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Evaluation the Potential of Using Plant-Based Milk Substitutes in Ice Cream Production

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Abstract: In recent years, the different dietary needs of consumers due to their health problems such as food allergies and lactose intolerance or lifestyle changes, well-being trends, and increasing awareness about environmental concerns causes an increment in consumers' demand to have more plant-based foods in the diet. In this regard, more sustainable alternatives for different food systems come into prominence, and the market size for new plant-based alternatives especially for dairy products is ever-increasing. Ice cream is a complex colloidal structure and is defined as a frozen foam that is considered a suitable matrix for plant-based milk substitutes. Although it is hard to obtain a stable colloidal ice cream structure when replacing cow's milk with plant-based alternatives, the coconut-based, soy-based, and almond-based milk alternatives are regarded as one of the most suitable choices for ice cream production. According to studies, coconut milk's fat and protein content helps the formation of emulsion and stabilization of the foam system. Also, it is indicated that soy-based ice cream is a good carrier for probiotics, has a better melting resistance, and has comparable sensorial properties with dairy ice cream when used together with milk alternative combinations. However, some technological, microbiological, and sensorial properties of plant-based ice creams were not similar to ice cream made with cow's milk. Eventually, innovative approaches to producing ice cream with different milk alternatives could be promising and beneficial for the sustainable food industry and should continue to be developed to meet the current needs and interests.

Keywords: Plant-based food; dairy alternatives; non-dairy beverage; ice cream; vegan; sustainability

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1. Introduction

Consumer demand for more plant-based foods has increased in recent years due to a variety of dietary needs brought on by health issues like food allergies and lactose intolerance as well as lifestyle changes, wellness trends, and growing environmental awareness. Concordantly, to meet the nutritional needs of the expanding global population, sustainable and wholesome alternative food sources are required. Recently, more environmentally friendly alternatives to various food systems have gained popularity, and the market for novel plant-based substitutes, particularly for dairy products, is constantly expanding [1]. As an example, milk substitutes made from nuts, legumes, cereals, and seeds used for ice cream production [2]. Ice cream is a semi-solid, delicious, and nutritious frozen dairy product that is widely consumed throughout the world [3]. There have been studies on the use of coconut-based milk substitutes in the production of ice cream, followed by soy-based and almond-based milk substitutes. In this regard, the use of plant-based milk substitutes in ice cream not only incorporates the nutritional values and health-promoting effects of plant compounds into ice cream but also results in the production of a novel product with specific properties, such as lactose-free products, which may be appealing and useful to consumers [4]. Therefore, the main aim of this study is to summarize the effects of plant-based milk substitutes on some technological and nutritional properties of ice cream.

2. Influence of Plant-Based Milk Substitutes on Technological and Nutritional Properties of Ice Cream

The chemical composition, texture, melting resistance, and flavor all play a significant role in how well ice cream is received by consumers [2]. Ice cream has the consistency of partially frozen foam with ice crystals and air bubbles. In other words, fat globules, air, and ice crystals that are dispersed in a frozen solution and concentrated with proteins and polysaccharides are the main structural elements of ice cream [5]. The main challenge in producing plant-based ice cream is to obtain a stable colloidal system because large dispersed particles found in plant-based milk substitutes, such as fat globules, solid raw material particles, proteins, and starch granules, make it challenging to produce a stable product that can be kept for a long time due to solid particle sedimentation or settling [2]. Besides, the protein content and quantity of milk used to make plant-based ice cream with the desired textural and sensory qualities are important because ice cream requires a strong protein structure due to its multi-phase mixture [6]. Studies show that the fat and protein content of coconut-based milk substitutes aids in the creation of emulsions and the stabilization of the foam system. Besides, it is easy to digest and contains a lot of minerals, vitamins, and antioxidants. Also, soy-based milk substitute is regarded as a suitable choice for ice cream due to their high nutritional quality, particularly in terms of protein content and amino acid balance [3]. Soy-based milk substitute has a similar nutritional value to cow's milk, providing 60 to 90% of the nutrient content of cattle [2]. Mendonça et al. produced ice cream with soy extract, soy kefir, and dehydrated jaboticaba peel. In particular, soy kefir-containing mixtures displayed high concentrations of the total phenolic component [7]. Moreover, the increase in the concentrations of sweet lupine and soy-based milk substitute combinations in ice creams was eventuated in better not only nutritional but also technological properties such as melting resistance, and acceptable sensorial features [2]. Also, ice cream made with almond-based milk substitutes performed better in the organoleptic evaluation due to its sweet aroma, whereas hemp-based milk substitute ice creams were only praised for their enhanced physicochemical and rheological properties [8]. Additionally, it has been stated that adding dietary fiber or some other stabilizers to the plant-based ice cream manufacturing process can enhance the product's rheological characteristics [1]. Furthermore, mixing plant-based milk substitutes is advised to take advantage of each milk substitute's unique properties and create plant-based ice cream with desirable textural and sensory qualities [4]. The major findings of using plant-based milk substitutes on the technological and nutritional properties of ice cream are shown in Table 1;

