

Research Article

Development and characterization of a vegan, reduced-calorie chocolate ice cream based on cauliflower

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Abstract - The objective of this study was to develop and characterize ReCream, a novel vegan, reduced-calorie chocolate ice cream incorporating cauliflower as the primary ingredient (33% by weight). The aim was to design a nutritionally enhanced frozen dessert that complies with Israeli front-of-pack nutritional labeling regulations and avoids warning labels for high sugar or saturated fat. Physicochemical properties (°Brix, overrun, melting rate, and hardness) were evaluated and compared with a control formulation lacking cauliflower. ReCream exhibited higher soluble solids ($p = 5.4 \times 10^{-5}$), reduced overrun ($p = 0.019$), and a slower melting rate ($p = 0.017$), while maintaining comparable hardness ($p = 0.3$). Sensory evaluation ($n = 16$) showed an average overall acceptability score of 4.1 out of 5, with 81% of panelists reporting no detectable cauliflower flavor. These results demonstrate that cauliflower can serve as a functional and sustainable base ingredient in vegan ice cream formulations, improving nutritional quality while maintaining desirable sensory characteristics.

Keywords: Cauliflower, vegan ice cream, functional foods, upcycling, saturated fat and sugar reduction

1. Introduction

Ice cream remains one of the most popular desserts worldwide. However, ice cream often contains high levels of added sugars and saturated fats, which are linked to adverse health outcomes when consumed excessively. Overconsumption of these components is strongly associated with increased risks of obesity, cardiovascular disease, and type 2 diabetes (Rippe & Angelopoulos, 2016). In response, many countries have adopted front-of-package (FOP) nutritional labelling systems designed to help consumers make healthier choices (Jones et al., 2019). These labels highlight products that surpass specific thresholds for nutrients deemed harmful in large amounts, such as sugars, saturated fats, sodium, and overall calorie content (Jones et al., 2019).

Chile pioneered FOP warning labels for foods high in sugar, saturated fat, and sodium (Corvalán et al., 2019), and similar regulations have since been implemented in countries such as Israel and Mexico (Samuel et al., 2024; Crosbie et al., 2023). In Israel, since 2020, products exceeding 10 g of sugar or 4 g of saturated fat per 100 g must display red FOP warning labels (Israel Ministry of Health, 2022). For ice cream, traditionally high in these components, meeting these requirements demands reformulation without compromising sensory quality, presenting both challenges and opportunities for innovation (Craig & Brothers, 2022).

Recently, the ice cream industry has become increasingly diverse, with plant-based alternatives gaining significant popularity. The vegan ice cream market, once a niche segment, is now among the fastest-growing parts of the frozen dessert industry. Global demand for dairy-free ice cream is projected to expand at a compound

annual growth rate (CAGR) exceeding 15% between 2024 and 2030 (Grand View Research, Inc, 2024). This rapid growth reflects broader consumer shifts towards plant-based diets, driven by health concerns, environmental issues, and ethical commitments to animal welfare (Venter de Villiers et al., 2024). Given the increasing demand for healthier options, research aims to develop ice cream that meets modern nutritional standards, avoids label warnings, and still provides the rich, indulgent sensory experience consumers desire. To accomplish this, we included cauliflower as a functional ingredient, utilizing its low energy density and nutritional benefits (Wang et al., 2022). Cauliflower is a vegetable rich in dietary fiber, minerals, and bioactive compounds, which may contribute to increased solid content and improved viscosity in frozen desserts. These functional attributes support the hypothesis that cauliflower can enhance both texture and stability in reduced-calorie ice cream. Cauliflower contains glucosinolates, phytochemicals that are responsible for the spicy taste and pungent aromas of cruciferous vegetables (Prieto et al., 2019). While these compounds offer potential health benefits (Cohen et al., 2019), they may present sensory challenges in delicate food matrices like ice cream. Therefore, various strategies are needed to mask unwanted flavors while maintaining their functional role in texture and nutritional value (Hwang, 2019).

