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Development of Functional Ice Cream Using Dahlia Tuber Flour *(Dahlia pinnata)* and Unripened Coconut Pulp as Fibre Source

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ABSTRACT

Ice cream, a popular frozen dairy product, can be developed as a functional food. This study aimed to create ice cream using dahlia tuber flour (a high-fiber waste product) as a fiber source and coconut pulp as a milk fat substitute. Inulin was extracted using hot water and ethanol precipitation, yielding 28.6 g (35.75%) of the total. Ice cream formulations involved dahlia flour (5%, 15%, 25%) and coconut pulp (25%, 15%, 5%). The observed parameters included hedonic, organoleptic, physical, and chemical properties. Based on organoleptic parameters, the best formulation was F1 (5% dahlia flour, 25% coconut porridge). F1 produced ice cream with 3.33% fat, 5.46% protein, 1.34% ash, 3.24% soluble food fiber, and 43.44% total solids. The ice cream had a yellowish-white color (L* 82.75, a* 0.43, b* 14.4). The hedonic values for F1 were color 4.49, aroma 4.46, taste 3.54, texture 4.05, and overall liking 3.92.

INTRODUCTION

In recent years, the field of functional foods has grown rapidly, driven by consumer demand for products that offer health benefits beyond basic nutrition requirements. The increased consumer focus on health and immunity has further strengthened this trend. Consumers are increasingly looking for foods that are not only delicious but also contribute positively to their well-being. Ice cream, a frozen dairy product, is one of the world's most popular desserts, appealing to all age groups. However, its traditional formulation, which is high in saturated milk fat and sugar, often conflicts with modern healthy eating patterns (Lubis, 2018). This paradox, where traditional ice cream is high in saturated fats and sugars, makes it an ideal vehicle for the development of functional foods. In Indonesia, the ice cream market is growing, and there is a push for healthy product innovation (low-fat, plant-based, and functional variants), making research on fibre-fortified ice cream relevant both scientifically and commercially (Moliboga et al., 2022). The global demand for functional products (prebiotics, probiotics, fibre, and plant-based ingredients) continues to rise, and manufacturers view ice cream as a promising platform for incorporating these functional ingredients (immunity, digestion, and GI reduction) (Fadilah & Sutedjo, 2024).

The main challenge in creating healthier ice cream is the role of fats. Milk fat is essential for the characteristic creamy texture, rich flavour, and structural stability of ice cream (Petkova & Denev, 2015). Directly reducing or eliminating fat can cause significant sensory and structural defects in food products. Research has shown (Tang et al., 2025) that reducing the fat content in ice cream causes degradation in texture and taste; low-fat ice cream tends to have a less creamy texture and is coarser and grainier than full-fat ice cream. Fat substitutes are needed to overcome this problem. These ingredients are generally carbohydrate- or protein-based and can mimic the physical and chemical properties of fat, contributing to the viscosity, mouthfeel, and structural integrity.

This study explored the synergistic use of two underutilised local Indonesian resources as new functional ingredients. The first is dahlia tubers *(Dahlia pinnata).* Although this plant is cultivated for its flowers, the tubers are often discarded as agricultural waste. These tubers are a rich source of inulin, a well-known prebiotic soluble fibre, with reported concentrations of 30-40% (Sunarti et al., 2022). Inulin is often used in ice cream to add fibre, improve creaminess and stability, and replace fat (Kheto et al., 2023).

The second resource is unripe coconut pulp *(Cocos nucifera L)*. Unlike mature coconuts, which are rich in long-chain triglycerides (LCT), unripe coconut pulp contains fats dominated by medium-chain fatty acids (MCFA), such as lauric acid. Medium-chain fatty acids (MCFA) are metabolised differently from long-chain triglycerides, offering potential health benefits, making young coconut meat a suitable candidate for fat substitutes. In addition, young coconut meat is a source of galactomannan, another soluble dietary fibre with prebiotic properties, which can also function as a natural stabiliser, contributing to viscosity and texture in the mouth (Gadizza et al., 2017). Research (Santana et al., 2011) shows that green/young/unripe coconut pulp can replace fat, milk, emulsifiers, and stabilisers in chocolate ice cream; the final product is very similar to conventional ice cream and receives high sensory acceptance (≈93% of panellists).

