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DENTISTRY DEGREE

**SUGAR FREE ISN'T RISK FREE: INVESTIGATING THE
EFFECTS OF ARTIFICIAL SWEETENERS ON ORAL
HEALTH**

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RESUMEN

Introducción: El aumento del uso de edulcorantes artificiales y no nutritivos ha sido impulsado por estrategias de salud pública destinadas a reducir el consumo de azúcares libres y prevenir la caries dental. A pesar de su clasificación como “seguros para los dientes”, sus efectos sobre la salud oral son complejos y dependientes del contexto. **Objetivos:** Evaluar críticamente el impacto de los edulcorantes artificiales sobre la salud oral, incluyendo la actividad de bacterias cariogénicas, la desmineralización del esmalte, el pH de la placa y la composición del microbioma oral, en comparación con la sacarosa o la ausencia de edulcorantes. **Metodología:** Se realizó una revisión sistematizada de la literatura utilizando bases de datos como PubMed, Scopus y ScienceDirect, incluyendo estudios revisados por pares publicados entre 2015 y 2025 seleccionados según criterios predefinidos. **Resultados:** La mayoría de los edulcorantes artificiales no son fermentables por bacterias orales, lo que reduce la producción de ácidos y el potencial cariogénico en comparación con la sacarosa. Los polioles, especialmente el xilitol, mostraron efectos anticariogénicos significativos, incluyendo la inhibición de *Streptococcus mutans*, la alteración de la formación de biopelículas y el aumento del flujo salival, favoreciendo la remineralización del esmalte. Por el contrario, los edulcorantes de alta intensidad como el aspartamo, la sucralosa y la sacarina presentan efectos principalmente neutros. Sin embargo, factores como la acidez de las bebidas, la frecuencia de consumo y el tiempo de exposición pueden contribuir a la erosión del esmalte independientemente del tipo de edulcorante. Además, se han observado posibles cambios en el microbioma oral, aunque su relevancia clínica aún no es concluyente. **Conclusiones:** Aunque los edulcorantes artificiales pueden reducir el riesgo cariogénico, considerar que “sin azúcar” equivale a “sin riesgo” es una simplificación excesiva.

Palabras clave: Odontología, edulcorantes artificiales, caries dental, microbioma oral, xilitol

ABSTRACT

Introduction: The increasing use of artificial and non-nutritive sweeteners has been driven by public-health strategies aimed at reducing free sugar intake and preventing dental caries. Despite their widespread classification as “tooth-friendly,” emerging evidence indicates that their effects on oral health are multifactorial and context-dependent rather than universally protective. **Objectives:** This study aimed to critically evaluate the impact of artificial sweeteners on oral health outcomes, including cariogenic bacterial activity, enamel demineralization, plaque pH, salivary response, and oral microbiome composition, compared with sucrose or no-sweetener exposure. **Methodology:** A systematised literature review was conducted using major scientific databases, including PubMed, Scopus, and ScienceDirect, incorporating peer-reviewed studies published between 2015 and 2025 selected according to predefined inclusion and exclusion criteria. Both experimental and clinical studies were analyzed to ensure a comprehensive evaluation of current evidence. **Results:** Most artificial sweeteners were found to be non-fermentable by oral bacteria, resulting in reduced acid production and lower cariogenic potential compared with sucrose. Polyols, particularly xylitol, demonstrated strong anti-cariogenic effects, including inhibition of *Streptococcus mutans*, disruption of biofilm formation, reduction of bacterial adhesion, and stimulation of salivary flow, thereby promoting enamel remineralization. In contrast, high-intensity sweeteners such as aspartame, sucralose, and saccharin exhibited predominantly neutral effects, with limited clinical evidence supporting direct protective benefits. However, product-related factors, including beverage acidity, frequency of consumption, and exposure time, were shown to contribute significantly to enamel erosion independently of sweetener type. Emerging evidence also suggests that artificial sweeteners may alter oral microbiome composition, although the clinical implications of these changes remain uncertain. **Conclusions:** Artificial sweeteners may reduce sugar-related cariogenic risk, but the assumption that “sugar-free” equates to “risk-free” is overly simplistic, as oral health outcomes depend on complex interactions between biological, behavioural, and environmental factors.

Keywords: Dentistry, artificial sweeteners, dental caries, oral microbiome, xylitol

1. INTRODUCTION

The last five decades have witnessed a dramatic rise in the availability and consumption of **non-nutritive sweeteners (NNS)** and sugar alcohols across foods, beverages, oral-care products, and pharmaceuticals, driven by reformulation trends and growing consumer demand for low-calorie options (1,2). Marketed as calorie-saving and glycaemic-friendly alternatives to sucrose, these compounds including high-intensity sweeteners (e.g., aspartame, sucralose, stevia) and polyols (e.g., xylitol, erythritol) are widely promoted for weight and glycaemic management (2,3). From a cariology perspective, most approved NNS and many polyols are **non-fermentable** by major cariogenic bacteria and therefore do not directly fuel the acid production that causes enamel demineralization; this biochemical property underpins the long-standing classification of many sugar-free products as “tooth-friendly” (4–6). That perceived dental safety, combined with public-health efforts to reduce free-sugar intake and extensive product reformulation by food manufacturers, has driven the proliferation of sugar-free items, from chewing gums and lozenges to toothpastes and beverages, that contain NNS or polyols (1,7). Nevertheless, recent experimental and sequencing studies complicate the simple messaging that “sugar-free = safe.” While polyols such as **xylitol** and **erythritol** show reproducible anticariogenic effects in many clinical trials and meta-analyses (reduced *S. mutans* counts, lower caries increment under defined dosing/vehicle conditions), the magnitude of benefit is dose- and product-dependent (8–10). Concurrently, a growing number of *in vitro* and *in vivo* investigations report that some high-intensity NNS and other sugar substitutes may alter biofilm architecture, bacterial adhesion properties, and plaque community composition in context-dependent ways; findings that raise questions about potential indirect effects on oral ecology and host salivary responses (5,11). Finally, the net impact of sugar substitutes on oral health reflects interactions among sweetener chemistry, delivery vehicle (for example gum vs beverage), frequency/dose, and host factors such as saliva flow and baseline microbiome composition; this multi-factorial interplay explains why “sugar-free” status alone cannot guarantee a risk-free outcome for oral health (9,12).