This study aimed to develop a vegan chocolate ice cream using cauliflower as the main ingredient, sweetened with natural alternatives, and designed to meet nutritional labelling regulations. Additionally, using surplus cauliflower, often regarded as a by-product in the food industry, could improve the product's sustainability by reducing food waste.

2. Materials and methods

2.1 Ingredients

Several preliminary formulations were initially screened to optimize the ice cream’s texture, taste, and nutritional profile. These included variations in the base liquids, types and concentrations of sweeteners and stabilizers, as well as different percentages of cauliflower. The final ice cream formulation included the following ingredients (Table 1): cauliflower, unsweetened almond drink (Alpro,

Strauss, Israel)/unsweetened rice drink (Alpro, Strauss, Israel), water, white sugar (Sugat, Israel), allulose (Health Garden, Israel), maple syrup (Shkedia, Israel), inulin (Universal, Israel), unrefined coconut oil (Shaked Tavor, Israel), cocoa powder (Maya, Israel), 85% cocoa dark chocolate (Splendid Elite, Israel), pea protein (Spirulife, Israel), natural vanilla extract (Watkins, USA), mono- and diglycerides (Eshbal, Israel), salt (Melach Haaretz, Israel), guar gum (Dr. Sergio Broyde, Israel), and monk fruit sweetener (Atid Yarak, Israel).

Table 1. Percentage composition of each ingredient (per 100 g) in ReCream ice cream and the control. In the control sample, cauliflower was replaced with an equivalent amount of water.

Ingredient	Control (g/100 g)	ReCream (g/100 g)
Water	41.93	8.60
Unsweetened almond drink	26.13	26.13
Cauliflower	—	33.33
White sugar	5.60	5.60
Allulose	5.33	5.33
Maple syrup	5.07	5.07
Inulin	4.40	4.40
Unrefined coconut oil	3.60	3.60
Cocoa powder	3.33	3.33
Dark chocolate (85% cocoa)	2.00	2.00
Pea protein	1.33	1.33
Natural vanilla extract	0.53	0.53
Mono- and diglycerides	0.24	0.24
Salt	0.23	0.23
Guar gum	0.22	0.22
Monk fruit sweetener	0.04	0.04