The combination of dahlia tuber flour (a source of natural inulin fibre) and coconut pulp (a natural fat replacer) in ice cream formulations has not been widely studied. This study not only focuses on increasing the fibre content but also on maintaining the physical quality, melt stability, and sensory properties through complementary ingredient pairings. This study has the potential to produce prebiotic functional ice cream without using commercial additives.

RESEARCH METHODS

Research Materials

Dahlia tubers *(Dahlia pinnata)* were sourced from local farmers in Malino, Gowa Regency, South Sulawesi, Indonesia. Unripe coconut (*Cocos nucifera L.*, Genjah variety), skim milk powder, full cream milk (Greenfields), sugar, salt, vanilla, carboxymethyl cellulose (CMC) stabiliser, and SP (Super Polymer) emulsifier were purchased from local markets in Makassar. Commercial inulin was used as the reference standard for FTIR analysis. All chemicals used for the proximate analysis, including n-hexane and ethanol, were of analytical grade.

Methods and Analysis Parameters

Preparation of ingredients dahlia tuber flour (DTF) was freshly harvested dahlia tubers (2.5 kg) were washed, peeled, and cleaned. The tubers were sliced into 2 mm thick chips and dried in a cabinet oven at 80°C for 6 h. The dried chips were milled using a disk mill and sieved sequentially through 80-mesh and 100-mesh screens to produce a fine flour (315.43 g yield).

The unripe coconut pulp (UCP) was opened, and the pulp (meat) was separated from the coconut water. The pulp was then scraped, washed with mineral water, and drained. The pulp was then blended with its own coconut water at a 1:3 ratio (pulp:water) for 5 min to create a smooth puree.

Inulin extraction and characterisation to validate the primary functional component, inulin was extracted from the prepared DTF. A 80 g sample of DTF was subjected to hot water extraction (800 mL water at 75°C) with constant stirring for 1 h. The mixture was vacuum-filtered while warm (40°C) to obtain 648 mL of the filtrate. Inulin was precipitated by adding

259.2 mL of absolute ethanol (40% v/v of filtrate) and holding the mixture in a freezer for 24 h. The precipitate was recovered by centrifugation (3500 rpm, 15 min) and dried in an oven at 60°C for 4 h to determine the yield. The chemical structure of the extracted inulin was confirmed using fourier-transform infrared (FTIR) spectroscopy (Shimadzu) and compared with a commercial inulin standard (Yuliana et al., 2014).

The study employed a completely randomised design (CRD) with four treatments and three replicates. The experimental factor investigated was the combination of dahlia tuber flour (DTF) and unripe coconut pulp (UCP). The four treatment levels were as follows: F0 (control, without DTF and UCP), F1 (5% DTF:25% UCP), F2 (15% DTF:15% UCP), and F3 (25% DTF:5% UCP).

Ice cream production for the functional formulations (F1-F3) shown in Figure 1, liquid ingredients (water and UCP) and dry ingredients (sugar, salt, skim milk, vanilla, and DTF) were mixed. The mixture was heated to 75°C for 2-4 minutes with stirring. CMC was added, and stirring was continued until the mixture thickened. The mixture was cooled to 40°C and homogenised using a hand mixer for 5 min. The mixture was then aged in a freezer for a minimum of 4 h. The frozen mix was scraped, the SP emulsifier was added, and the mix was whipped at high speed for 15 min to incorporate air (overrun). The final product was packed and hardened in a freezer at -18°C for 24 h before analysis. The control (F0) was prepared similarly using full-cream milk instead of DTF and UCP (Nuryati et al., 2020).