1.1 What Are Sweeteners?

They are substances added to foods and beverages substituting sugar or scientifically referred to as glucose/sucrose. These non-nutritive substances are increasingly getting more incorporated into our daily life due to the fact that they are very low in calories or even non-caloric in some of the variants. This increase of usage is associated to the artificial sweeteners health benefits, in the case of sugar alcohols, slower metabolism rate as they turn into glucose slowly, benefiting us by requiring little to no insulin

production to be metabolized by the body. Slowly metabolizing guarantees that the blood sugar levels won't spike endangering diabetic patients (13). Sweeteners in general can come in multiple forms either natural or artificially manufactured and they share some similarities and benefits such as being non-cariogenic (13). Plenty of differences however do exist and those will be expanded upon later in this paper. When compared to normal table sugar (sucrose), sweeteners can vary in sweetening intensity relative to sugar with some reaching up to around twenty thousand times sweeter such as advantame and others like aspartame only being 200 times sweeter than sugar (14).

1.2 Synthetic (artificial) sweeteners

1.2.1 Overview of Synthetic Sweeteners

Low calorie sweeteners (LCS), in relation to sweeteners with higher values of calories such as sugar and corn syrups, contain little to no calories with a high ratio of sweetness per gram of substance. LCS can be found very frequently in items marked as diet or sugar free products or even sold as a standalone general-purpose sweetener to be used however the consumer wants to (15). They are very useful for the general public that need the sweetness but are trying to lose weight using substances that are as deemed by the FDA to be safe for consumption, stating they are safe for use after conducting studies (16).

1.2.2 Aspartame

The sweeteners come in different commercial names, and each are marketed differently in every market around the world. However in the case of the United States and the FDA approved brands we can find the sweetener Aspartame marketed under the names Nutrasweet®, Equal®, and Sugar Twin® (14). Aspartame is not free of calories, however due to the fact that it is 200 times more sweeter than table sugar, consumers tend to use it in less amounts, therefore ending up with lower calories gained to achieve the same sweetness (17).

1.2.3 Saccharin

Another very commonly found sweetener in the American market, **saccharin**, widely available under the market names of Sweet and Low®, Sweet Twin®, Sweet'N Low®, and Necta Sweet®. Ranging from 200 to 700 times sweeter than sugar however it has been linked to development of bladder cancer in laboratory rats in the early 1970s (14,18). After additional congress mandated studies, saccharin and the development of bladder cancer in rats has been deemed irrelevant in humans. Furthermore in 2000, the National Toxicology Program of the National Institutes of Health came to the conclusion that saccharin is

not carcinogenic and should be taken off the list of substances with potential carcinogenic properties and have the warning label on saccharin products removed (19).

1.2.4 Acesulfame Potassium (Ace-K)

Acesulfame Potassium (Ace-K) is an odorless and colorless crystalline powder available in the market as Sunett® and Sweet One®, has 200 times the sweetness of sugar. This sweetener has the ability to be stable during high heat, making it a suitable replacement for sugar to be used in baked foods as its decomposition point is at 225° C (20). The FDA reviewed more than 90 studies to identify any possibilities of toxicity regarding Acesulfame Potassium. These studies focused on carcinogenicity, metabolism and reproductive effects (14).

1.2.5 Sucralose

Sucralose, another artificial sweetener that is used as an ingredient to replace sugar in reduced calorie foods and beverages sold under the names Equal Sucralose® and SPLENDA® Original as table top sweeteners (21). Sucralose is around 600 times sweeter than sugar. It is found in various types of foods, whether they're baked goods, drinks, chewing gums, dairy desserts. Like Acesulfame Potassium it is stable in high temperatures allowing its use in baking (14). The studies the FDA reviewed to determine the safety of Sucralose focused on possible toxic effects to the reproductive and nervous systems, carcinogenicity and metabolism as well. The FDA also reviewed human clinical trials to address metabolism and effects on patients with diabetes (14).

1.2.6 Neotame

Neotame is very similar and chemically related to Aspartame however the latter is less stable chemically. Neotame is 8,000 times sweeter than table sugar and 40 times sweeter than Aspartame (22). Neotame has a glycemic index of zero, meaning it does not raise blood glucose levels. This characteristic makes it a suitable sweetener for individuals managing blood sugar levels, such as those with diabetes (23). Like the other sweeteners it is also approved for use in baking as a sugar substitute as it is heat stable. The studies reviewed by the FDA focused on toxic effects on the immune, reproductive and nervous systems (14). Due to its high sweetness potency, only a minuscule amount of neotame is required to achieve the desired sweetness in products. Consequently, it contributes negligible calories to the diet, aligning with its classification as a non-caloric sweetener (14).

1.2.7 Advantame

Advantame is relatively 20,000 times more sweeter than sugar and is also approved as a food additive. It is safe to use in baked goods due to its heat stability and is used as a general purpose sweetener and flavor enhancer in foods, excluding red meats and poultry (24). Due to its high sweetness potency, only a minuscule amount of advantame is required to achieve the desired sweetness in products. Consequently, it contributes negligible calories to the diet, aligning with its classification as a non-caloric sweetener (25). In the studies the FDA reviewed 37 animal and human studies designed to observe any possible toxic effects on humans, including the immune system, reproductive, and developmental systems. The National Cancer Institute (NCI) notes that artificial sweeteners, including advantame, are used in such small amounts that their caloric contribution is negligible. While some animal studies have explored links between artificial sweeteners and cancer, human studies have not confirmed these associations (19).

1.3 Natural Sweeteners

1.3.1 Overview of Natural Sweeteners

With regards to the natural sweetener form, that is sourced or based from plants and fruits they can be divided into two subgroups of high and low intensity sweeteners. Common high intensity variants are Stevia and Monkfruit, 150 to 200 and around 200 times sweeter than sugar respectively (26). The lesser sweet variant are mainly sugar alcohols which are carbohydrates however they are not metabolized by cariogenic bacteria nor increase blood glucose levels sharply. They are mainly found in sugar free candy, chewing gums and cookies (3).

1.3.2 Stevia

Stevia, a plant native to South America (*S Rebaudiana Bertoni*) first consumed over 200 years ago, is a naturally sourced zero calorie substance used as a flavoring ingredient and a sweetener that substitutes sugar. Only high purity stevia leaf extract containing 95% or more steviol glycosides are approved by major regulating bodies such as the World Health Organization (WHO) and the Joint Food and Agriculture Organization (27).