2.2 Processing (The overall process is illustrated in Figure 1)

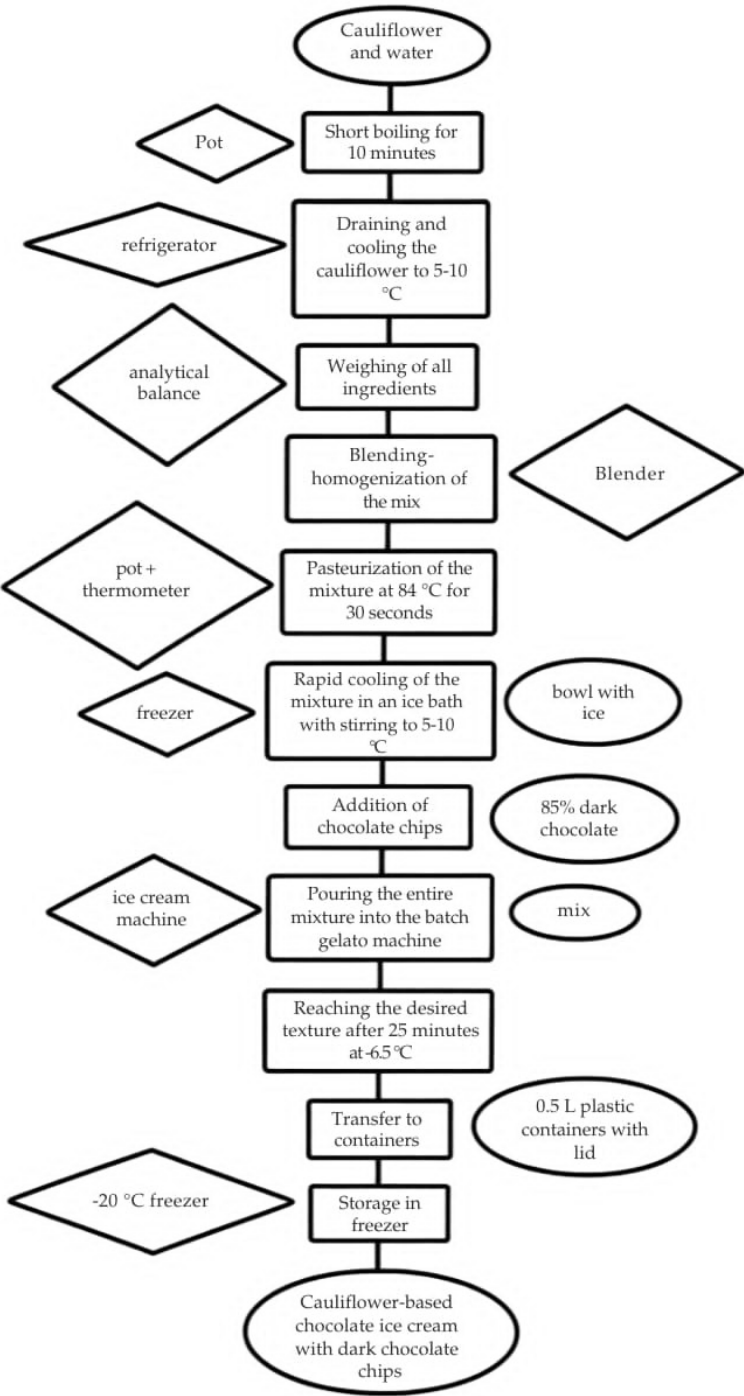


Figure 1. Flowchart illustrating the production process for ReCream ice cream.

2.2.1 Cauliflower preparation

Fresh white cauliflower (*Brassica oleracea* var. *botrytis*) was sourced locally and stored at 4 °C until use. All cauliflower used in the experiment originated from the same local supplier (Kiryat Shmona, Israel) and was stored at 4 °C for no longer than three days before processing to ensure quality consistency. Before processing, florets and stems were trimmed, washed thoroughly with potable water, and cut into uniform pieces. The cauliflower segments were boiled in water at 100 °C for about 10 minutes until soft. After thermal treatment, the cauliflower was immediately drained and cooled in an ice bath to 5–10 °C to stop further cooking and maintain quality.

2.2.2 Mixing

The boiled cauliflower was combined with the other ingredients (see Table 1 for final formulation percentages), and the mixture was blended at high speed using a blender (Kennedy, China) until a smooth and uniform consistency was obtained. The control formulation followed the same procedure as described above, replacing cauliflower with an equivalent amount of water to maintain total mass consistency.

2.2.3 Pasteurization

The homogeneous mixture was pasteurized by heating to 84 °C and held at that temperature for 30 seconds. This step guaranteed microbial safety and improved the functionality of the stabilizer and emulsifier. After pasteurization, the mixture was quickly cooled in an ice-water bath to 5–10 °C, and then chopped dark chocolate (85% cocoa solids) was manually added to ensure even distribution throughout the product.

2.2.4 Freezing and aeration

The mixture was stirred and frozen in an ice cream batch freezer machine (Frigomat G5, Italy). A standard ice cream

setting was used, providing greater consistency and a preparation time of approximately 25 minutes, with continuous movement and agitation. Simultaneously, air was incorporated into the mixture, and it was frozen to a final temperature of -6.5 °C. The products were stored in plastic containers and kept frozen in a conventional freezer at -20 °C. All analyses were conducted within one week of storage at -20 °C.

2.3 Analytical measurements

2.3.1 Brix (%)

Brix levels were measured in the pre-frozen mixture using a digital refractometer (Atago PAL-1, Japan) to assess the concentration of soluble solids, as described by [da Silva Faresin et al. \(2022\)](#). Analyses were performed in three technical replicates for each formulation.

2.3.2 Overrun (%)

Overrun, indicating the amount of air incorporated during freezing, was calculated by measuring the weight difference between the liquid mix and the frozen product in containers of identical volume. It was expressed as a percentage using the formula ([Marshall et al., 2003](#)): $\text{Overrun (\%)} = [(\text{Weight of mix} - \text{Weight of ice cream}) / \text{Weight of ice cream}] \times 100$. Analyses were performed in three replicates for each formulation.