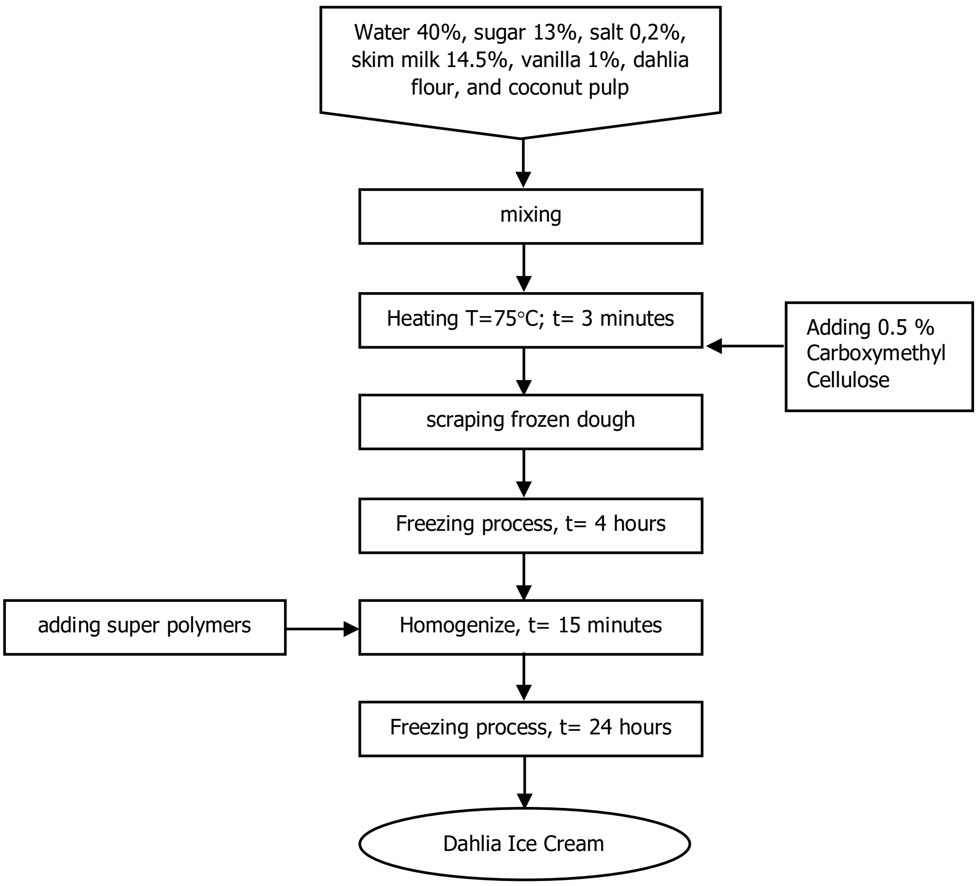

Figure 1. Flow chart of ice cream making process

Parameter analysis organoleptic analysis: Sensory properties were evaluated using a hedonic test with 35 untrained panellists. The panellists scored colour, aroma, taste, texture, and overall liking on a 7-point scale (1 = extremely dislike, 7 = extremely like) (Bresly et al., 2023). Physical analysis overrun was measured volumetrically using a volumetric method.

The melting rate was determined by placing a 5 g sample on a flat surface at ambient temperature and recording the time (in minutes) required for it to melt completely (Nuryati et al., 2020). The viscosity of the thawed mixture was measured using a Viskometer ND-J8 (spindle no. 4.12 rpm). Colour was measured objectively using a Colorimeter CS-10 to obtain CIE L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) values (Patriani & Wahyuni, 2022).

Proximate composition was determined using standard methods (Cleary et al., 2012). Fat content (Soxhlet), protein content (Kjeldahl), ash content (muffle furnace, 550°C), and total solids (via moisture content using a moisture analyser at 105°C). Soluble dietary fibre (SDF) based on the organoleptic results, the best formulation (F1) was selected for soluble fibre analysis. SDF was quantified using the enzymatic-gravimetric method (Cleary et al., 2012) at the accredited laboratory of the center for standardization and agro-industrial services (BBIA) in Bogor, Indonesia. Statistical analysis significant differences between treatment means ($p<0.05$) were assessed using Duncan's Multiple Range Test (DMRT). All statistical analyses were performed using SPSS version 25.

RESULTS AND DISCUSSION

Inulin Extraction from Dahlia Tubers

Inulin extraction, performed via hot water extraction and ethanol precipitation, yielded 28.6 g of dahlia inulin, corresponding to a 35.75% yield. Samples (0.5 g) of dahlia and commercial inulin were analysed using FTIR to compare their functional groups. The FTIR spectra of dahlia inulin and commercial inulin are shown in Figure 2.