1.3.3 Monk fruit

Monk fruit, also known as *luo han guo* or *swingle fruit*, is a fruit originating from southern China. Having centuries of usage in eastern medicine as a digestive aid. Monkfruit's extracts have been used to provide calorie free sweetness in low/no calorie foods and beverages (28). It is a potent sweetener that is around

200 times more sweeter than sugar. Although it has not been thoroughly tested in animals, the fact that it has been consumed in China for centuries implies that it is safe to consume, however chronic adverse effects may well have escaped detection (29).

1.4 Sugar Alcohols

1.4.1 Overview of Sugar Alcohols

Sugar Alcohols, also known as polyols, are additives found being used as bulking agents as well as sweeteners providing, relative to sugar, lesser amounts of calories. This family of sugar alcohols contains the following sweeteners; Sorbitol, Xylitol, Erythritol and many more (13).

1.4.2 Sorbitol

Sorbitol is naturally found in fruits and vegetables and is manufactured from corn syrup. It only has 50% of the relative sweetness of table sugar, meaning twice the amount has to be used to achieve the same sweetness level. It has a lower tendency of causing diarrhea compared to mannitol (30). It is non cariogenic and is used commonly in chewing gums and by diabetic patients due to its inability to suddenly increase blood sugar levels by absorbing slowly. However, as with most things in life if consumed in excessive amounts they tend to have side effects and regarding Sorbitol, it will have a laxative amount at around 50 grams consumed (31).

1.4.3 Xylitol

Xylitol is a sugar substitute present naturally in a lot of plants and also produced by some bacteria and fungi. Although it is found in very little quantities in fruits and vegetables (32). Xylitol contains around 2.4 Kcal per gram when compared to sugar's 4kcal per gram, however contrary to the latter it is incompletely absorbed by the body as the major part of xylitol passes to the small intestine and is fermented by the colonic microbiota(33). Regarding glycaemic and insulinaemic responses, xylitol has a very low glycaemic index (around 7 to 13) with minimal insuline response in healthy adults. This characteristic makes it suitable for diabetic patients or people on need of glycaemic control in general (34).

1.4.4 Erythritol

Erythritol is a very common sweetener, an ingredient observed in many advertised weight loss and diabetes managing diets. Alongside the common use of replacing table sugar, it is used to bulk up other artificial sweeteners and is one of the manufacturers' favorite ingredients as it is ideal for "diet" foods due to the low calory amount and in terms of taste and texture it is nearer than some of the other sweeteners

(35). Erythritol is a substance that the gastrointestinal system has high tolerance towards equating to low insulin and blood glucose levels. This allows it to act as an antioxidant in type two diabetic people by refining endothelial function (13).

1.4.5 Lactitol

Lactitol as a sweetener only has around 30 to 40% of sugar's sweetening effect, but some of its characteristics is that lactitol is very similar in taste and solubility but it's hence why it commonly found in sugar-free ice cream candies, baked goods, chewing gums © (30).

Lactitol is a disaccharide alcohol (polyol) derived from the hydrogenation of lactose, the natural sugar found in milk. Through catalytic hydrogenation (usually using nickel catalysts), the aldehyde groups in lactose are reduced to alcohol groups, forming β -galactosyl-sorbitol (a sugar alcohol) (36). Lactitol has been approved globally as a food additive and pharmaceutical ingredient and is generally recognized as safe by the FDA in the United States. In 2015 and 2020 the EFSA and FDA reaffirmed its safety respectively at intended levels of consumption noting that gastrointestinal tolerance is the main limitation (37).

1.4.6 Isomalt

Isomalt, a disaccharide sugar alcohol, usually paired with sucralose to provide more sweetness. It is poorly absorbed by the body therefore it provide half the calories relative to sugar (38). Isomalt is suitable for people looking to change their lifestyles into more of a healthy lifestyle without giving up everything. It keeps more food options available for consumption that otherwise would not if made with sugar. It is a perfect substitute of sugar for people that want to moderately improve their diets without taking extreme measures (39). Isomalt has functional properties similar to bulk sweeteners (i.e., it can replace sugar in various confectionery applications and retains certain mouth-feel / crystallisation behaviours) (40). It is produced from sucrose in a two-step process, which makes isomalt chemically and enzymatically more stable than sucrose (41).

1.4.7 Maltitol

Maltitol a type of carbohydrate called a polyol occurring naturally in many fruits and vegetables. It is produced from starches that are rich in the sugar maltose, a two glucose containing saccharide. Similar to the other sugar alcohols, mannitol does not contain a lot of calories and is relatively less sweet than sugar. It is 90% as sweet as sugar and contains about 50% of calories per gram (42). Chemically it is the reduced form of maltose, so it behaves as a polyol: sweet, non-reducing, and less rapidly metabolized than table

sugar. Maltitol is often supplied as a syrup (maltitol syrup) or as crystalline powder; it is used widely as a bulk sweetener because it mimics many functional properties of sucrose but with lower available energy per gram.(43) Because of its laxative potential, many jurisdictions and guidance documents recommend consumer information (e.g., “excess consumption may have a laxative effect”) when products contain significant polyol levels; regulatory comments and petitions in the last several years have emphasized clearer labelling for polyol-containing foods and for disclosure in products marketed to children (44).

1.4.8 Hydrogenated Starch Hydrosylates (HSH)

Hydrogenated Starch Hydrosylates (HSH) in syrup form, part of a family including maltitol and sorbitol syrups as well, is used as a bulking sweetener in various foods developed in the 1960s by a Swedish company. As HSH syrup does not crystallize, it is frequently used in sugar free candies and is perfectly suited in blends alongside other low calorie sweeteners (45).

1.5 Oral-Health Implications of Artificial Sweeteners

1.5.1 Public-Health Context and Rationale

Dental caries remains a major global public-health burden, affecting billions of people and severely impairing oral function and quality of life (46). As the relationship between free sugars and cariogenesis is well established, modern public-health recommendations increasingly promote reducing sugar consumption and substituting it with non-nutritive or artificial sweeteners (46,47). However, the assumption that “sugar-free” automatically means “safe for teeth” is overly simplistic, because dental caries result from complex interactions between diet, microbial ecology, saliva flow, and enamel susceptibility (48,49).