2.3.3 Melting rate

Melting behavior was assessed by placing 200 g of ice cream in metal strainers at room temperature (25 °C). Melt weight was recorded after 60 minutes to assess the melting profile and structural stability of the ice cream, similarly to the methodology described by [El-Nagar et al. \(2002\)](#). Analyses were performed in three replicates for each formulation.

2.3.4 Texture

Texture analysis of the formulations was conducted following the methodology

described by [da Silva Faresin et al. \(2022\)](#). A texture analyzer (TA1, Lloyd UK) equipped with a 5 mm cylindrical probe was used to measure hardness at -20°C. Penetration depth was set to 5 mm with a test speed of 2 mm/s. Peak force (N) was recorded to assess product firmness. To generate force-time curves, the frozen dessert samples were placed at the center of the platform in a sterile glass container. Hardness was determined as the peak force measured during the initial compression cycle. Texture analyses were performed in four technical replicates for each formulation.

2.4 Sensory evaluation

The sensory panel included 16 semi-trained evaluators (12 females and 4 males), students from the Faculty of Food Science in Tel-Hai University of Kiryat Shmona and the Galilee, aged 21–43 years. Two participants were regular consumers of vegan ice cream, eight consumed it occasionally, and six did not consume vegan ice cream at all. Each panelist received coded samples (~ 50g) served at -10°C. Using a 5-point hedonic scale (1 = dislike extremely, 5 = like extremely), participants rated the following attributes: sweetness, bitterness, creaminess, and overall liking. Additionally, the sensory evaluation included questions about the perception of ice crystals and off-flavors associated with cauliflower. Responses were recorded on a 3-point scale: 'not noticeable', 'slightly noticeable', and 'strongly noticeable'. All assessments were carried out under controlled lighting and temperature conditions in individual booths to minimize external influence.

2.5 Calculation of nutritional values

Nutritional values were calculated using Tzameret software, a professional nutritional analysis tool developed and maintained by the [Israel Ministry of](#)

[Health \(2022\)](#). The database provides up-to-date information on the nutrient composition of foods commonly consumed in Israel and is widely used in dietary assessments and nutritional research ([Shimony et al., 2025](#)).

2.6 Statistical analysis

A two-tailed t-test was conducted to determine statistical significance between formulations, using a 95% confidence level ($p < 0.05$). All analyses were performed with Minitab version 17 (Minitab, Inc., USA).

3. Results

Several preliminary formulations were initially screened for texture, flavor balance, and compliance with Israeli nutritional labeling regulations. The formulation that provided the optimal sensory and structural characteristics was selected for final analysis and comparison with the control sample. The developed formulation of ReCream ice cream (Table 1) primarily relies on cauliflower (33.33%) and unsweetened almond drink (26.13%) as the product's base. Additional ingredients include water, sugar, dietary fiber (inulin), natural sweeteners (allulose, maple syrup, monk fruit), plant-based fat (unrefined coconut oil), cocoa powder, dark chocolate, pea protein, vanilla, salt, stabilizer and emulsifier in small amounts.

The nutritional values per 100 g (Table 2), calculated using Tzameret software ([Israel Ministry of Health, 2022](#)), show that ReCream ice cream provides 126 kcal, with 5.7 g of fat (4 g saturated), less than 0.5 g trans-fat, and no cholesterol. Sodium content is relatively low (109 mg), and total carbohydrates amount to 22.3 g, of which 10 g are sugars (2.5 teaspoons). The product also supplies 2.8 g of protein, 5.6 g of dietary fiber, 1.7 mg of iron, and 12 mg of vitamin C, which originates entirely from the cauliflower.

Table 2. Nutritional values per 100 g of ReCream ice cream and the control, as calculated by Tzameret software.