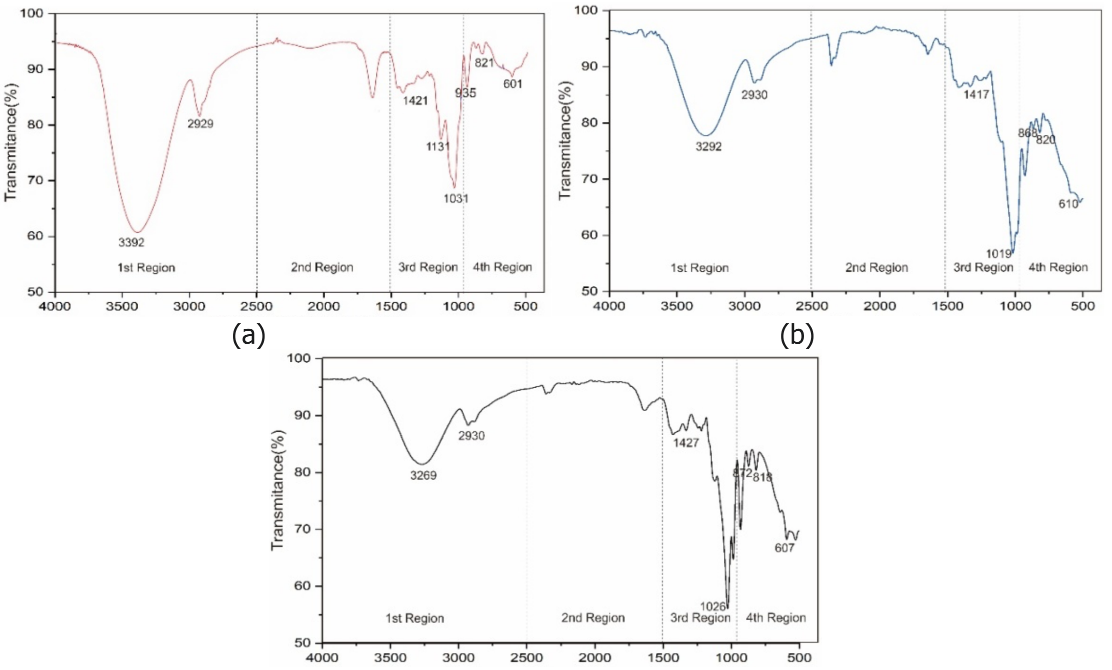

Figure 2. Commercial spectrum (a), chicory root inulin (Akram & Garud, 2020) (b), and dahlia tuber inulin spectrum (c)

The extraction of the main active ingredient from 80 g of DTF yielded 28.6 g of dry inulin extract, representing a high yield of 35.75%. This confirms that the dahlia tubers sourced for this study are a potent raw material for producing inulin. The chemical identity of the extract was confirmed using fourier-transform infrared (FTIR) spectroscopy, and the results are presented in Table 1. The spectrum of the dahlia inulin extract showed strong correlations with both the commercial inulin standard and published data for chicory root inulin. The key characteristic peaks of the dahlia extract included a broad

O-H stretching band at 3269 cm^{-1}, C-H asymmetric stretching at 2930 cm^{-1}, and a strong C-O-C cyclic ether stretching at 1026 cm^{-1}, all of which were mirrored in the commercial standard (3292, 2930, and 1019 cm^{-1}, respectively). Most importantly, the dahlia extract exhibited a peak at 818 cm^{-1}, corresponding to the β-(2-1) glycosidic bonds that form the fructose chain backbone of inulin. This "fingerprint" peak, which appeared at 820 cm^{-1} in the commercial standard, validates that the extracted polysaccharide is indeed inulin, confirming the viability of DTF as a source of prebiotic fibre (Yuliana et al., 2014). This finding is critical for developing the proposed functional food product. The confirmed presence of high-quality inulin ensures that the addition of DTF to ice cream significantly contributes to the soluble dietary fibre content, thereby elevating the product from a standard dessert to a functional food with potential gut health benefits.