Table 1. The major effects of using plant-based milk substitutes on the technological and nutritional properties of ice cream.

	Plant-Based Milk Substitute	Major Technological Findings	Major Nutritional Findings	References
Tree Nuts	Coconut	Melting resistance↑, Viscosity↑, Hardness↑, Overrun↑, pH↑, Sensory acceptability↑	Protein↑, Total solids↑, Total soluble solids↑, Fat↓	[9]
	Coconut	Time of the first drop↓ (with increased inulin content), Melting resistance↑ (after 45 min., with increased inulin content), Overrun↓, Hardness↑ (with increased locust bean gum content), Dark color↑ (with increased inulin content), Taste↑, Creamy consistency↑	Fat↑	[10]
	Coconut	Moisture↑, pH↑ (coconut-based milk substitute and guava pulp)	Energy↑, Total solid↑, Fat↑, Iron↑, Ascorbic acid↑, Calcium↑, Protein↑	[11]
	Coconut	pH (6.33 ± 0.01), Titratable acidity (0.33 ± 0.05%), Overrun (66.76 ± 1.44%)	Total solids (38.02 ± 0.14%) Moisture (61.86 ± 0.33%) Fat (11.66 ± 0.60%) Protein (4.18 ± 0.16%) Ash (0.41 ± 0.25%) Total phenolic content (0.093 ± 0.002 GAE mg/g) DPPH radical scavenging activity (60.39 ± 0.02 mg/g) Total antioxidant capacity (0.36 ± 0.04 mmol (AAE)/g)	[12]
	Coconut	Overrun↓, Flavour↑, Taste↑	Solids-non-fat↑, Total solids↓, Total phenolics↑, Minerals↑	[13]
	Coconut	Overrun↓- Melting rate↓- Hardness↑ (increasing levels of sodium caseinate replacement), Body and Texture↑- Flavor and Taste↑ (with increasing SC concentration)		[14]
	Coconut	Foam capacity↓-Foam stability↑ (with increasing proportion of coconut-based milk substitute), Viscosity↑ (with increasing proportion of mung bean extract)	Water content↓- Total solids↑	[15]
Legumes	Soy	Viscosity↔, Fat globule size↔, Hardness↔, Melting rate↔, Overrun↓- Fat destabilization↑ (commercial vegetable oil), Mouth coating↑ (heavy cream), Off-flavor↑ (commercial vegetable oil and commercial high oleic soybean oil), Flavor, Texture, and Overall liking↑ (commercial high oleic soybean oil and heavy cream)		[16]
	Soy Kefir	Acidity↑, Sensory scores↑ (addition of kefir)	Phenolic compounds, Viability of probiotics↑ (higher than 10 log CFU/g)	[7]
Legumes and Nuts	Soy and Coconut combination	pH↑, Melting rate↓, Viscosity↑, Freezable water↑		[3]
	Soy and Coconut combination	Acid and bile tolerance↑, Total acceptability↓	Probiotic survival↑ (soy milk), Probiotic survival↓ (coconut milk)	[17]
	Soy and Coconut combination	Apparent viscosity↔, Hysteresis↓, Particle size↓, Freezable water↓		[18]

