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Valorisation of Peanut Milk Residue in Ice Cream Cone Development

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Abstract

The growing emphasis on sustainable food production and zero-waste practices has led to increasing interest in the valorisation of agro-industrial by-products. Peanut milk, a plant-based dairy alternative, generates a nutrient-rich residue during its production, which is often discarded despite its potential as a valuable food ingredient. This review explores the feasibility of utilizing peanut milk residue in the development of edible ice cream cones, particularly in conjunction with peanut-based ice cream. The compositional richness of the residue characterized by high fiber, protein, and residual fat makes it a promising component for cone formulations, offering nutritional enhancement and improved functional properties.

Existing literature highlights successful incorporation of plant-based residues, such as those from cereals and legumes, in baked goods and edible packaging. However, limited research has specifically addressed the application of peanut milk residue in cone development. This review critically examines related studies on the use of food by-products in bakery products, the textural and sensory qualities of alternative ice cream cones, and the compatibility of peanut-based ingredients in sustainable product design.

The integration of peanut milk residue in ice cream cone development not only supports circular food system models but also offers economic and environmental advantages. By utilizing both the milk and its by-product in a complementary food system, this approach promotes innovation in sustainable, plant-based desserts and edible packaging solutions.

Keywords: Peanut Milk, Ice Cream, Development, Good Technology, Allied Health Sciences

1. Introduction

The rising demand for sustainable food processing has led to a growing emphasis on waste valorization as a vital component of modern food systems. Agro-industrial processes generate large quantities of by-products and residues, which, if unmanaged, contribute to environmental degradation. Waste valorization, the process of converting food waste and by-products into valuable materials or products, offers a promising route toward achieving a circular and sustainable bioeconomy (Maina *et al*., 2017; Sharma *et al*., 2023) [1, 2]. It promotes the efficient use of natural resources while simultaneously reducing the ecological footprint of food production (Tropea, 2022) [3].

In recent years, innovations in food waste management have focused on utilizing plant-based residues for the development of functional foods and biodegradable packaging materials. The European Union, for example, has stressed the need to balance safety, nutrition, and sustainability when valorizing food processing by-products (Rao *et al*., 2021) [4]. Researchers have highlighted that transforming food residues into new products not only supports waste reduction but also aligns with global sustainability goals (Arancon *et al*., 2013) [5].

Peanut milk, a nutritious and increasingly popular plant-based dairy alternative, generates a fibrous residue during production. This residue, often discarded, is rich in dietary fiber, protein, and micronutrients, making it suitable for incorporation into value-added food products. Developing edible ice cream cones from peanut milk residue presents an innovative opportunity to valorize this by-product, contributing to a zero-waste model and promoting sustainable consumption (Sharma *et al*., 2023; Tropea, 2022) [2, 3].

1.1 Overview of peanut milk and peanut-based dairy alternatives

The increasing demand for plant-based food alternatives and sustainable production practices has brought attention to

innovative uses of agro-industrial by-products. Among these alternatives, plant-based milk substitutes such as those derived from almonds, soy, oats, and peanuts have gained popularity due to their health benefits, environmental advantages, and suitability for lactose-intolerant and vegan consumers (Paul *et al*., 2020; Silva & Smetana, 2022) [6, 7]. Peanut milk, in particular, is noted for its rich nutritional profile, including proteins, healthy fats, and bioactive compounds (Diarra *et al*., 2005; Moharana *et al*., 2020) [8, 9]. Despite its potential as a functional beverage, the production of peanut milk generates a significant amount of residue or pomace, which is commonly discarded or underutilized.

This peanut milk residue, however, retains valuable nutrients such as fiber, proteins, and lipids, presenting a unique opportunity for its incorporation into value-added food products (Pandey & Poonia, 2020) [8]. Utilizing this by-product in applications like edible packaging or bakery goods can contribute to zero-waste food processing and sustainable product development. As consumers and industries alike shift toward circular and eco-conscious food systems, transforming peanut milk residue into edible ice cream cones emerges as an innovative strategy that combines nutrition, waste reduction, and environmental responsibility.

1.2 Problem of agro-industrial by-product disposal

The utilization of agro-industrial by-products, such as peanut milk residue, offers a promising pathway toward sustainable food innovation, zero-waste processing, and circular economy development. Traditionally discarded as waste, peanut milk residue is rich in fiber, protein, and other nutrients, making it a valuable ingredient for developing functional food products such as edible ice cream cones. This approach not only reduces environmental impact but also adds economic value by transforming waste into marketable goods (Freitas *et al*., 2021) [10]. Compared to conventional disposal methods, valorization practices such as incorporation into food matrices demonstrate lower environmental burdens and improved life cycle performance (Valenti *et al*., 2020) [11]. Furthermore, the integration of such by-products into food systems aligns with global efforts to conserve resources and reduce reliance on synthetic additives and non-biodegradable materials (Senthilkumar *et al*., 2020) [12].

