JOURNAL OF CURRENT RESEARCH IN FOOD SCIENCE

E-ISSN: 2709-9385
P-ISSN: 2709-9377
Impact Factor (RJIF): 5.71
JCRFS 2025; 6(2): 260-265

www.foodresearchjournal.com
Received: 09-10-2025
Accepted: 12-11-2025

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Development and evaluation of dairy-free ice cream made with almond milk and white dragon fruit

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DOI: https://www.doi.org/10.22271/foodsci.2025.v6.i2d.284

Abstract
The study focuses on development and evaluation of dairy-free ice cream using almond milk and white dragon fruit as a functional ingredients to replace traditional dairy ingredients. Almond milk is a dairy free alternative which is valued for its subtle nutty flavor and improved nutrient content. Incorporating white dragon fruit makes the ice cream rich in antioxidants with mild refreshing taste. Experimental trails were conducted by varying the percentage of white dragon fruit puree as 10%, 15%, 20%, 25%, 30% respectively. Formulated samples were evaluated by semi trained panelists using a 9 point Hedonic scale to determine the sensory characteristics such as color, flavor, taste, texture and overall acceptability. Physicochemical analysis of optimized sample results in low fat and low calories compared to control sample. This study concludes that addition of 30% dragon fruit puree to ice cream formulations improved overall sensory and chemical properties. Microbial analysis confirmed that all microbial counts ranges were within the safe and permissible limits by following FSSAI standards. These findings suggested the successful utilization of plant based ingredients to develop nutritionally enriched and microbiologically safe dairy-free ice cream.

Keywords: Almond milk, White dragon fruit, Dairy-free ice cream, Sensory evaluation

Introduction
Ice cream is a widely consumed frozen dessert globally, valued for its smooth texture, refreshing flavor and sensory appeal. Traditional ice cream is typically prepared using dairy ingredients such as milk, cream, emulsifiers and stabilizers, often enhanced with flavors from fruits and nuts. Sweeteners like sugar or its alternatives are commonly added to improve taste. However, a growing consumer shift towards healthier, sustainable and allergen-free foods has encouraged the development of dairy alternatives. In recent years, plant based and lactose-free ice creams have gained prominence due to increasing awareness of lactose intolerance, vegan dietary practices and demand for low-cholesterol formulations. These trends have accelerated research into plant derived milks and fruit-based ingredients capable of providing desirable structure and nutritional value in frozen desserts.

Almonds are rich in phytochemicals which contribute to their health promoting properties. Their nutrient profile prevents the formation of free radicles, which helps to lower the risk of heart diseases. Almond milk is known for its nutty flavor and creamy texture serving as a low calorie nutritious dairy free alternative to traditional milk, with low levels of saturated fats and cholesterol. It blends easily with different ice cream flavors. Although, it has lower fat & protein content, it offers rich mouthfeel &contributes structural stability to ice cream. Additionally, it enhances emulsion stability, resulting smoother texture. Usage of almond milk aligns with increasing consumer interest in plant derived desserts, making it as a crucial ingredient for functional foods.

Dragon fruit is a tropical and unique fruit that is classified under the family of Cactaceae. Hylocereus undatus commonly known as white dragon fruit or pitaya with white flesh and edible black seeds. It has a potential source of antioxidants and micro nutrients with higher amount of vitamin C, calcium, potassium and dietary fiber, polyphenols and betacyanins. It acts as a natural colorant and flavor enhancer. Its distinctive appearance and subtle sweetness with mild refreshing taste results in improved consumer acceptability. Incorporating, dragon fruit puree into ice cream has slight effects on viscosity, overrun and melting resistance. High fiber content contributes to better texture of ice cream by minimizing the growth of ice crystals during freezing process.

Coconut cream is a vital ingredient in the vegan ice cream formulation, as it is rich in MCT & Lauric acid around 20 to 25% possessing antimicrobial and energy boosting properties. It imparts mild sweet and tropical flavor which enhances palatability of ice cream. High fat content helps to improve overrun and melting resistance. It acts as a natural emulsifier which stabilizes the fat and water interface during freezing. It enables the structural stability to dairy-free ice cream.

Stabilizers and thickeners are essential components in ice cream making, significantly influencing the texture, stability and shelf life. Combined action of these constituents, delay the onset of recrystallization and improve freezing and thawing stability. Commonly used stabilizers include guar gum, carrageenan, carboxy methyl cellulose (CMC) and locust bean gum, contributing to the rheological properties of the mix. They plays a key role in improving aeration ensuring uniformity and preventing wheying off during melting.

