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Development and characterization of lactose-free hibiscus and strawberry coconut milk ice cream as a functional food

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Abstract

Lactose intolerance affects a significant portion of the global population, necessitating the development of dairy-free alternatives with enhanced nutritional and sensory properties. This study focuses on formulating and evaluating a lactose-free ice cream incorporating hibiscus (*Hibiscus rosa-sinensis*) and strawberry (*Fragaria ananassa*) into a coconut milk base. Three formulations with varying hibiscus-strawberry ratios were developed and analyzed for sensory attributes, nutritional composition, and microbiological stability. The sensory evaluation identified Mixture C (25% hibiscus juice) as the most preferred variant, offering an optimal balance of taste, texture, and nutritional benefits. The ice cream exhibited high anthocyanin (29.3 mg/100 g) and vitamin C (7.96 mg/100 g) content, reinforcing its antioxidant potential. Microbiological analysis confirmed its safety, with a shelf life of 30 days under frozen storage. This study highlights the potential of plant-based functional foods in addressing dietary restrictions while promoting health benefits.

Keywords: Lactose-free, functional food, hibiscus, strawberry, coconut milk

1. Introduction

Lactose intolerance is a prevalent gastrointestinal condition caused by insufficient lactase enzyme activity, leading to difficulties in digesting lactose (Vesa, Marteau, & Korpela, 2000)^[1]. This condition affects a significant portion of the global population, particularly individuals of African, Asian, Hispanic, and Native American descent (Ingram, Mulcare, Itan, Thomas, & Swallow, 2009)^[2]. Symptoms such as bloating, abdominal pain, and diarrhoea arise from undigested lactose undergoing fermentation in the colon, impacting both quality of life and nutritional health (Di Rienzo *et al.*, 2013)^[3]. Managing lactose intolerance typically involves dietary modifications, including the use of lactose-free alternatives and enzyme supplements (Gotz, Rasinperä, Torniainen, & Löfgren, 2014)^[4].

In response to this dietary challenge, the development of functional foods presents an innovative approach to addressing nutritional gaps. Hibiscus and strawberries are rich in antioxidants and bioactive compounds, offering potential health benefits when incorporated into food products (Giampieri *et al.*, 2012)^[5]. Hibiscus *rosa-sinensis* has been recognized for its phytochemical properties, including flavonoids and anthocyanins, which contribute to its therapeutic potential (Siddique, Saleem, & Bashir, 2012)^[6]. Additionally, studies have highlighted the cytotoxic and antimicrobial properties of hibiscus extracts, further supporting its use in functional food development (Ali, 2010; Kumar, Kumar, & Singh, 2011)^[7, 9]. Coconut milk serves as an effective dairy substitute, providing a creamy texture while being naturally lactose-free (Suyitno, 2003)^[8].

Combining these ingredients, hibiscus with strawberry coconut milk ice cream emerges as a novel dietary option catering to individuals with lactose intolerance. This study aims to develop and evaluate a lactose-free ice cream formulation that integrates hibiscus and strawberry into a coconut milk base. By optimizing processing and freezing methods, the goal is to maximize the retention of bioactive compounds, ensuring both nutritional benefits and sensory appeal. This research contributes to the growing interest in functional foods, promoting inclusivity in dietary choices while enhancing public health outcomes. This study will offer insights into the potential of this innovative ice cream as a viable alternative for lactose-intolerant individuals, supporting broader efforts to integrate functional foods into everyday nutrition.

This project aims to develop a lactose-free hibiscus and strawberry coconut milk ice cream that combines nutritional benefits with sensory appeal. Additionally, the study seeks to determine the nutritional composition of the developed ice cream, focusing on macro and micronutrients, as well as bioactive compounds that contribute to its functional properties. Furthermore, this research aims to highlight the potential health benefits of regular consumption of the ice cream, reinforcing its role as a functional food. By addressing the gap in lactose-free dessert options, this study contributes to the growing demand for innovative, health-conscious food products and sets the foundation for future research in functional food development.

2. Materials and Methods

This study was conducted in Coimbatore, Tamil Nadu, a city known for its industrial and commercial significance. Samples for product development and sensory evaluation were selected from the local population. Strawberries (*Fragaria ananassa*) were sourced from Pazhamudhir, Coimbatore, washed thoroughly, dried, and selected based on acidity levels. Hibiscus flowers (*Hibiscus rosa-sinensis*) were collected from home-grown plants in Erode, shadow-dried for three days, and boiled in fresh water to obtain the extract. Coconut milk was freshly prepared by grating and pressing coconut meat to extract the thick milk used as the lactose-free base. Honey and maple syrup were used as natural sweeteners, sourced from a local supermarket.

