Perspective

Insect flour and dental caries: Friends or foes?

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Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl*. 2025;62(1):9–12

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Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
None declared

Received on November 12, 2024
Reviewed on November 14, 2024
Accepted on December 4, 2024

Published online on February 20, 2025

Cite as
Mazur M, Ndokaj A, Brugnoli I, et al. Insect flour and dental caries: Friends or foes? *Dent Med Probl.* 2025;62(1):9–12. doi:10.17219/dmp/196883

DOI
10.17219/dmp/196883

Keywords: dental caries, wheat grains, insect flour, flour-based confectionery, nutritive and non-nutritive improvement

This article explores the cariogenic potential of insect flours, highlighting their nutritional benefits and sustainability, while emphasizing the need for further research on their impact on oral health.

Dental caries is a widespread non-communicable disease affecting individuals across all age groups globally. Recent advancements in the research on human oral microbiota have led to a paradigm shift from viewing dental caries as an infectious, communicable disease, primarily caused by *Streptococcus mutans*, to perceiving it as an 'ecological catastrophe'.[1] Oral microbiome, as part of human microbiota, can be interpreted in terms of ecological principles, system biology and a holistic approach.[2] From this perspective, the development of caries stems from a disruption in the balance of the resident oral microbiota, leading to a reduction in microbial diversity, favoring acidogenic species, adapted to low-pH environments. The main factors driving this dysbiosis include frequent sugar exposure, a reduced salivary flow and inadequate disruption of oral biofilm.[3,4] Consistently, diets rich in processed sugars and starches are linked to a higher incidence of caries. Starch, particularly from wheat-based grains, constitutes a significant portion of the human diet, accounting for 40–75% of total dietary intake in Western populations.[5] Processed starches, once gelatinized, are rapidly hydrolyzed by oral amylases into glucose, maltose, maltotriose, and low-molecular-weight dextrins. These starch-rich food particles, when trapped on the tooth surface, act as an ideal substrate for sugar retention and bacterial acid production, lowering the local pH and initiating the process of enamel demineralization.

Human exposure to foods prepared through the high-temperature cooking of refined sugar and starch suspensions leads to increased biofilm-induced acidogenicity. Among starches, flour starches exhibit the highest acidogenic potential, while processed starches result in prolonged pH drops below 5.5.[6] The combination of starch and sucrose is particularly harmful, causing the most significant enamel mineral loss. The Western diet, characterized by the frequent consumption of processed foods rich in sugar and starch, is associated with food addiction, overeating and obesity, and is a primary risk factor for the development of dental caries.

In recent years, Western dietary patterns have been shifting, with a growing preference for plant-based foods and reduced meat consumption.[7] This shift reflects the increasing consumer awareness of the environmental consequences of intensive farming, health concerns related to dietary risk factors and a broader openness to cultural influences from other regions. In light of these trends and taking into consideration the need for alternative protein sources, insects have emerged as a viable addition to the Western diet. In early 2023, the European Union (EU) approved the sale of crickets, locusts and darkling beetle larvae for human consumption, and insect flour can now be incorporated into various food products.[8] The edible insect market in Europe is expected to reach €2.7bn (£2.3bn) by 2030.[8] Globally, over 2 billion people already consume insects as part of their regular diet, as insect flour is rich in essential amino acids, calcium (Ca), iron (Fe), potassium (K), vitamins B2 and B12, and fatty acids.

Considerations

This study sought to assess the cariogenic potential of insect flours in comparison with conventional flours. The rationale for this investigation arises from the increasing interest in insect-based diets, largely due to their environmental sustainability and purported nutritional benefits. Despite an extensive review of the literature, no studies that directly examine the impact of insect flours on dental caries were found. This lack of evidence emphasizes the novelty of the subject and highlights the necessity for focused research in this area.

The absence of studies on the cariogenic properties of insect flours raises several important considerations. Firstly, it suggests that the intersection between dental health and insect-based diets remains largely unexplored by the scientific community. Given the rising inclusion of insect products in the Western diet, driven by environmental and health concerns, this gap in research is particularly striking. With the EU's approval of insect flours for human consumption in early 2023 and the projected expansion of the edible insect market, this emerging area could have substantial implications for public oral health.[8]

The Food and Agriculture Organization of the United Nations (FAO/UN) predicts that the global population will exceed 9.1 billion by 2050, posing a significant challenge in meeting the corresponding food demand. Ensuring an adequate supply of high-quality protein will be essential for the physical and cognitive development of individuals. In this regard, entomophagy – the consumption of insects as a source of nutrients – presents itself as a sustainable and feasible alternative.[9] Edible insects, as a non-traditional food source, offer a promising solution to pressing issues, such as food security and environmental preservation. Insect farming presents numerous advantages, including minimal space and time requirements, the absence of reliance on cereal-based feeds, reduced CO_2 emission, and lower water and land usage.[10]

Despite these benefits, entomophagy is often met with aversion in many Western societies, where consuming insects is perceived as distasteful and associated with primitive behaviors. In contrast, in regions across Africa, Asia, Latin America, and among indigenous peoples in North America, insects have been regularly consumed as staple foods or delicacies, and they likely played an important nutritional role for early human ancestors. An estimated 1,900 species of insects have been utilized as food, with beetles (Coleoptera) accounting for 31% and caterpillars (Lepidoptera) for 18% of global insect consumption, while termites (Isoptera) represent only 3%.[11]