Nutrient	Control	ReCream
Energy (kcal)	119	126
Total fat	5.6 g	5.7 g
Saturated fatty acids	4 g	4 g
Trans fatty acids	Less than 0.5 g	Less than 0.5 g
Cholesterol	0 mg	0 mg
Sodium	106 mg	109 mg
Total carbohydrates	20.9 g	22.3 g
Sugars	9.6 g	10 g
Sugar equivalents	2.4 teaspoons	2.5 teaspoons
Protein	2.1 g	2.8 g
Dietary fiber	5.1 g	5.6 g
Iron	1.4 mg	1.7 mg
Vitamin C	0 mg	12 mg

Overrun analysis showed that the ReCream formulation had an average overrun of $32.4 \pm 1.9\%$, compared to $42.3 \pm 3.5\%$ in the control ice cream, which used water instead of cauliflower (values

represent mean $\pm$ standard deviation, $n = 3$). This difference was statistically significant ($p = 0.019$), indicating that the ReCream formulation incorporated less air during freezing.

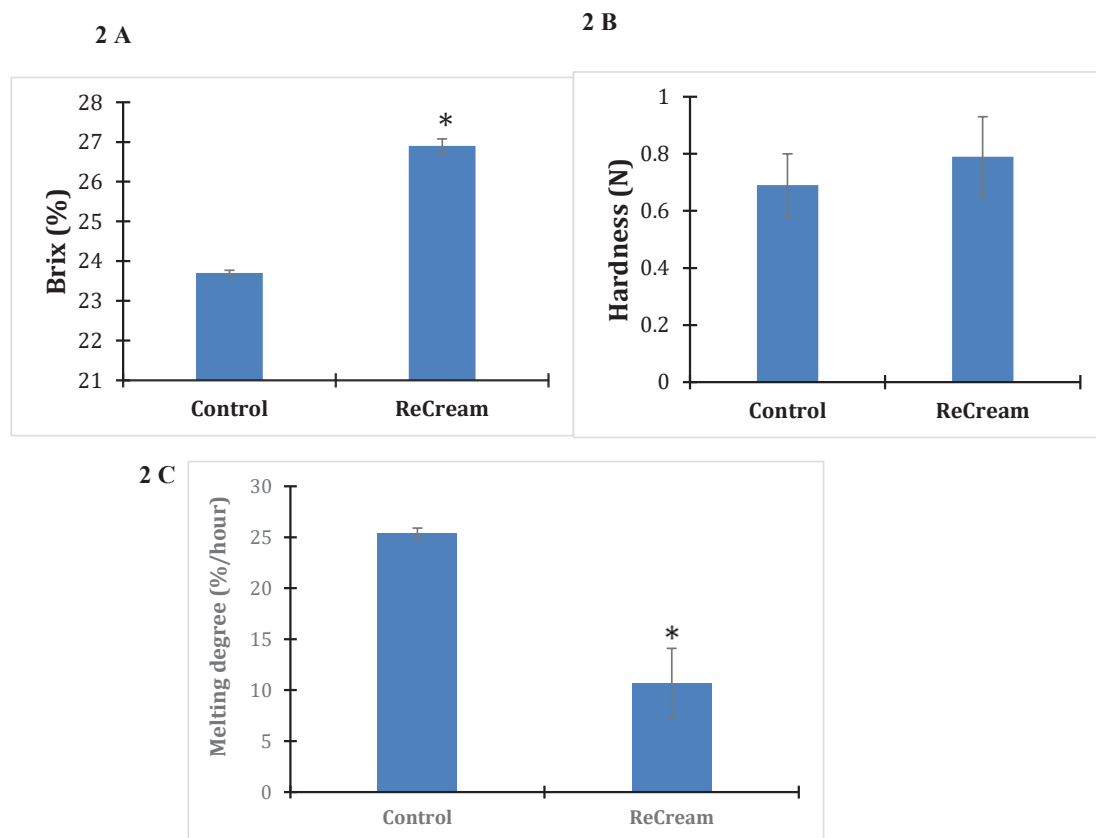


Figure 2. Analytical measurements of Control and ReCream ice cream samples. A. Brix percentage measured before freezing using a refractometer; bars represent mean $\pm$ standard deviation from three technical replicates, * $p < 0.05$. B. Hardness (N), measured at -20°C with a texture analyzer; bars represent mean $\pm$ standard deviation from four technical replicates. C. Melting degree, presented as the percentage of melted mass over a 1-hour period at room temperature; bars represent mean $\pm$ standard deviation from three replicates, * $p < 0.05$.