Legumes Legumes and Seeds	Soy and Coconut combination	Consistency index↑, Viscosity↑, Melting resistance↑, Total sensory scores↓ (soy-based milk substitute)	*L. acidophilus* La-05 probiotic survival percentage↑ (coconut-based milk substitute), *B. bifidum* Bb-12 probiotic survival percentage↑ (soy and coconut-based milk substitute)	[19]
	Soy and Coconut combination	Melting rate↓, Apparent viscosity↑, Particle size↑, Total acceptability↓		[20]
	Soy and Coconut combination	pH↓	Probiotic growth↑	[21]
	Soy and Sesame combination	Overrun↔- Hardness and Consistency↑- Cohesiveness↓- Air bubbles↑ (optimized ice cream) Tg (Glass transition temperature)↓- Ice content↓- Unfreezable water↑- Frozen water↓ (soy-based ice cream), Mean particle diameter↔ (optimized ice cream), Sensory attributes↑		[4]
	Sweet Lupin and Soy combination	Overrun↑, Melting resistance↑, Taste and Texture ↔ (up to 25% replacement)	Protein content↑-Fat ↑ (soy), Ash↑, Fiber↑, Total carbohydrate↑	[2]
Nuts	Almond Drink	Consistency↑-Apparent viscosity↑-Particle size↓ (addition of stabilizers), Density↔		[22]
	Almond and Hemp combination	Viscosity↑- Consistency↑- Appearance↑ (hemp-based milk substitute and pectin), Sensory↑ (almond-based milk substitute)		[8]
	Fresh and Dried Walnut combination	Overrun↑, Rheological properties↑, Brightness value↓, Different volatile compounds↑, Sensory evaluation↔	Fat↑, Protein↑, Unsaturated fatty acid↑	[6]
Seeds	Bambara Groundnut	Sensory characteristics↔	Fat↓, Ash↓, Protein↑, Carbohydrate↑, Calcium↑, Iron↑, Potassium↑, Magnesium↑, Tannin and Phytate contents↑	[23]
	Hemp Drink	Melting rate↑- Unfreezable water content↑ (almond and hemp protein-containing products) Shear stress↑- Consistency coefficient↑- Pseudoplastic character↑ (addition of microbial transglutaminase and guar gum), Color, Smell, Final taste, and Texture↑ (addition of almond protein), Sensory attributes↑ (addition of guar gum)	Probiotic activity↑, Probiotic viability↑ (prebiotic-supplemented samples) Antioxidants and Phenolic compounds↑	[24]
Cereals, and Legume	Rice, Lentil, and Chickpea combination	Overrun↑, Apparent viscosity↑, Hardness↑, Gumminess↑, Adhesiveness↑, Springiness↑, Cohesiveness↓, Ice particulate↑, Artificial taste↑	High cell density↑ (>10^7 cfu/mL), Ash↑, Protein↓, Dry matter↑	[26]

↓ indicates increment is different, ↑ indicates decrease is different, ↔ indicates increment or decrease is not different.

Examining the results of Table 1 revealed notable variations among ice creams made with plant-based milk substitutes. In conclusion, plant-based milk substitutes can be used in the production of ice cream with significant physicochemical, nutritional, and sensorial properties [3].

Another of the topics that has received the most research is whether ice cream made with plant-based milk substitutes is a conducive environment for probiotics [21] because normally ice cream accepted is an excellent substrate for preserving the functional properties of probiotics over time [17]. An example to make fermented ice cream with *L. acidophilus* and *B. bifidum*, soy and coconut-based milk alternatives, as well as combinations of these milk alternatives with cow milk (25%, 50%, and 75%) were used. When a mixture of 75% soy and 25% coconut-based milk alternatives was used in place of cow milk, the probiotic development of *L. acidophilus* and *B. bifidum* in fermented ice cream was increased [21]. Moreover, studies are being conducted to incorporate fermentation into the process of making ice cream. A sophisticated frozen dairy dessert called fermented ice cream combines the physical properties of ice cream with the flavor and nutritional benefits of fermented milk products [20,27].

3. Conclusion

Consequently, the sustainable food industry may ultimately benefit from creative methods for making ice cream with various milk substitutes, and these methods should be developed further to satisfy present and increasing needs and interests. It is important to optimize and adjust both plant-based milk substitutes and ice cream production process parameters. In this regard, plant-based ice cream should be reasonably priced, have desirable organoleptic properties, be wholesome, and be environmentally friendly. To improve plant-based ice cream's quality and acceptability, it is crucial to increase product stability, reduce or eliminate undesirable flavors, boost nutritional value, and enhance sensory attributes. On the other side, generally, the protein content and quality, as vitamin, and mineral bioavailability of plant-based milk alternatives are lower when compared to cow's milk. Therefore, plant-based ice creams should enhance not only the technological but also the nutritional perspective. To summarize, more research is needed within the scope of the subject to compare the benefits and drawbacks of various plant-based products including ice cream based on their nutritional qualities and environmental impacts.

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