2.1 Development of Hibiscus and Strawberry Ice Cream

Three different mixtures of ice cream were formulated, incorporating hibiscus extract, strawberries, coconut milk, and natural sweeteners. The selected mixture was subjected to nutrient content analysis, ensuring an optimal balance of flavour, texture, and nutritional value. The selected mixture was prepared by blending the ingredients for 15-20 minutes. The mixture was then transferred into glass containers and frozen for 24 hours. Post-freezing, the ice cream was packed and sent for sensory evaluation and laboratory analysis.

2.2 Analysis of Nutritional and Microbiological Parameters

The developed ice cream was analyzed for nutritional and microbiological properties using standardized FSSAI and AOAC methods. The nutritional and microbiological analysis of the developed hibiscus and strawberry ice cream was conducted using standardized methods to ensure

accuracy and reliability. The moisture and ash content were determined using the IS 3077:1992 method, while the fat content was analyzed following the AOAC 950.4 method. Protein levels were assessed using the Kjeldahl method as per IS 7219, and carbohydrate content was determined using the IS 1657 method. The energy content was calculated based on the EFLT/SOP/03/05 method, and dietary fiber was evaluated following the ISO 6541 method. Vitamin C levels were measured using the IS:5838-1970 method, while calcium content was determined through EDTA titration as per IS 5949-1990. Additionally, the anthocyanin content was quantified using the pH differential method. Microbiological analysis was performed to ensure product safety. These analyses provide a comprehensive overview of the nutritional composition and microbiological quality of the lactose-free ice cream, ensuring its suitability for consumption.

2.3 Shelf-Life Assessment

The shelf life of the developed ice cream was evaluated by storing it in airtight containers with ice cubes to prevent texture degradation. Physical and sensory attributes were monitored over time to determine optimal storage duration.

2.4 Sensory Evaluation

Sensory analysis was conducted using a panel of thirty trained judges, evaluating attributes such as appearance, taste, flavour, texture, and consistency. A nine-point hedonic scale was used to assess acceptability, ranging from "dislike extremely" to "like extremely." Sensory data were analyzed to refine the product and ensure consumer acceptance.

3. Results and Discussion

3.1 Product Development of Lactose-Free Hibiscus and Strawberry Ice Cream

Three different formulations (Mixture A, Mixture B, and Mixture C) with varying ratios of strawberry and hibiscus juice were developed and tested. Mixture C, which contained 25% hibiscus juice, was selected as the optimal formulation based on preliminary sensory evaluation and nutritional composition. This formulation provided a distinctive tartness from hibiscus while complementing the natural sweetness of strawberries, resulting in an appealing flavour profile. Additionally, the high anthocyanin content from hibiscus enhanced the functional benefits of the product, contributing to its antioxidant properties.

Table 1: List of four formulated mixtures

S.no	Mixture	Combination	Ingredients
1	A	Strawberry + 15% Hibiscus juice	25% strawberry + 15% Hibiscus juice +5% honey + 5% maple syrup + 50% coconut milk
2	B	Strawberry + 20% Hibiscus juice	20% strawberry + 20% Hibiscus juice + 5% honey +5% maple syrup + 50% coconut milk
3	C	Strawberry + 25% Hibiscus juice	15% strawberry + 25% Hibiscus juice + 5% honey + 5% maple syrup + 50% coconut milk

3.2 Nutritional Analysis of Formulated Mixture

The selected Mixture C underwent a comprehensive nutritional analysis to assess macronutrient and micronutrient content. Compared to USDA (2019) standards, the developed ice cream met the recommended dietary allowance for several essential nutrients, making it a

suitable dietary option for lactose-intolerant individuals. The anthocyanin content (29.3 mg/100 g) was higher than that found in other plant-based sources such as mangosteen (23.4 mg/100 g), highlighting the functional benefits of hibiscus in the formulation.