Table 1. FTIR Spectrum Interpretation of Inulin Samples

Interpretation	**Absorben Tape cm^{-1}**		
	Inulin Dahlia	**Commercial Inulin**	**Inulin Chicory Root** (Akram & Garud, 2020)
O-H stretching	3269	3292	3392
CH_2asymetric	2930	2930	2929
CH symetric (CH_3)	2885	2889	2880
Deformation CH, OH, CH_2fructose ring	1427; 1331	1417; 1334	1421; 1336
C-O	1243	1266	1220
C-O-C cyclic	1026	1019	1031
Residu α-D-Glucopyranosyl	986	988	935
Ring vibration of 2-ketofuranose	872	868	873
β-(2-1) Glycosidic bonds	818	820	821
Piranosa ring	607	610	601

Organoleptic Analysis of Ice Cream

Sensory analysis is critical for determining the consumer viability of functional products. As shown in Table 2, the F0 (control) formulation, made with full cream milk, was significantly ($p<0.05$) preferred over all functional formulations (F1, F2, and F3) in terms of taste and overall liking. This result was expected because the fat and flavour profiles of dairy cream are highly familiar and preferred by consumers.

Table 2. Hedonic Organoleptic of Ice Cream

Parameters analysis	**Formulation**			
	F0	**F1**	**F2**	**F3**
Color	6.00^{C}	4.48^{b}	3.89^{ab}	3.78^{a}
Aroma	5.70^{b}	4.45^{a}	4.27^{a}	4.02^{a}
Flavor	5.81^{c}	3.54^{b}	2.86^{a}	2.35^{a}
Texture	4.86^{b}	4.08^{a}	4.05^{a}	3.91^{a}
Overall	5.64^{c}	3.91^{b}	3.40^{ab}	2.94^{a}

Note: *Means in the same row with different superscripts (a, b, c) are significantly different ($p<0.05$).*

Among the functional formulations, a clear negative dose-response relationship was observed with increasing DTF concentrations. As the DTF content increased from 5% (F1) to 15% (F2) and 25% (F3), the average taste score significantly decreased from 3.54 (acceptable) to 2.86 (somewhat dislike), and 2.35 (dislike). A similar sharp decline was also observed in overall liking, falling from 3.91 (neutral) for F1 to 2.94 (somewhat dislike) for F3. This significant decrease in acceptance levels was attributed to the characteristic bitterness. This bitter taste is likely caused by the presence of natural compounds in the dahlia tubers, such as flavonoids and saponins (Bresly et al., 2023). These findings identify a critical limiting factor: although higher DTF concentrations (F3) could theoretically provide more fibre, they are not acceptable from a sensory perspective. Therefore, formulation F1 (5% DTF and 25% UCP) was selected as the best formulation because it achieved the most successful balance between functional ingredient addition and sensory acceptance.

Physical Analysis of Ice Cream

The physical properties of ice cream, particularly overrun, viscosity, and melting rate, are interrelated and crucial for product quality. A significant physical trade-off was observed between the overrun and viscosity, which was directly related to the DTF concentration. The increase in volume owing to the addition of air was highest in F1 (85.21%), which significantly exceeded that of F0 (70.66%). This suggests that the combination of 5% DTF and 25% UCP in F1 has optimal viscosity and composition, which aids in the formation and stability of the air bubbles during churning. However, as the DTF concentration increased, the overrun decreased sharply to 61.23% in F2 and 50.42% in F3. This was inversely correlated with viscosity, which increased dramatically from 46.87 cP in F1 to 94.03 cP in F3. At high concentrations (F2 and F3), inulin and starch in the DTF bound large amounts of water, creating a very thick mixture. This excessive viscosity likely inhibited air absorption, preventing the mixture from expanding properly during shaking (Nuryati et al., 2020).

The melting rate analysis showed that the control (F0), with 5.10% milk fat, had the slowest melting time (16.00 min). Milk fat creates a partially coalesced network that stabilises air bubbles and insulates the product. The functional formulations, which replaced the fat network with a carbohydrate-based water-binding matrix (inulin, galactomannan), melted faster. F1 (13.06 min), F2 (12.86 min), and F3 (12.70 min) showed progressively faster melting as the fat-mimicking UCP was reduced and water-binding DTF was increased. Although faster than the control, the melting time of F1 (13.06 min) is still within an acceptable range for a frozen dessert and aligns with the 15-20 minutes standard noted in the BSN.