Incorporating almond milk and white dragon fruit into dairy-free ice cream enhances the product with appealing color and natural nutrients. However, this formulation presents several challenges in achieving creaminess, ensuring uniform blending of almond milk with fruit puree and attaining desirable melting and textural stability are critical considerations during product development.

The development of almond-milk-based ice cream enriched with white dragon fruit represents an effort to merge nutritional benefits with modern consumer preferences for vegan and health oriented foods. This study aims to formulate and evaluate dairy-free ice cream with varying levels of white dragon fruit puree and to perform physicochemical, sensory and microbial attributes and to identify the most acceptable blend that balances flavor, texture, stability, nutritional and quality parameters.

Materials and Methods

Raw materials

The raw materials required for the dairy free ice cream preparation are procured from Vijetha Super marts, Reliance Fresh & suppliers like Roha Private Limited, Naresh Tag overseas, Danisco and Sri Venkateswara Private Limited. The main ingredients are:

Almond Milk

High quality almonds were choosen for extraction of milk, which imparts slightly sweet taste, nutty flavor and creamy texture to ice cream.

White Dragon Fruit

Fresh and ripen dragon fruits were preferred for making puree. As it contributes refreshing flavor to ice cream.

Coconut Cream

Mature coconuts were used for coconut cream preparation. It acts as a natural emulsifier and high fat content mimics the creaminess of dairy fat producing a rich & smooth texture by improving aeration.

Soy Protein Isolate

Highly refined soy protein isolate was selected, typically containing around 90% protein. Additionally, it aids in water binding capacity and foam stabilization.

Glycerol Monostearate Powder

It is a white, odorless, tasteless powder preferred as a food grade ingredient in ice cream formulation. It helps in regulating ice crystal growth and preventing sandiness during freezing.

Corn Starch

Little amount of corn starch was added into ice cream blend. It acts as a thickening agent by forming a gel like network matrix which helps in maintaining viscosity and structural stability of ice cream.

Sugar

High quality refined sugar was added to improve the sweetness of ice cream. As, it reduces the freezing point by maintaining the size of ice crystals.

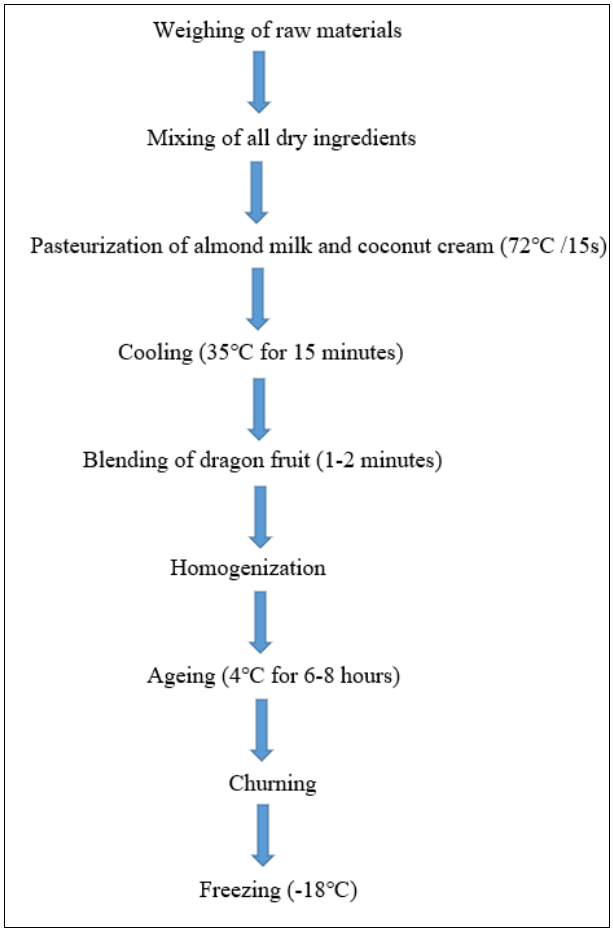
Methods

1. Preparation Of Almond Milk

Initially, the damaged and discolored almonds were removed. Take 1 cup of raw almonds in room temperature water and soak for 8–12 hours or overnight then, it results in softening of almonds and flavor enhancement. Drain the soaked water and rinse thoroughly with cool water (15–20 °C) to remove enzyme inhibitors and residues. Later, soaked almonds were added to a blender with 2 cups of fresh cool water. Allow to blend at high speed for 1 to 2 minutes until the mix becomes creamy and white in a blender. The blended mix was strained through muslin cloth or fine sieve. Squeeze or press to extract all the liquid. Almond milk was taken into a clean and airtight container and placed in a refrigerator at ≤ 4 °C. It should be utilized within 3–5 days.