Table 2: Nutrient content and microbiological analysis of ice cream from selected formulated Mixture C

S.no	Nutrients	Values/100 g
1	Moisture	61.3%
2	Ash	6.96%
3	Fat	6.24%
4	Protein	3.61%
5	Carbohydrate	21.89%
6	Energy	158.16 Kcal
7	Fiber	1.03%
8	Vitamin C	7.96 mg
9	Calcium as Ca	123.0 mg
10	Anthocyanins	29.3 mg
11	Shelf life	3.0 days
12.	TPC	3×10 ⁴ CFU/ml
13	<i>E. coli</i>	Absent

3.3 Sensory Evaluation of Developed Ice Cream

A sensory analysis was conducted using a 9-point hedonic scale to evaluate attributes such as appearance, taste, flavour, texture, consistency, and overall acceptability. The panel consisted of both trained evaluators and potential consumers. The results showed that Mixture C received the highest scores across all sensory parameters.

Table 3: Organoleptic evaluation of the judging panel

Attributes	Control	Variation A	Variation B	Variation C
Appearance	7.6±0.8	7.3±1.2	7.5±1.1	8.2±0.6
Taste	7.5±0.9	6.7±1.3	7.1±0.7	8.2±0.9
Flavour	7.7±0.7	7±1.0	6.9±0.9	8.4±0.8
Texture	7.6±0.8	7.1±1.3	7±0.9	8.1±0.8
consistency	7.7±0.7	7.1±1.2	7.2±1.1	8.1±0.7
Overall acceptability	7.8±0.8	7.2±1	7.3±0.9	8.5±0.8

3.4 Shelf-Life and Microbiological Stability

The ice cream’s shelf life was tested over 30 days under frozen storage conditions (-18°C). The sensory scores remained within an acceptable range, with overall acceptability decreasing only slightly from 8.5 on Day 0 to 7.9 on Day 30. Microbiological analysis showed a total plate count increase from 3 × 10⁴ CFU/ml to 6 × 10⁴ CFU/ml, remaining within safe consumption limits. The absence of *E. coli* and other harmful microbes confirmed the product’s microbiological safety. Statistical analysis was conducted using ANOVA to assess differences among the three formulations based on sensory evaluation. F-ratios were calculated for each attribute, with significance set at p < 0.05 and p < 0.001. This identified the most preferred formulation and validated sensory findings quantitatively. The analysis confirmed that hibiscus and strawberry ice cream provide essential nutrients required for a balanced diet, making it an effective alternative to conventional dairy-based desserts. This research highlights the potential of hibiscus and strawberry as functional ingredients in dairy alternatives. Future studies may focus on optimizing stabilization and emulsification processes to further improve texture and shelf stability, as well as exploring variations in fruit-based formulations to enhance consumer appeal. The developed ice cream presents a novel, nutritious, and consumer-friendly option for individuals seeking lactose-free alternatives with added health benefits.

Table 4: Shelf-life evaluation of Hibiscus and Strawberry Ice cream

Days	Sensory score (Overall Acceptability)	Microbial Count (CFU/ml)
Day 0	8.5	3×10 ⁴ CFU/ml
Day 7	8.3	4×10 ⁴ CFU/ml
Day 15	8.1	5×10 ⁴ CFU/ml
Day 30	7.0	6×10 ⁴ CFU/ml

Table 5: One-way ANOVA for the sensory attributes of the developed ice cream

		Sum of Squares	Df	Mean Square	F	Sig.
Appearance	Between Groups	14.892	3	4.964	5.020	.003*
	Within Groups	114.700	116	.989		
	Total	129.592	119			
Taste	Between Groups	36.425	3	12.142	11.460	<.001**
	Within Groups	122.900	116	1.059		
	Total	159.325	119			
Flavour	Between Groups	40.492	3	13.497	16.069	<.001**
	Within Groups	97.433	116	.840		
	Total	137.925	119			
Texture	Between Groups	22.825	3	7.608	7.537	<.001**
	Within Groups	117.100	116	1.009		
	Total	139.925	119			
Consistency	Between Groups	20.867	3	6.956	6.803	<.001**
	Within Groups	118.600	116	1.022		
	Total	139.467	119			
Overall acceptability	Between Groups	30.733	3	10.244	12.036	<.001**
	Within Groups	98.733	116	.851		
	Total	129.467	119			

*Significant at p<0.05 and **Significant at p<0.001

4. Conclusion

The development of hibiscus with strawberry ice cream represents a significant advancement in the creation of functional foods tailored for individuals with lactose

intolerance. Overall, this study establishes a strong foundation for the commercialization of a functional food product that meets the dietary needs of lactose-intolerant individuals while promoting overall health and wellness.

With further optimization and innovation, hibiscus with strawberry ice cream has the potential to become a widely accepted and beneficial addition to the functional food market, contributing to improved dietary choices and enhanced consumer well-being.

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