The Brix measurements indicated that the ReCream formulation had a significantly higher soluble solids content (26.6%) compared to the control (23.8%) ($p = 5.4 \times 10^{-5}$; Figure 2A). Hardness measurements showed that the ReCream ice cream had a slightly higher average value (0.78 N) compared to the control (0.68 N) (Figure 2B). Although this increase suggests a firmer structure, the two-tailed t-test confirmed that the difference was not statistically significant ($p = 0.3$). Nevertheless, the results indicate that the inclusion of cauliflower in the

formulation may have contributed to a modest improvement in structural firmness. Melting degree analysis showed that the ReCream ice cream melted more slowly than the control (Figure 2C). While the control exhibited an average melting degree of $25.4 \pm 0.5\%$ per hour, the ReCream formulation displayed a significantly lower value of $10.7 \pm 3.4\%$ per hour (values represent mean $\pm$ standard deviation, $n = 3$). This difference was statistically significant ($p = 0.017$). Additionally, the time to the first drop melt, measured with a stopwatch, varied

notably between the samples: the control started to release the first drop after 23 minutes, whereas the ReCream formulation took approximately 50

minutes. This lower melting rate reflects improved structural stability at room temperature, which is a desirable feature in frozen desserts.

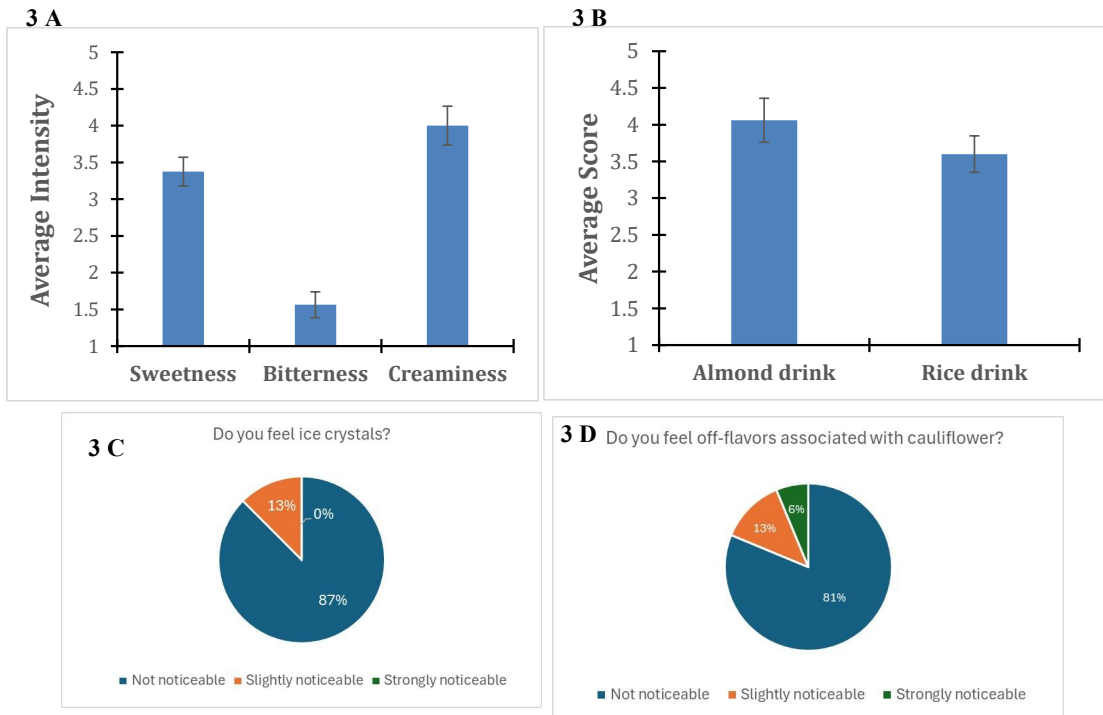


Figure 3. Sensory evaluation results of the ReCream formulation. Panelists ($n = 16$) evaluated: A. Mean values for sweetness, bitterness, and creaminess, B. Comparison of overall liking scores between ice cream samples made with almond and rice drinks. Almond drink represents the ReCream formulation, while rice drink serves as a control sample. Bars represent mean $\pm$ standard error. A-B: Sensory evaluations were conducted using a 5-point hedonic intensity scale (1 = very low, 5 = very high). C. Sensory evaluation of ice crystal perception. D. Sensory evaluation of off-flavors associated with cauliflower. C-D: Results are presented as percentage of responses for each category: “Not noticeable”, “Slightly noticeable”, and “Strongly noticeable”.

Sensory evaluation results from 16 panelists (Figure 3) show that the ReCream ice cream has positive sensory attributes. Creaminess received a high average score (4.0), indicating a rich and smooth texture (Figure 3A). Sweetness was rated relatively high (3.4), suggesting a well-balanced sweetness that was generally accepted (Figure 3A). Bitterness received a low average score (1.6), indicating minimal perceived bitterness, which is desirable in chocolate-based

frozen desserts (Figure 3A). The ice cream made with almond drink received a higher overall liking score (4.1) compared to the formulation with rice drink (3.6), which replaced almond drink and served as a control (Figure 3B), supporting the suitability of almond drink as a plant-based milk alternative for vegan ice cream development. However, the difference was not statistically significant ($p = 0.28$).