2. Preparation Of Coconut Cream

Mature coconuts were selected and manually dehusked and deshelled. The kernels were thoroughly washed under potable water to remove dirt and debris. The cleaned endosperm was immediately comminuted into a fine paste to increase the surface area, there by facilitating efficient extraction of intracellular lipids and proteins. The coconut paste was homogenized with hot water at (70–80 °C) and allowed to stand for 5–10 minutes**,** promoting thermal disruption of cell walls and enhanced solubilization of fat globules and coconut proteins**.** The mixture was subsequently filtered using a muslin cloth to separate the liquid phase (coconut milk) from the insoluble fiber fraction. The extracted milk was stored at 4 °C for 6–8 hours without agitation. During this cold resting period, the fat/cream rises to the top layer. The upper cream layer was carefully skimmed, transferred into pre-sterilized containers and stored under refrigeration conditions at (<4°C) for 5–7 days to maintain freshness.



Flow chart on Preparation of Dairy-free ice cream

Preparation Of Dairy- Free Ice Cream

Initially, weight of all dry and wet ingredients were measured using weighing balance. Accurate weights must be taken for the ingredients like (GMS powder, corn starch and soy protein isolate) which were added in small proportions. All the dry ingredients (sugar, GMS powder, soy protein isolate) should be thoroughly mixed to prevent the formation of lumps. The almond milk and coconut cream were gently heated in a sauce pan until the temperature reaches up to 72℃ for 15 seconds. Later, measured proportion of corn starch was added into hot mix along with dry ingredients by continuous stirring. As it allows the starch gelatinization, solubilization & denaturation of soy protein and activation of GMS emulsifier. The hot mix was allowed to cool up to 35℃ for 15 minutes by occasional stirring. Rapid cooling stabilize emulsion in the ice cream mixture. The dragon fruit was blended for 2 minutes until it becomes into smooth and homogeneous paste. Later, required amount of dragon fruit puree was added into the ice cream mix. All wet and dry ingredients were blended along with fruit puree by using high speed blender for 2 -3 minutes. The homogenized base was transferred into food grade container and stored at 4℃ for 6-8 hours, which allows complete hydration of stabilizers, proteins and improved viscosity. Later, the aged mix was churned with hand blender for every 30 minutes in the duration of 2-3 hours. It is a crucial step in ensuring the air incorporation and preventing ice crystal formation in ice cream mix. The churned ice cream was transferred to deep freezer at a temperature of -18℃, which allows the hardening of ice cream.

Formulation

Different trails were conducted by varying the proportions of white dragon fruit puree (0%, 10%, 15%, 20%, 25%,30% and 35% respectively) to attain better texture and flavor in Dairy-free ice cream. Control sample was prepared with dairy ingredients like milk and cream and 6 trail samples were prepared by replacing dairy products with almond milk and white dragon fruit puree.

Table 1: Formulations of the Trail samples

Ingredients	Control	Trail 1	Trail 2	Trail 3	Trail 4	Trail 5	Trail 6
Almond milk (%)	-	51.5	46.5	41.5	36.5	31.5	26.5
Dragon fruit puree (%)	-	10	15	20	25	30	35
Sugar (%)	14	14	14	14	14	14	14
Milk (%)	63.5	-	-	-	-	-	-
Coconut cream (%)	-	20	20	20	20	20	20
Cream (%)	20	-	-	-	-	-	-
Soy protein Isolate (%)	-	2	2	2	2	2	2
Corn starch (%)	2	2	2	2	2	2	2
GMS Powder (%)	0.5	0.5	0.5	0.5	0.5	0.5	s0.5

Evaluation Of Dairy- Free Ice Cream

Sensory Evaluation

The sensory characteristics like color, flavor, taste, texture and overall acceptability of Dairy – free ice cream were evaluated by a semi trained panel members. Samples were presented in coded containers under uniform conditions. Panelists scored each attribute using a structured 9-pointhedonic scale and the mean scores were calculated to assess the organoleptic quality and consumer acceptability of the formulated ice cream.