1.5.2 Perceived Benefits of Sugar Substitutes

Recent systematic reviews indicate that low-intensity sweeteners such as xylitol and sorbitol significantly reduce cariogenic bacterial loads and caries incidence in children and adolescents (50,51). A 2024 Journal of Dentistry meta-analysis confirmed that these sugar alcohols reduce caries in permanent teeth, although no randomized controlled trials currently exist for high-intensity sweeteners such as sucralose, aspartame, or saccharin (50). Similarly, a 2024 International Dental Journal review demonstrated that xylitol and erythritol inhibit cariogenic bacteria, but evidence remains insufficient for other artificial sweeteners (51).

These findings highlight that while some sugar-free alternatives lower risk, the scientific basis for high-intensity non-nutritive sweeteners (HINS) remains weak (50,51).

1.5.3 Microbiological Mechanisms and Cariogenic Potential

Mechanistic data suggest that most artificial sweeteners are non-fermentable by *Streptococcus mutans* and therefore considered non-cariogenic (6,52). The International Sweeteners Association (ISA) reported in 2023 that low- and no-calorie sweeteners cannot be metabolized into acids by oral bacteria, which theoretically prevents caries formation (6). Likewise, an in-vitro study demonstrated that acesulfame-K, aspartame, saccharin, and sucralose suppressed *S. mutans* and *S. sanguinis* growth compared with sucrose, reducing acid production and biofilm formation (52). Nevertheless, “non-cariogenic” does not necessarily mean “caries-preventive,” since some enamel studies have shown measurable surface softening even without sucrose exposure (47,53). In addition, certain “sugar-free” formulations contain acidic flavourings, carbonation, or polyols that independently promote enamel erosion and demineralisation (47).

1.5.4 Behavioural and Product-Related Risk Factors

Behavioural and product-context factors also influence oral-health outcomes. Consumers frequently perceive “sugar-free” as “risk-free,” overlooking the roles of consumption frequency, plaque accumulation, saliva flow, fluoride exposure and overall dietary acidity (47,53). A 2023 review cautioned that although artificial sweeteners reduce sugar-driven caries, frequent intake of acidic or flavoured sugar-free products can still contribute to enamel wear and microbial imbalance (53).

1.5.5 Research Gaps and Scientific Uncertainty

Despite their growing presence in foods and beverages, the long-term oral-health implications of artificial sweeteners remain insufficiently defined. Recent evidence highlights substantial gaps in research on high-intensity sweeteners (HINS), as most available data pertain to polyols rather than compounds such as sucralose, aspartame, saccharin, or acesulfame-K (54,55). A 2024 meta-analysis confirmed that while polyols demonstrate consistent reductions in *Streptococcus mutans* levels, clinical evidence for HINS remains minimal and largely restricted to in vitro findings (56). Likewise, a 2023 review in the *British Dental Journal* emphasized the lack of long-term human studies assessing enamel outcomes, microbiome alterations, or real-world consumption patterns, noting that current evidence is too heterogeneous to draw firm conclusions (57). These limitations, together with the influence of formulation acidity, flavouring

additives, and behavioural factors, underscore the need for comprehensive research capable of evaluating artificial sweeteners under realistic use conditions (58–60).

1.5.6 Relevance to the Present Study

In summary, artificial sweeteners show promise as lower-risk sugar substitutes but the current evidence remains incomplete (46,47,50,51). Understanding the contexts in which residual oral-health risks persist is essential for clinicians, dietitians and policymakers (46,47). Therefore, this study aims to critically evaluate the claim that “sugar-free isn’t risk-free,” integrating microbiological, enamel and behavioural evidence to support evidence-based recommendations for oral-health practice (46,47,50,51).

2. RESEARCH OBJECTIVE

To evaluate the relationship between the **consumption of artificial sweeteners (I)** and **oral health outcomes (O)** in **human populations (P)**, compared with **sucrose or no-sweetener exposure ©**. This will include the assessment of caries incidence, pH variations, enamel integrity, and microbial changes, in order to determine whether non-nutritive sweeteners have protective or adverse effects on oral health.

Research Question

“In individuals consuming artificial sweeteners, how does exposure to these compounds compared to sucrose or the absence of sweeteners affect oral health outcomes such as caries development, enamel demineralization, pH changes, microbial activity, and plaque formation?”

3. MATERIALS AND METHODS

Study Design

This research follows a **documentary (literature-based) research design**, aiming to analyze and synthesize existing scientific evidence regarding the effects of artificial sweeteners on oral health. The approach is **qualitative and analytical**, focusing on reviewing, interpreting, and comparing findings from peer-reviewed studies, government and institutional reports, and credible databases. The study does not involve direct experimentation or human participants. Instead, it compiles data from previous laboratory, clinical, and epidemiological studies to provide a comprehensive understanding of the topic “Sugar-Free Isn’t Risk-Free: Investigating the Effects of Artificial Sweeteners on Oral Health.”

Data Sources

Data were collected exclusively from **secondary sources** published within the **last 10 years (2015–2025)** to ensure relevance and scientific accuracy. The following sources were prioritized:

- **Scientific Databases:** PubMed, Scopus, ScienceDirect, SpringerLink, and Google Scholar.
- **Institutional and Government Websites:**
 - U.S. Food and Drug Administration (**FDA.gov**)
 - European Food Safety Authority (**EFSA.europa.eu**)
 - World Health Organization (**WHO.int**)
 - National Institutes of Health (**NIH.gov**)
 - Centers for Disease Control and Prevention (**CDC.gov**)
 - U.S. Department of Agriculture (**USDA.gov**)
- **Academic and Research Institutions:** Articles published by universities (.edu domains), professional dental associations, and recognized health organizations.
- **Trusted Nonprofit Sources:** Health foundations and research organizations (.org domains) such as the American Dental Association (ADA.org)

Search Strategy

A systematic search strategy was employed using a combination of **keywords** and **Boolean operators** to refine results. The main keywords included:

“artificial sweeteners,” “non-nutritive sweeteners,” “sugar substitutes,” “oral health,” “dental caries,” “Streptococcus mutans,” “xylitol,” “sorbitol,” “aspartame,” “sucralose,” “stevia,” “neotame,” “advantame,” “isomalt,” “maltitol,” “lactitol,” and “oral microbiome.”