Valorizing peanut milk residue for edible cone production can serve as a practical model for sustainable food product development, especially in regions with high peanut production. It supports environmental sustainability by minimizing waste and contributes to food security through the creation of nutritious, plant-based alternatives. As supported by existing studies, the effective reuse of agro-industrial residues can enhance both ecological and economic performance across the supply chain (Valizadeh & Sobhanirad, 2009) [13]. Hence, this review underscores the need for further research and industry collaboration to optimize peanut residue applications in food systems and scale sustainable innovations globally.

1.3 Objectives of the Review

The primary objective of this review is to explore the potential of peanut milk residue a nutrient-dense by-product generated during peanut milk and ice cream production for its utilization in the development of edible ice cream cones. With the global rise in demand for sustainable food systems and circular economy practices, there is a growing need to valorize agro-industrial waste into value-added products (Maina *et al*., 2017; Freitas *et al*., 2021) [1, 11]. This review seeks to assess the compositional and nutritional attributes of peanut milk residue, which is rich in fiber, protein, and micronutrients, making it suitable for food product development (Diarra *et al*., 2005; Moharana *et al*., 2020) [8, 9]. It also aims to analyze recent innovations in waste valorization technologies and compare their environmental and economic benefits to conventional disposal methods (Valenti *et al*., 2020; Senthilkumar *et al*., 2020) [11, 12]. Further, the review examines existing literature on the development of edible cones and similar bakery products using alternative flours and food processing residues, evaluating their functional, physical, and sensory properties (Hlaváčová *et al*., 2022) [14]. In doing so, it highlights the role of functional food innovation in advancing sustainable, fiber-enriched, and eco-friendly products (Xiong *et al*., 2019; Stabnikova *et al*., 2023) [15, 16]. Finally, the review identifies research gaps and proposes future directions for enhancing the application of peanut milk residue in high-fiber, gluten-free, and biodegradable food systems.

2. Peanut Milk and Its Residue

The valorization of agro-industrial waste into high-value food products represents a crucial step toward achieving sustainable, circular, and resource-efficient food systems. Peanut milk residue, often discarded during plant-based milk production, possesses substantial nutritional and functional potential for innovative applications such as edible ice cream cones. Transforming such by-products into food not only reduces environmental pollution but also promotes economic and ecological sustainability (Freitas *et al*., 2021; Singh *et al*., 2021) [11, 17]. Compared to conventional disposal methods, sustainable reuse strategies such as food incorporation exhibit a significantly lower environmental footprint, as demonstrated by life cycle assessment studies (Valenti *et al*., 2020) [11]. Furthermore, technologies and approaches that convert waste into energy or value-added food products are gaining momentum as part of global efforts to mitigate food loss and enhance food security (Senthilkumar *et al*., 2020) [12]. This review highlights that peanut milk residue, when appropriately processed and formulated, can serve as a valuable functional ingredient in gluten-free and high-fiber cone production, supporting a shift toward waste-to-food systems. Continued research, industry collaboration, and consumer awareness are essential to unlocking the full potential of such waste-derived innovations in the food sector.

2.1 Composition of peanut milk

Peanut milk has emerged as a nutritious, cost-effective, and sustainable plant-based milk alternative, with promising prospects for valorization of its by-products. Rich in protein, healthy fats, and essential micronutrients, peanut milk offers comparable nutritional quality to conventional dairy and other plant-based milks (Diarra *et al*., 2005; Abou-Dobara *et al*., 2016) [8, 18]. Various studies have shown that the method of preparation including soaking, blanching, and fermentation significantly influences the milk's proximate

composition and sensory acceptability (Yadav *et al*., 2018; Jain *et al*., 2013) [19, 20]. Notably, pressure blanching and lactic acid fermentation have been shown to enhance both the chemical composition and flavor profiles of peanut milk, thereby improving its marketability (Jain *et al*., 2013; Lee & Beuchat, 1991) [20, 21].

Despite its growing popularity, a large portion of the residue generated during peanut milk processing is often discarded, leading to a loss of valuable nutrients. However, this residue retains a high concentration of fiber, protein, and bioactive compounds, making it a suitable candidate for incorporation into functional food products such as edible cones. Utilizing this by-product can reduce food waste while contributing to nutritional enrichment and sustainability in food systems. Thus, the effective use of peanut milk residue in food innovation aligns with zero-waste principles and adds value to plant-based milk processing chains (Diarra *et al*., 2005; Abou-Dobara *et al*., 2016) [8, 18].

3. Nutritional and functional properties of peanut milk residue

Peanuts and their by-products offer exceptional nutritional and functional potential, making them valuable ingredients in the development of health-oriented and sustainable food products. Rich in protein, dietary fiber, essential fatty acids, and bioactive compounds, peanuts serve as a functional food capable of supporting heart health, weight management, and glycaemic control (Arya *et al*., 2016; Akhtar *et al*., 2014) [22, 23]. During peanut milk production, a nutrient-dense residue is generated, often overlooked despite its continued richness in protein, fiber, and minerals (Diarra *et al*., 2005) [8]. Valorizing this residue in food applications such as bakery products not only reduces waste but also enhances the nutritional value of the end product.

