explain individual differences in salivary pH buffering capacity observed in our participants. Additionally, the impact of age, sex, and protein composition on salivary function, as described in prior research, suggests areas for further exploration, particularly as our sample was limited to a younger demographic. The broader insights into salivary protein composition, enzymatic activity, and antimicrobial action from previous research underscore the multifaceted role of saliva, beyond just pH regulation, in maintaining oral health [6].

Similar to previous investigations highlighting a deeper pH drop in individuals with elevated caries risk, our research observed a significant reduction in salivary pH immediately following sugar consumption, with a gradual but incomplete recovery within one hour. This reflects the vulnerability of the oral environment during the acidogenic challenge. Additionally, studies show that individuals without caries exhibit a stronger buffering capacity, suggesting that the resilience of salivary systems plays a vital role in mitigating the effects of pH drops [11]. The incomplete pH recovery observed among participants mirrors the weakened physiological response described in the literature when the oral environment is exposed to repeated fermentable carbohydrate intake. This is particularly relevant, as the continuous exposure to such dietary components may impair the saliva's ability to neutralize acid effectively, increasing the risk of caries progression. The consensus in the literature supports the idea that the pH control mechanisms in the oral cavity are governed by complex ionic and protein interactions, a dynamic that is consistent with the buffering effects observed in our findings [12].

Previous research has consistently demonstrated that food consumption induces an initial decrease in salivary pH, followed by a gradual recovery [13]. Acidic foods, such as apples and citrus fruits, often lower salivary pH below the critical threshold of 5.5, significantly increasing the risk of enamel demineralization. These studies further highlight the slow oral clearance of certain foods, such as apples, leading to prolonged acidogenic effects that persist beyond 12 minutes [14]. Similar findings indicate that fresh fruits maintain a low pH for extended periods, thereby posing a sustained risk to oral health. Additionally, comparisons of various foods, such as chocolate and biscuits, reveal that both significantly reduce salivary pH, though the levels typically remain above critical thresholds. Notably, the recovery rate of salivary pH is slower for chocolate during the initial minutes post-consumption but ultimately exceeds that of biscuits due to its faster clearance from the oral cavity [14-16]. In contrast, sugar-free chewing gum demonstrates a favorable effect on salivary pH, promoting an immediate increase attributed to enhanced salivary buffering and flow [17].

The study's findings align with this body of research, particularly in observing a significant initial decline in salivary pH following the consumption of sugar-containing chocolate, accompanied by a gradual recovery within one hour. However, unlike the immediate and substantial recovery associated with sugar-free chewing gum, the response to chocolate was slower and incomplete, underscoring the limitations of salivary buffering mechanisms in counteracting prolonged acidogenic challenges [17,18]. Furthermore, the study supports the notion that food texture and retention properties significantly influence salivary pH dynamics. The slower clearance time of sugary foods, such as chocolate, highlights their potential to sustain an acidic oral environment, increasing the risk of enamel demineralization compared to foods with more rapid clearance rates. These observations emphasize the importance of considering food-specific characteristics when evaluating their impact on salivary buffering capacity, oral health, and the development of dietary recommendations aimed at reducing caries risk.

The implications of this research extend beyond individual observations, offering a foundation for targeted strategies aimed at reducing sugar consumption. Measures such as implementing sugar taxes, clear labeling of sugar content in food products, and establishing guidelines for daily sugar intake could effectively address the root causes of sugar-related oral health issues. These approaches contribute to the broader goals of preventive dentistry and public health by prioritizing oral health maintenance and reducing the burden of dental diseases on populations.

Future studies should aim to investigate the variability in salivary buffering capacity among individuals, considering factors such as salivary flow rate, composition, and lifestyle

influences like smoking and dietary habits [8]. Additionally, expanding the research to include a variety of dietary stimuli, such as acidic beverages or sugar substitutes, could provide a broader understanding of their effects on salivary pH. The use of more precise measurement tools, such as pH meters, should be considered to improve the accuracy of pH assessments, particularly in studies requiring detailed biochemical analysis. From a public health perspective, integrating educational programs that promote awareness of the impact of dietary sugars on oral health could play a vital role in mitigating the risk of dental caries. These programs, targeting schools and community health centers, could help instill healthier dietary habits from an early age, ultimately reducing the burden of sugar-related oral health conditions.

These advancements in research design could significantly contribute to the development of comprehensive public health strategies. By understanding the long-term effects of sugar and other dietary factors on salivary pH, targeted interventions to mitigate oral health risks can be devised. Such efforts could include education campaigns, dietary guidelines, and policy measures to reduce sugar consumption, ultimately benefiting public health and reducing the prevalence of dental and periodontal diseases. The results of this study align closely with previous research, which has demonstrated that sugar consumption lowers salivary pH, creating favorable conditions for the proliferation of cariogenic bacteria. These studies consistently show that salivary pH drops rapidly following sugar intake and gradually returns to normal levels over time, a pattern that confirms the previously noted observations. This concordance with existing literature reinforces the validity of the findings and highlights the well-established relationship between sugar consumption and changes in salivary pH.

In conclusion, the interplay between sugar intake, salivary pH, and oral health represents a significant area of study with profound public health implications. By elucidating the physiological mechanisms and risks linked to sugar consumption, this research underscores the necessity for collective efforts to curb sugar intake. Such initiatives have the potential to markedly reduce the prevalence of dental caries and periodontal diseases, thereby improving oral health outcomes and enhancing the quality of life for individuals and communities worldwide.

CONCLUSIONS

This study demonstrates the significant impact of sugar consumption on salivary pH, highlighting a rapid drop in pH immediately after intake and a gradual, yet incomplete, recovery within one hour. These findings emphasize the critical role of saliva in buffering oral acidity and the risks posed by prolonged acidogenic conditions, such as increased vulnerability to dental caries. Addressing sugar consumption through dietary education, public health policies, and targeted interventions is essential for mitigating oral health risks. Future research should explore broader dietary influences, individual variability in salivary buffering capacity, and more precise measurement methods to deepen our understanding and enhance preventive strategies.

Conflicts of Interest

The authors declare no conflict of interest.

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