Search strings used in databases included examples such as:

- “Artificial sweeteners AND dental caries prevention”
- “Sugar substitutes AND oral microbiota”
- “Xylitol OR sorbitol AND Streptococcus mutans”
- “Non-nutritive sweeteners AND enamel demineralization”
- “Polyols” AND “saliva” AND “caries prevention”
- “Artificial sweeteners” AND “enamel demineralization” AND “microbiome”

- “Sugar substitutes” OR “non-nutritive sweeteners” AND “*Streptococcus mutans*”

Filters applied:

- Publication date: 2015–2025
- Language: English
- Document type: Peer-reviewed journal articles, Research articles, reviews, official reports, and systematic reviews with full-text availability

Article Screening and Selection Process

The screening process followed three stages. First, all retrieved references were imported into Zotero, where duplicates were removed. Second, titles and abstracts were screened to exclude studies unrelated to the oral effects of artificial sweeteners, following predefined inclusion and exclusion criteria. Finally, full texts of the remaining articles were assessed for methodological quality, relevance, and availability of measurable outcomes. Only studies meeting all eligibility requirements were included in the final dataset, ensuring a current and credible evidence base.

Data Extraction Process

Following the final study selection, key information was extracted using a standardized template to ensure consistency and comparability. Extracted data included the authors, publication year, study design (in vitro, in vivo, or clinical), the specific sweetener examined, and the study model or sample type. Measured oral health outcomes, such as plaque pH changes, microbial activity, enamel microhardness, or caries development, were also recorded along with each study’s main findings. Source reliability indicators, including journal indexing and potential funding bias, were documented to support methodological transparency and strengthen comparative analysis.

INCLUSION AND EXCLUSION CRITERIA

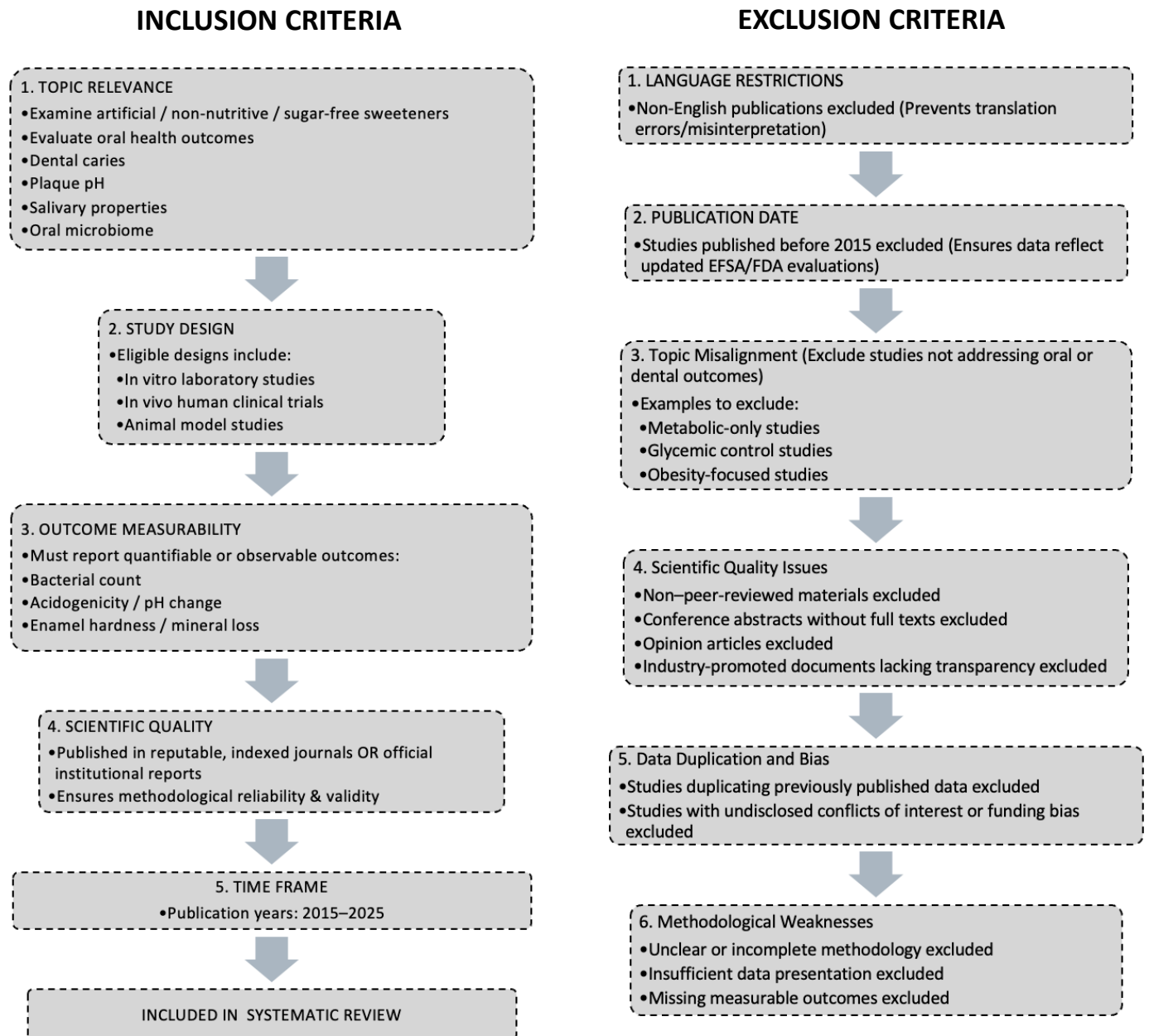


Diagram 1

4. RESULTS

4.1 Study Selection

The literature search identified a total of 102 records from electronic databases and reference management software. After removal of duplicates and application of the publication date filter (2015–2025), the remaining articles underwent title and abstract screening. Studies were excluded if they did not evaluate artificial or non-nutritive sweeteners or lacked relevance to oral-health outcomes. Full-text assessment was subsequently performed using predefined eligibility criteria. Only studies investigating outcomes such as cariogenic bacterial activity, enamel demineralization, oral microbiome changes, plaque pH variation, or dental caries incidence were included. Following this process, **20 studies** were selected for final analysis, comprising randomized controlled trials, observational studies, in vitro experiments, and systematic reviews. This methodological diversity allowed for a comprehensive but heterogeneous evidence base.