For instance, incorporating defatted peanut cake flour into cookies has been shown to significantly improve their protein and fiber content while maintaining acceptable sensory characteristics (Suleman *et al*., 2023) [24]. This reinforces the feasibility of using peanut-derived ingredients to formulate functional foods that align with the goals of clean-label, high-protein, and waste-minimizing diets. Therefore, the valorization of peanut milk residue particularly in edible products like ice cream cones presents a promising, sustainable avenue to enhance both food quality and environmental stewardship in the agri-food industry.

4. Ice Cream Cone Development: Background

Ice cream cones have long served as an edible, functional, and eco-friendly solution for serving frozen desserts, eliminating the need for disposable containers. Traditionally, these cones are made from refined wheat flour, sugar, and fats, offering a crisp texture and pleasant taste. However, rising health awareness and sustainability concerns have driven the exploration of alternative ingredients that are nutritionally superior and environmentally responsible (Mhatre *et al*., 2022) [25].

Recent innovations have focused on enhancing the functional profile of cones by incorporating whole grains, millets, and agro-industrial residues such as fruit pomace, bran, and nut-based by-products. Such incorporation not only improves fiber and protein content but also adds value to food industry waste, promoting circular economy practices. Studies have shown that replacing refined flour with nutrient-dense ingredients can result in cones that are gluten-free, high in dietary fiber, and rich in antioxidants, without compromising consumer acceptability (Hlaváčová *et al*., 2022) [14].

The development of cones using plant-based residues such as peanut milk pomace aligns with zero-waste food innovation strategies. Peanut residue is particularly promising due to its favorable texture, high protein, and fiber content, making it suitable for integration into baked products like ice cream cones (Suleman *et al*., 2023) [24]. Such efforts not only reduce food loss but also lead to the creation of value-added, functional foods that support both consumer health and sustainable processing systems.

5. Demand for gluten-free, high-fiber, plant-based alternatives

The incorporation of plant-based by-products and gluten-free ingredients into food systems has gained momentum in response to rising health awareness, gluten intolerance, and the push for sustainable food innovations. Recent research highlights the successful utilization of agro-industrial residues and alternative flours such as soy, pea, sorghum, and pumpkin seed as functional substitutes for wheat flour in bakery and processed foods (Wang & Jian, 2022; Bhattarai, 2024) [26, 27]. These alternatives not only cater to dietary restrictions but also add nutritional benefits such as increased protein, fiber, and bioactive compounds (Difonzo *et al*., 2022) [28].

In the context of ice cream cone development, using gluten-free and plant-based ingredients derived from food waste can improve product quality while contributing to circular economy goals. Sorghum, for example, has been noted for its potential as a gluten-free grain with desirable baking properties (Hegde *et al*., 2023) [29]. Similarly, the valorization of peanut milk residue represents an innovative approach that combines waste minimization with nutritional enhancement, offering scope for producing functional and sustainable edible cones.

Overall, this body of research supports the integration of plant-based and gluten-free alternatives as viable pathways to promote health, reduce waste, and develop novel food products aligned with consumer and environmental demands.

6. Use of Peanut Residue in Edible Cones

The inclusion of legume- and soy-based flours in bakery formulations has shown promising outcomes in improving both the nutritional profile and functional characteristics of dough and final products. Studies indicate that flours derived from soy and pulses can significantly enhance protein content, dietary fiber, and essential amino acids in baked goods, while also influencing rheological and textural properties critical for product quality (Zhang, 2021; Neji *et al*., 2023) [30, 31]. Moreover, plant-based protein ingredients are increasingly recognized for their role in sustainable food development and as viable alternatives to animal-based proteins (Akhtar *et al*., 2022) [32].

In the context of edible cone development, incorporating such protein-rich plant-based flours particularly those derived from food processing residues like peanut milk

pomace offers dual benefits: nutritional enhancement and waste valorization. As supported by recent findings, legumes and pulses not only improve the structural integrity of dough but also align with the rising consumer demand for high-protein, plant-based, and functional foods.

Thus, leveraging plant-derived protein sources in bakery applications contributes to health-focused product innovation and a more sustainable food system.

Conclusion

Peanut milk residue, often discarded as waste, holds significant potential for valorization into high-value food products such as edible ice cream cones. Rich in proteins, fiber, and bioactive compounds, this by-product can enhance the nutritional profile and structural quality of baked goods while contributing to sustainable food processing. Utilizing peanut residue aligns well with zero-waste and circular economy principles by transforming agro-industrial waste into functional, marketable solutions. This approach not only reduces environmental impact but also adds economic value through resource optimization.

The incorporation of plant-based residues in edible packaging offers a promising alternative to conventional, non-biodegradable materials. It supports the development of gluten-free, nutrient-enriched, and environmentally friendly products that meet growing consumer demands for sustainable and health-conscious options. As the food industry seeks innovative solutions to minimize waste and maximize utility, the exploration of peanut milk residue in product development sets a precedent for broader applications of food by-products.

Continued interdisciplinary research and pilot-scale experimentation are encouraged to fully understand the processing behavior, shelf-life, and consumer acceptance of peanut-based edible cones and similar innovations. Such studies will be instrumental in scaling up zero-waste strategies and integrating sustainable materials into mainstream food production.

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