Most panelists (87%) reported that ice crystals were not noticeable in the product (Figure 3C). A small proportion (13%) found them slightly noticeable, with no panelists reporting strong detection, suggesting a smooth texture with minimal crystal formation (Figure 3C). Additionally, the majority of panelists (81%) reported no noticeable off-flavors related to cauliflower (Figure 3D). A smaller proportion (13%) found them slightly noticeable, and only 6% perceived strong off-flavors (Figure 3D), indicating that the cauliflower flavor was effectively masked in the formulation.

4. Discussion

Due to the rising obesity epidemic in the Western world, which leads to higher prevalence and mortality from chronic diseases such as diabetes, hypertension, cardiovascular conditions, and cancer, many countries have introduced mandatory nutritional labelling regulations on food packaging. These regulations aim to alert consumers to products containing high levels of sugar, saturated fat, salt, and calories (Corvalán et al., 2019). Since 2020, Israel has implemented mandatory food labelling, setting thresholds for sugar and saturated fat at above 10% and 4%, respectively (Israel Ministry of Health, 2022). Industrial ice cream is categorized as an ultra-processed food, typically high in sugar and saturated fat, and is therefore often labelled with red FOP warning symbols. In recent years, research efforts have focused on improving the nutritional profile of ice cream and even imparting it with additional functional properties, such as enrichment with protein, vitamins, antioxidants, and dietary fiber (Genovese et al., 2022). In this study, we developed a vegan ice cream with nutritional values below the FOP warning label thresholds set by the Israeli Ministry

of Health, achieved by incorporating cauliflower as a primary ingredient, which accounts for 33% of the total formulation. According to the Israel Ministry of Health's "Tzameret" software data, cauliflower contains 10% solids (primarily carbohydrates, proteins and minerals), 1% sugars, and 0% saturated fat. Therefore, its contribution to the final product is 3.3% solids, 0.33% sugars, and 0% saturated fat. Based on the nutritional values calculated in "Tzameret", the cauliflower-based ice cream contains 34.1% solids, 10% sugars, and 4% fat (Table 2). Hence, cauliflower contributes 9.7% of the ice cream's total solids, 3.3% of its total sugars, and 0% of its saturated fat. These nutritional features enabled us to increase the total solids content of the ice cream to a level close to that of commercial ice cream (~35% solids) (Marshall et al., 2003), while modestly raising the sugar content to achieve a desirable creamy texture without requiring FOP label warnings.