4.2 Effects on Cariogenic Bacteria

Across the included studies, artificial and non-nutritive sweeteners consistently demonstrated **reduced cariogenic potential compared with sucrose**. Experimental microbiological investigations showed significantly lower acid production when oral bacteria were exposed to sweeteners rather than fermentable carbohydrates (46). This effect is primarily explained by the inability of cariogenic bacteria, particularly *Streptococcus mutans*, to metabolize these compounds into organic acids. As a result, plaque pH remains closer to neutral, reducing the likelihood of enamel demineralization (46). In addition, several studies reported **direct inhibitory effects on bacterial growth and biofilm formation**. For instance, stevia was shown to reduce biofilm formation and suppress virulence-associated gene expression in *S. mutans* (47). Similarly, sugar alcohols such as xylitol demonstrated reductions in bacterial growth and metabolic activity (32). Overall, the findings suggest that artificial sweeteners not only lack fermentability but may also interfere with bacterial pathogenic mechanisms, although these effects vary depending on the specific compound.

4.3 Polyols and Anti-Cariogenic Effects

Among all sweeteners evaluated, **polyols, particularly xylitol, showed the strongest and most consistent anti-cariogenic effects**. Mechanistically, xylitol cannot be effectively metabolized by cariogenic bacteria. Instead, it disrupts bacterial energy production pathways, leading to reduced growth and decreased acid production (32). This phenomenon has been widely described as a “futile metabolic cycle,” in which

bacteria expend energy without generating harmful by-products. Clinical evidence supports these findings. Randomized controlled trials involving xylitol-containing chewing gum demonstrated **reductions in bacterial counts and improvements in oral health indicators**, particularly in pediatric populations (48). Furthermore, systematic reviews and meta-analyses reported **reduced caries incidence in children and adolescents exposed to sugar substitutes**, reinforcing the preventive potential of polyols (49,50). Additionally, xylitol-containing chewing gum stimulates salivary flow, enhancing buffering capacity and promoting enamel remineralization. These combined mechanisms position polyols as the most clinically effective category of sugar substitutes in caries prevention.

4.4 Effects on Enamel and the Oral Environment

The majority of in vitro studies indicated that artificial sweeteners cause **significantly less enamel demineralization than sucrose**, supporting their classification as non-cariogenic (51). However, an important finding across several studies was that **enamel integrity is strongly influenced by factors independent of the sweetener itself**, particularly beverage acidity. Experimental studies on carbonated drinks demonstrated that acidic formulations can cause significant enamel erosion regardless of whether they contain sugar or artificial sweeteners (52,53). Furthermore, randomized crossover trials evaluating sweetened beverages showed that **plaque pH and bacterial proliferation are influenced by the overall composition of the product**, rather than solely by the type of sweetener used (54). These findings highlight that replacing sucrose with artificial sweeteners reduces cariogenic risk but does not eliminate the potential for enamel damage when other erosive factors are present.

4.5 Effects on the Oral Microbiome

Emerging evidence suggests that artificial sweeteners may influence the **composition and diversity of the oral microbiome**. Experimental biofilm studies demonstrated structural changes in microbial communities following exposure to different sweeteners (4). Similarly, clinical pilot studies reported alterations in microbial diversity among human participants consuming various sweeteners (5). Observational studies in children further indicated that dietary sweetener intake may contribute to microbiome variability (55). While these findings indicate that sweeteners can modulate microbial ecosystems, the **clinical relevance of these changes remains unclear**. It is not yet established whether these alterations lead to beneficial, neutral, or harmful outcomes in the long term.

4.6 Summary of Findings

Overall, the evidence indicates that artificial sweeteners:

- Exhibit **lower cariogenic potential than sucrose** (46)
- May reduce **bacterial growth and biofilm formation** (47)
- Show **strongest preventive effects in polyols**, particularly xylitol (49,50)
- Have **minimal direct impact on enamel compared to acidic factors** (52,53)
- May **alter the oral microbiome**, though implications remain uncertain (5)

4.7 Data Extraction

No.	Study	Study Design	Sweetener Investigated	Subject Tested On	Outcome Measures	Key Findings
1.	Razdan et al. (2016)	In vitro experimental study	Five artificial sweeteners	Extracted human teeth	Enamel demineralization depth	Artificial sweeteners caused significantly less enamel demineralization than sucrose
2.	Kaur et al. (2018)	Randomized controlled trial	Xylitol chewing gum	Children	Oral health status and bacterial counts	Xylitol gum improved oral health indicators and reduced cariogenic bacteria
3.	Zhu et al. (2021)	In vitro microbiological study	Non-nutritive sweeteners	Cariogenic oral bacteria	Acid production and cariogenic potential	NNS showed lower acidogenic potential than sucrose
4.	AlKanderi et al. (2023)	Laboratory biofilm study	Stevia	<i>Streptococcus mutans</i> biofilms	Biofilm formation and gene expression	Stevia inhibited biofilm formation and reduced virulence gene expression
5.	Barajas-Torres et al. (2022)	Randomized crossover clinical trial	Carbonated beverages with sweeteners	Adolescents	Oral pH and bacterial proliferation	Sweetened beverages influenced oral pH and bacterial growth
6.	Maladkar et al. (2022)	In vitro dental experiment	Acidic beverages	Extracted human teeth	Enamel erosion	Acidic drinks caused significant enamel erosion
7.	Inchingolo et al. (2023)	Experimental enamel study	Carbonated soft drinks	Enamel samples	Mineral loss	Carbonated drinks contributed to enamel demineralization