Physico Chemicalevaluation

Chemical properties like moisture (AOAC 925.45), protein (AOAC & IS SP: 18 Part XI), Ash (AOAC 930.30), fat (AOAC 925.32), fiber (AOAC 962.09), carbohydrate content (AOAC986.25), calories, pH(AOAC 981.12), titrable acidity (AOAC 920.124) and total soluble solids (TSS) (AOAC 932.12) for the control and optimized sample were assessed using established analytical procedures. Proximate analysis and Physical / Functional properties like Overrun, Viscosity and Melting rate of the samples were carried out in accordance with the standard methods prescribed by the Association of Official Analytical Chemists (AOAC). These methods were used to quantitatively determine the major nutritional constituents and to evaluate the influence of almond milk, coconut cream and dragon fruit incorporation on the overall compositional profile of the product.

Determination of viscosity

The Brookfield viscometer was calibrated. And the aged ice cream mix should be free from air bubbles, which was placed in the sample cup. The appropriate spindle was immersed at 20 °C, and measurements were recorded after stabilizing the motor at the selected speed. Torque, viscosity and temperature values were noted. Finally, the spindle was cleaned and dried after analysis.

Determination Of Overrun

It was calculated by comparing the weight of a specific volume of ice cream mix before freezing to the weight of the same volume after freezing. The difference in weight reflects the amount of air incorporated.

Determination of melting resistance

A weighed portion of ice cream was placed on a 3mm fine mesh over a beaker and allowed to melt at 25 °C under undisturbed conditions. The melted fraction was collected and weighed at regular intervals up to 120 minutes. The cumulative weight data were used to calculate the melting rate as a percentage of the initial sample weight**.**

Microbial Analysis

To assess the microbial safety, some of the microbial tests like *E. coli*, Yeast & Molds, Total Viable Count (TVC) and Enterobacteriaceae were conducted for control and optimized ice cream samples by following standard AOAC methods. Samples should be homogenized properly before testing to obtain the accurate microbial colonies.

Determination of *Escherichia Coli* (AOAC 991.14)

Ten grams of ice cream was homogenized in 90 mL of sterile Buffered Peptone Water to obtain a 1:10 dilution. One milliliter of the dilution was mixed with Tryptone Bile X-glucuronide agar and incubated at 45 °C. E. coli colonies were enumerated after 48 hours.

Determination Of Total Viable Count (TVC)(AOAC 966.23)

Ten milliliters of Plate Count Agar (PCA) were poured into petri plates and allowed to solidify for 60 s. The plates were incubated inverted at 30 °C for 72 hours**.** Following incubation, the resulting white colonies were counted to determine the total viable microbial load.

Determination Of Yeast & Molds (AOAC 997.02)

Ice cream samples were serially diluted and plated on Potato Dextrose Agar (PDA)**.** Plates were incubated at 25 °C for 5–7 days to allow yeast and mold growth. Colonies were counted and expressed as CFU per gram of sample**.**

Determination of Enterobactriaceae (AOAC 2003.01)

One milliliter of appropriate sample dilution was inoculated onto petri plates and Violet Red Bile Glucose Agar (VRBGA) was added using the pour plate method. Later, petri plates were incubated in the inverted position at 30 °C for 24 to 48 hours**.** Colonies appearing red to purple which are ≥2 mm in diameter with surrounding bile precipitation were counted to determine microbial load.

Results and Discussions

The primary objective of this study was to create a plant-based ice cream with almond milk and varying proportions of white dragon fruit puree to achieve improved nutritional value, while maintaining desirable sensory attributes, physicochemical and microbial aspects.