Insects are a valuable source of both micro- and macronutrients essential for human nutrition. The macronutrient content of insect flours varies significantly, with the protein levels ranging from 30% to 65%, lipids from 7% to 77%, and carbohydrates from 5% to 20%. Insect flours are particularly rich in protein, and provide essential amino acids, vitamins and minerals, though they generally contain lower carbohydrate levels than traditional grain flours.[12–14]

The reduced carbohydrate content of insect flours may potentially limit the substrates available for oral bacteria to generate acids, a key factor in the development of dental caries.[15] Additionally, the high protein and fat content in insect flours could contribute to creating a less cariogenic oral environment, although this assumption requires empirical validation. Furthermore, it is plausible that integrating insect flours into the diet may promote a more balanced oral microbiota, countering dysbiotic shifts commonly driven by frequent sugar intake, which contribute to dental caries.

The lack of research in this area emphasizes the need for targeted investigation. Key areas for future research include: in-vitro and in-vivo studies – laboratory and clinical studies to assess the influence of insect flours on the formation of dental plaque, acid production and enamel demineralization; comparative analyses – evaluating the cariogenic potential of insect flours relative to well-known grain flours like wheat and maize, which have established links to dental caries, as well as comparing them with other high-protein flours with similar macronutrient profiles; and long-term dietary studies – examining the long-term effects of incorporating insect flours into diets on oral health outcomes across diverse population groups.

Future investigations should adhere to robust methodologies, including well-designed randomized controlled trials (RCTs), appropriate sample sizes and standardized caries assessment measures. Employing validated tools for bias assessment and comprehensive data analysis will be essential to generate reliable, high-quality evidence.

The adoption of insect flours into Western diets reflects a broader shift toward more sustainable and health-conscious food choices. However, a thorough

Table 1. Key findings on the cariogenic potential, nutritional benefits, sustainability, and potential risks of insect flours

Thematic area	Key message	Details
Cariogenic potential of insect flours	Insect flours may have a lower cariogenic potential as compared to conventional flours	Lower content of fermentable carbohydrates, reducing acid production by oral bacteria
Nutritional benefits	Rich in protein, essential amino acids, vitamins, and minerals	High protein content (30–65%), low carbohydrate content (5–20%)
Reduced caries risk	Lower content of fermentable carbohydrates	Less substrate for cariogenic bacteria, reducing acid production and enamel demineralization
Sustainability	Sustainable food sources with low environmental impact	Minimal land and water use, reduced CO_2 emission
Potential risks	Possible contaminants and allergens	Need for further research on contaminants, allergens and biological risks

understanding of the health impact, including oral health, is vital. Public health policies and dietary guidelines will benefit from evidence-based insights about the implications of such emerging dietary trends.

It is important to note that the incorporation of insects into the human diet may pose several potential risks, which require further extensive research. These risks can be categorized into 3 key areas:

- contaminant risks: Insects may contain chemical contaminants, including mycotoxins, pesticides, heavy metals, organochlorine compounds, and dioxins, which can originate from their rearing substrates or environmental exposure.[16] Additionally, certain insect species from the Coleoptera, Lepidoptera and Orthoptera orders have been found to consume various types of plastic polymers, with infrared spectroscopy revealing degraded plastic fragments in insect frass.[17] While the impact of this on human health remains uncertain, there is insufficient evidence to dismiss it as insignificant;
- biological risks: Insects can harbor microorganisms, such as bacteria, viruses and parasites, which may pose a health risk to humans,[18] and could potentially serve as sources of future epidemics or pandemics;
- allergenic risks: Some insect components, such as chitin, can trigger allergic reactions, manifested through various symptoms, including eczema, rhinitis, conjunctivitis, bronchial asthma, urticaria, dizziness, and in severe cases, anaphylaxis.[19]

The European Food Safety Authority (EFSA) has indicated that the prevalence and concentration of contaminants in insects or insect-based foods depend on factors such as the method of production, the stage of harvest and the substrates used for rearing.

Furthermore, the recent introduction of insect flour-based products that contain concentrated amounts of insects presents a new safety concern. Unlike traditional insect consumption, which typically involves whole insects eaten fried or grilled, insect flours may allow higher intake of potential allergens and contaminants, potentially leading to unknown public health outcomes.

This article underscores the potential of insect flours as an alternative to traditional grain-based flours. Their reduced carbohydrate content, combined with nutritional benefits and environmental sustainability, positions them as a promising food source. However, further research is needed to address potential risks, including contaminants and allergens. Table 1 provides a concise summary of the key findings and their implications.

Summary

This paper identifies a notable gap in research concerning the cariogenic potential of insect flours. The findings emphasize the novelty of this subject and the pressing need for focused investigation. Given the limited understanding of public health implications,[20] alongside the increasing consumption of insect-based products, it is crucial to explore their effects on both general and oral health. Future studies should address this gap with rigorous, high-quality research to inform dietary guidelines and public health policies.

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