8.	Jeong et al. (2024)	Experimental biofilm study	Various sweeteners	Oral microbial biofilms	Biofilm composition	Certain sweeteners altered oral biofilm structure
9.	Zakis et al. (2024)	Randomized clinical pilot study	Different sweeteners	Human participants	Oral microbiome composition	Sweeteners influenced oral microbial diversity
10.	Liang et al. (2024)	Clinical meta-analysis	Sugar substitutes	Human clinical studies	Cariogenic bacteria levels	Sugar substitutes reduced cariogenic bacterial counts
11.	Luo et al. (2024)	Meta-analysis	Sugar substitutes	Children and adolescents	Caries prevention	Sugar substitutes associated with lower caries risk
12.	Kohli et al. (2024)	Experimental oral health study	Non-sugar substitutes	Oral bacteria	Cariogenic activity	Substitutes showed lower cariogenic activity than sucrose
13.	Nagaral et al. (2023)	Observational study	Artificial sweeteners	Children	Sweetener intake and oral health	Artificial sweetener consumption requires monitoring in children
14.	Ng et al. (2024)	Literature-based clinical review	Dietary sugars	Human populations	Caries risk assessment	High sugar intake remains a key caries risk factor
15.	Cheever et al. (2025)	Cross-sectional epidemiological study	Free sugar consumption	Children	Dental caries prevalence	Higher sugar intake strongly associated with caries development
16.	Defata et al. (2023)	Observational microbiome study	Dietary sweeteners	School-aged children	Oral microbiome composition	Diet influenced oral microbial diversity
17.	Pondolfino (2024)	Experimental oral health study	Sugar alcohols	Oral bacterial cultures	Bacterial growth	Sugar alcohols showed reduced cariogenicity
18.	Al Humaid (2018)	Literature-based clinical analysis	Sweeteners in medications	Pediatric oral medications	Cariogenic potential	Sweetened medications may increase caries risk
19.	Gasmi Benahmed et al. (2020)	Microbiological study	Xylitol	Oral bacteria	Bacterial growth	Xylitol inhibited growth of <i>S. mutans</i>
20.	Saraiva et al. (2020)	Experimental metabolic study	Maltitol	Human metabolism models	Cariogenic potential	Maltitol exhibited low cariogenic potential

Table 1

5. DISCUSSION

The findings of this review indicate that artificial and non-nutritive sweeteners generally exhibit a lower cariogenic potential compared with fermentable carbohydrates such as sucrose. This observation is consistent with the established understanding of dental caries as a biofilm-mediated disease driven by acid production following bacterial metabolism of dietary sugars (53). In contrast, most artificial sweeteners are not readily metabolized by cariogenic bacteria, resulting in reduced acidogenic activity

and a more stable oral pH environment (46). However, while the substitution of sucrose with non-nutritive sweeteners appears beneficial in reducing cariogenic potential, the results of this review highlight that oral health outcomes are influenced by a broader range of factors. These include the physicochemical properties of the sweetener, its delivery vehicle, consumption patterns, and host-related factors such as saliva composition and oral hygiene practices. Therefore, the relationship between artificial sweeteners and oral health should be interpreted within a multifactorial framework rather than as a direct cause–effect relationship.

5.1 Polyols and Their Role in Caries Prevention

Among the different categories of sweeteners, polyols, particularly xylitol, demonstrate the most consistent and clinically relevant anti-cariogenic effects. Unlike high-intensity artificial sweeteners, xylitol not only lacks fermentability but also actively interferes with bacterial metabolism. Specifically, cariogenic bacteria such as *Streptococcus mutans* are unable to efficiently metabolize xylitol, leading to disruption of intracellular energy pathways and reduced acid production (32). This mechanism is supported by microbiological studies showing decreased bacterial growth and reduced biofilm formation in the presence of xylitol (32). These findings are consistent with the meta-analyses by Liang et al. (50) and Luo et al. (49), which reported reductions in cariogenic bacterial levels and caries incidence. **In contrast, studies focusing on high-intensity artificial sweeteners did not demonstrate comparable reductions in caries outcomes**, highlighting a key difference between passive sugar substitution and active antimicrobial effects. Furthermore, clinical evidence reinforces these findings. Randomized controlled trials evaluating xylitol-containing chewing gum have demonstrated reductions in cariogenic bacterial counts and improvements in oral health indicators, particularly in children (48). These results are aligned with systematic reviews of polyols (49,50), but **contrast with the limited and largely laboratory-based evidence available for other non-nutritive sweeteners (46)**. Additionally, the salivary stimulation associated with chewing gum plays an important role in enhancing the protective effects of xylitol. Increased saliva flow contributes to buffering plaque acids, facilitating remineralization, and improving oral clearance of food debris. Therefore, the observed benefits of xylitol may result from a combination of biochemical and mechanical effects rather than the sweetener alone.

5.2 Artificial Sweeteners with Neutral Cariogenic Potential

In contrast to polyols, high-intensity artificial sweeteners such as aspartame, sucralose, and saccharin appear to exert primarily neutral effects on oral health. These compounds are not fermented by oral

bacteria and therefore do not contribute to acid production or enamel demineralization (46). However, evidence for direct antimicrobial or anti-cariogenic effects is limited. While some experimental studies suggest that certain sweeteners may reduce bacterial adhesion or biofilm formation, these findings are inconsistent and often derived from in vitro models (4,47). **For example, while AlKanderi et al. (47) demonstrated inhibitory effects of stevia on biofilm formation, Zhu et al. (46) reported primarily reduced acidogenicity without strong antimicrobial activity,** illustrating variability in observed mechanisms. The primary benefit of these sweeteners therefore lies in their ability to replace sucrose in the diet, reducing exposure to fermentable carbohydrates. This distinction between passive (non-cariogenic) and active (anti-cariogenic) effects is important when interpreting the overall impact of different sweeteners on oral health. Furthermore, the reliance on in vitro studies highlights a key limitation in the current evidence base. Laboratory conditions do not fully replicate the complexity of the oral environment, where factors such as saliva, dietary habits, and microbial interactions play a critical role (46).

5.3 Influence on the Oral Microbiome

An emerging area of interest is the potential effect of artificial sweeteners on the oral microbiome. The oral cavity hosts a highly complex microbial ecosystem, and alterations in microbial composition may influence the balance between health and disease. Several studies included in this review reported changes in microbial diversity and biofilm structure following exposure to different sweeteners (4,5,55). **For instance, experimental biofilm studies such as Jeong et al. (4) demonstrated structural alterations in microbial communities, whereas clinical pilot studies by Zakis et al. (5) reported shifts in microbial diversity in vivo,** suggesting that findings may vary depending on study design. However, the clinical implications of these changes remain unclear. Alterations in microbial composition do not necessarily indicate dysbiosis or disease progression. In some cases, increased diversity may even be associated with a more stable microbial ecosystem. Moreover, most available studies are short-term or experimental in nature, limiting the ability to assess long-term outcomes. Further research is required to determine whether these microbiome changes have meaningful clinical consequences for oral health.