Objective colour analysis (CIE Lab*) corroborated the observations of the sensory panel. F1 recorded the highest lightness value (L* = 82.75), appearing slightly brighter than the control (F0, L* = 80.68). In contrast, as the DTF concentration increased in F2 and F3, the L* values decreased significantly to 72.05 and 68.42, respectively, resulting in a noticeably darker product. This trend aligns with the hedonic results, confirming the panellists' preference for lighter-coloured ice cream, as reflected in the significantly higher acceptance scores for the brighter formulations (F0 and F1) than for the darker ones.

Chemical Analysis and Soluble Dietary Fiber of Ice Cream

Proximate analysis provided quantitative evidence of the successful modification of the product. Table 3 compares the control formulation (F0) with the best formulation (F1) and the relevant Indonesian National Standards (SNI). The primary objective of reducing milk fat content was achieved. F1 had a fat content of 3.33%, which was significantly lower than the 5.10% in the full cream milk control. This demonstrates the role of UCP and DTF as effective fat substitutes in ice cream (Cleary et al., 2012). However, it is critical to note that the 3.33% fat content is below the SNI 01-3713-1995 minimum of 5% required to be legally labelled as "Ice Cream" in Indonesia. Therefore, the product developed is more accurately classified as a "functional low-fat frozen dessert.

The core functional objective of this study was unequivocally met. Analysis of F1 confirmed a soluble dietary fibre (SDF) content of 3.24%. This fibre is derived from the synergistic combination of inulin from 5% dahlia tuber flour and galactomannan from 25% unripe coconut pulp. A standard 50 g serving of this product provides approximately 1.62 g of prebiotic soluble fibre, validating its classification as a true functional food.

Table 3. Proximate Analysis and Functional Components of Control and Best Formulation

Parameter (%)	F0 (control)	F1 (5% DTF + 25% UCP)	Standar SNI 01-3713-1995
Fat content	5.10	3.33	Min. 5 %
Protein content	6.52	5.46	Min. 2.7 %
Total solids	60.87	43.44	Min. 43 %
Ash content	1.33	1.34	-
Soluble dietary fiber	n/a	3.24	-

Importantly, the other structural components remained within acceptable standards. The protein content of F1 (5.46%) and the total solids (43.44 %) both met or exceeded the SNI minimums (2.7 % and 43 %, respectively). This ensures that the product maintains sufficient body and nutritional value, avoiding the thin, icy texture of many low-fat alternatives.

CONCLUSION

This study successfully developed a new functional frozen dessert by replacing milk fat with a synergistic mixture of dahlia tuber flour (DTF) and young coconut meat (UCP). Dahlia tuber material was verified as a high-potential source of inulin prebiotics, with an extraction yield of 35.75%, and its chemical structure was confirmed through FTIR analysis. Based on a comprehensive organoleptic analysis, the optimal formulation was determined to be F1 (5% dtf and 25% ucp). This formulation achieved the best balance between sensory acceptance (overall liking score of 3.91) and nutritional value. The main limiting factor for higher fibre addition was the bitter taste of dtf at concentrations >5%. Formulation F1 was confirmed to be a low-fat (3.33%) and high-fibre product, containing 3.24% soluble dietary fibre. These functional benefits come from inulin in dahlias and galactomannan in coconuts, which are local foods or agricultural waste (tubers and pulp), thereby reducing dependence on imported food or industrial raw materials.

By incorporating these two components into ice cream products, it is possible to produce value-added foods that not only provide energy but also support digestive health, fibre status, and potential functional effects, such as prebiotics or antioxidants. This product also meets the SNI for protein and total solids, confirming its structural integrity.

Future research should focus on overcoming the sensory limitations of dahlia tuber flour. Exploring pre-processing techniques, such as bitterness removal or flavour masking agents, could allow for higher DTF concentrations to be incorporated, increasing fibre content while maintaining or improving consumer acceptance.The conclusion contains a summary of the results of the discussion and generalization of the results of the research conducted. Based on these conclusions, the author can also provide suggestions for practical action, theory development, and further research.

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