In addition to these nutritional adjustments, the analytical tests revealed that the overrun in the ReCream formulation was lower than in the control ice cream, while the melting resistance was higher. These results align with the findings of Dervisoglu and Yazici (2006), who reported that adding citrus fibers reduced the ice cream's overrun but also improved its resistance to melting. In their study, higher fiber content led to lower overrun and increased stability against meltdown (Dervisoglu & Yazici, 2006). A similar phenomenon may explain our results: the cauliflower fibers could have behaved similarly to citrus fibers, limiting air incorporation into the ice cream matrix while enhancing melting stability in the ReCream formulation. In addition, cauliflower likely enhanced structural integrity and water retention due to its fiber and pectin components, which may

have contributed to reduced ice crystal formation and improved emulsification stability in the ReCream formulation.

Cauliflower's relatively low caloric content (21 kcal/100 g) also facilitated the development of a reduced-calorie ice cream containing 126 kcal/100 g, compared to 160–250 kcal/100 g in regular vegan ice cream. Furthermore, cauliflower adds beneficial nutritional properties to the ice cream, such as dietary fiber, vitamins, minerals, and phytochemicals typical of cruciferous vegetables (Hwang, 2019). These phytochemicals also contribute to cauliflower's characteristic taste and aroma (Prieto et al., 2019); therefore, it was necessary to lessen their intensity through methods like boiling in water (Hwang, 2019) and to mask them with a pronounced chocolate flavor derived from cocoa powder and dark chocolate pieces. Sensory tests showed successful masking of the off-flavors of cauliflower, with 81% of participants reporting they did not detect them at all. Additionally, taste tests indicated a balanced flavor profile, with moderate sweetness, low bitterness, and an overall high rating (average of 4.1 out of 5). However, most of the sensory panel participants (87%) were not vegan, and 37% reported that they do not usually consume vegan ice cream. Therefore, to better reflect the preferences of this specific group, further testing with vegan participants is necessary. Notably, the two vegan participants in our panel rated the ice cream with the highest score of 5 out of 5.

Reducing fat and sugar content was necessary to avoid nutritional labelling but posed challenges in maintaining creaminess, sweetness, and sensory quality. To compensate for the fat reduction, mainly due to decreased coconut oil, inulin (4.4%) was incorporated as a soluble fiber with gelling and

water-binding properties, which increased viscosity, slowed ice crystal formation, and preserved creaminess (Akbari et al., 2019). To reduce sugar, its total content in the formulation was limited to 10%, combined with natural sweeteners such as maple syrup, allulose, and monk fruit (Castro-Muñoz et al., 2022). This strategy provided balanced sweetness while maintaining a high solids content and smooth texture similar to conventional industrial ice cream, along with a significantly improved nutritional profile. Since artificial sweeteners, commonly used in the industry, are associated with adverse health effects, the use of natural sweeteners was preferred (Kabthlymer et al., 2025). Allulose is a rare sugar used as a natural sweetener and considered a promising healthy alternative to added sugar (Mora & Dando, 2021). However, consumption of allulose (Han et al., 2018), similarly to inulin as a fiber source (Bonnema et al., 2010), may cause digestive discomfort and gastrointestinal symptoms; therefore, the amounts of both ingredients were limited to 5.3% and 4.4%, respectively.

Developing cauliflower-based ice cream aligns with the global trend of rising demand for vegan products and the shift towards plant-based diets, highlighting sustainability, health, and animal welfare (Tachie et al., 2023). Additionally, the product was tested and found suitable for utilizing agricultural by-products (cauliflower stems), potentially helping to reduce the food waste of this type currently present in the industry (Shinali et al., 2024). Therefore, the combination of technological innovation with nutritional and environmental benefits positions this developed ice cream as an innovative vegan alternative with genuine potential to enter the expanding global ice cream market.

5. Conclusions

The present study demonstrated the successful development of a vegan, reduced-calorie chocolate ice cream incorporating cauliflower as a key ingredient. The formulation achieved a desirable texture, a slow melting rate, and favorable consumer acceptance, while also maintaining a nutritional profile that aligns with front-of-pack labeling regulations. These findings highlight the potential of cauliflower as a sustainable and functional ingredient in plant-based frozen desserts, supporting the growing consumer demand for healthier and more environmentally friendly food products.

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