5.4 Effects of Sweetened Beverages on Enamel

A key finding of this review is that the impact of sweetened beverages on enamel is largely determined by their acidity rather than the type of sweetener used. Even in the absence of sucrose, acidic beverages have been shown to cause significant enamel erosion (52,53). This highlights an important limitation of

focusing solely on cariogenicity when evaluating oral health risks. While artificial sweeteners may reduce bacterial acid production, they do not mitigate the erosive effects of acidic components such as phosphoric or citric acid commonly found in soft drinks. **This is supported by the contrast between enamel-focused studies such as Razdan et al. (51), which showed reduced demineralization with sweeteners, and erosion studies such as Maladkar et al. (52), which demonstrated significant enamel damage due to acidity,** emphasizing that cariogenic and erosive processes are distinct but complementary. Additionally, factors such as frequency of consumption, duration of exposure, and salivary buffering capacity play a significant role in determining the extent of enamel damage. Therefore, the consumption of sugar-free but acidic beverages may still pose a risk to dental health, particularly when consumed frequently.

5.5 Public Health Implications

From a public health perspective, reducing free sugar consumption remains a priority due to its strong association with dental caries and other chronic diseases (53). Artificial sweeteners may provide a useful strategy for achieving this goal by reducing dietary sugar intake. However, the findings of this review suggest that artificial sweeteners should not be considered a complete solution. The perception that “sugar-free” products are inherently safe may lead to increased consumption of processed or acidic foods, potentially offsetting their benefits. Effective caries prevention requires a comprehensive approach that includes oral hygiene practices, fluoride exposure, dietary education, and regular dental care. Public health messaging should therefore emphasize a balanced understanding of oral health risks rather than focusing solely on sugar reduction.

5.6 Limitations

Several limitations should be considered when interpreting the findings of this review. A significant proportion of the included studies were laboratory-based, which may not accurately reflect real-world conditions within the oral cavity. In addition, there was considerable heterogeneity among studies in terms of design, sweetener types, and outcome measures, limiting comparability and generalizability. **For example, differences between in vitro studies (46,47) and clinical trials (48) highlight inconsistencies in methodological approaches and outcome interpretation,** further complicating direct comparisons. Furthermore, there is a lack of long-term randomized clinical trials evaluating the effects of high-intensity artificial sweeteners on oral health outcomes. This limits the strength of clinical recommendations and highlights the need for further research.

5.7 Future Research Directions

Future research should focus on long-term clinical studies evaluating the effects of artificial sweeteners under real-world conditions. In particular, studies investigating the interaction between sweeteners and the oral microbiome are needed to clarify their long-term impact on oral health (5). Additionally, research should explore the combined effects of dietary habits, product formulation, and host factors such as saliva and oral hygiene. Such studies would provide a more comprehensive understanding of the role of artificial sweeteners in oral health and support evidence-based clinical recommendations.

6. CONCLUSIONS

The objective of this review was to evaluate the effects of artificial and non-nutritive sweeteners on oral health, with particular focus on cariogenic bacteria, enamel integrity, and the oral microbiome. The findings demonstrate that most artificial sweeteners exhibit a significantly lower cariogenic potential compared with fermentable sugars such as sucrose, primarily due to their inability to be metabolized by oral bacteria into acids that contribute to enamel demineralization (46,53). However, the results also indicate that the impact of these compounds on oral health is not uniform and depends on the type of sweetener, its delivery form, and the broader dietary and behavioural context. Among the sweeteners evaluated, polyols, particularly xylitol, show the strongest and most consistent anti-cariogenic effects, supported by both microbiological evidence and clinical studies demonstrating reductions in cariogenic bacterial levels and caries incidence (32,48–50). In contrast, high-intensity artificial sweeteners such as aspartame, sucralose, and saccharin appear to be primarily non-cariogenic rather than actively protective, with their main benefit arising from replacing fermentable sugars rather than exerting direct antimicrobial effects (46). Importantly, this review highlights that “sugar-free” does not equate to “risk-free.” While artificial sweeteners reduce cariogenic potential, other factors, particularly beverage acidity, remain significant contributors to enamel erosion and oral health deterioration (52,53). Furthermore, emerging evidence suggests that artificial sweeteners may influence the oral microbiome, although the clinical significance of these changes remains unclear and requires further investigation (4,5,55). Several limitations of the current evidence base must be acknowledged, including the predominance of in vitro studies, heterogeneity in study design, and the lack of long-term randomized clinical trials assessing real-world outcomes. These limitations restrict the ability to draw definitive conclusions regarding the long-term effects of artificial sweeteners on oral health. Overall, the substitution of fermentable sugars with artificial and non-nutritive sweeteners represents a valuable strategy for reducing cariogenic risk,

particularly in the context of public health efforts to decrease sugar consumption. However, these compounds should be considered as part of a broader, multifactorial approach to oral health that includes appropriate dietary habits, oral hygiene practices, fluoride exposure, and regular dental care. Future research should prioritize long-term clinical studies and microbiome-focused investigations to better understand the complex interactions between sweeteners and the oral environment.

7. SUSTAINABILITY

The findings of this systematised review are closely linked to the environmental, social, and economic dimensions of sustainability. From a social and public-health perspective, the substitution of fermentable sugars with non-cariogenic sweeteners may contribute to the prevention of dental caries, which remains one of the most prevalent chronic diseases worldwide. Reducing caries incidence can improve quality of life, particularly in vulnerable populations, and decrease inequalities in oral health, aligning with Sustainable Development Goal (SDG) 3: Good Health and Well-Being. From an economic standpoint, the prevention of dental caries through reduced sugar consumption and appropriate use of sugar substitutes may lower the long-term costs associated with restorative dental treatments and public oral-health expenditure. Preventive strategies are generally more cost-effective than operative interventions, supporting the sustainability of healthcare systems. Regarding environmental sustainability, reduced demand for refined sugars may indirectly decrease the environmental impact associated with sugar production, including land use, water consumption, and energy expenditure. However, the industrial production of artificial sweeteners also has environmental implications that should be considered. Therefore, promoting evidence-based, moderate consumption of sugar substitutes within a preventive oral-health framework supports a balanced and sustainable approach consistent with SDGs 3 and 12 (Responsible Consumption and Production).

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