Table 1: Sensory Evaluation of Ice Cream Samples:

Samples	Color	Flavor	Taste	Texture	Overall Acceptability
Control	7.60±0.25	7.60±0.25	7.40±0.30	7.30±0.30	7.50±0.20
Trail 1	7.00±0.30	7.00±0.30	6.80±0.40	6.70±0.35	6.90±0.25
Trail 2	7.30±0.28	7.20±0.30	7.10±0.32	7.10±0.32	7.20±0.22
Trail 3	7.10±0.27	7.00±0.33	6.90±0.38	6.80±0.32	7.00±0.26
Trail 4	7.40±0.26	7.30±0.31	7.20±0.29	7.10±0.28	7.30±0.33
Trail 5	8.50±0.15	8.40±0.18	8.30±0.20	8.20±0.22	8.50±0.20
Trail 6	7.20±0.29	7.10±0.32	7.00±0.34	7.10±0.31	7.10±0.27

The above table summarizes the results of a sensory analysis of control sample and 6 trail variations. Each score is presented as a mean ± standard deviation. Nearly, 10 semi trained panel of evaluators assessed the sensory attributes using 9 point hedonic scale as it represents the rating from 1 to 9.

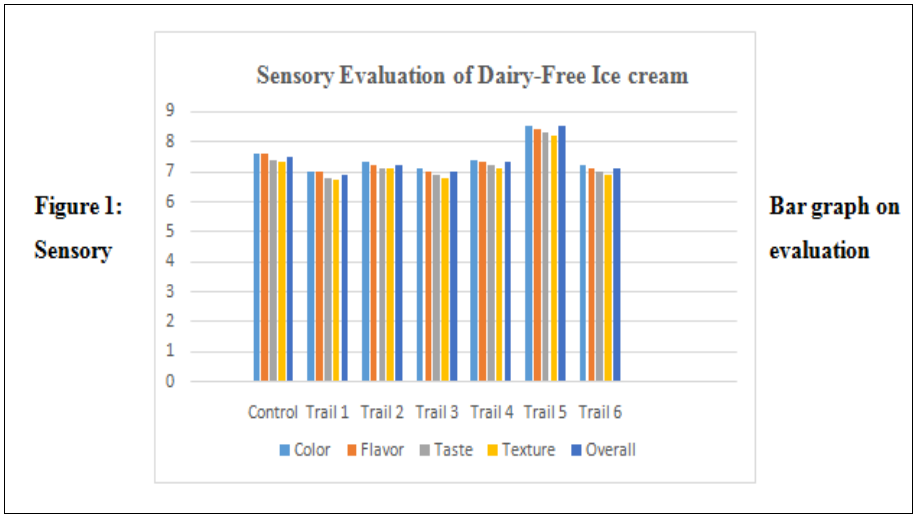


Figure 1: Bar graph on Sensory evaluation

Fig 1: Bar graph on Sensory evaluation

Table 2: Physicochemical Analysis of Control and Trail Samples:

Test parameter	Control sample	Trail - 5
Moisture (%)	60	63
Fat (%)	11.6	8.2
Protein (%)	3.2	3.6
Ash (%)	0.4	0.7
Crude fiber (%)	0.3	0.8
Carbohydrates (%)	24.8	24.5
Calories (Kcal /100 g)	216.4	186.2
TSS (%)	36	33
pH	6.8	6.4
Titratable acidity (%)	0.14	0.17
Viscosity (cP)	2300	2550
Overrun (%)	50	45
Melting rate (%)	30	33

The above table collectively highlights the proximate analysis results, chemical properties and functional modifications of control and optimized ice cream samples. These parameters were analyzed by following standard analytical laboratory techniques.

Table 3: Microbiological Analysis of Developed Ice Cream Samples**:**

S. No	Parameter	Control sample (cfu/g)	Trail sample (cfu/g)	Standard FSSAI limits (CFU/g)
1.	Total Viable Count (TVC)	3657	2489	≤ 1,00,000
2.	Yeast & mold	24	19	≤ 100
3.	E.coli	Absent	Absent	Absent in 25 ml
4.	Enterobacteriaceae	Absent	Absent	Absent in 25 ml

Microbial analysis was conducted for the control and Trail sample on the 30th day to determine the E. coli, Yeast & Molds, Total Viable Count (TVC) and Enterobacteriaceae colonies which was evaluated as (cfu /g).

Conclusion

The present study of Development and Evaluation of Dairy-free Ice cream made with Almond milk and White dragon fruit demonstrated the, conduction of 6 experimental trails by varying the ratios of white dragon fruit puree (Hylocereus undatus) as 5%, 10%, 15%, 20%, 25%, 30% and 35% respectively. The incorporation of white dragon fruit not only improved functional properties it also enhances visual and flavor profile. Sensory analysis revealed that addition of 30% dragon fruit puree exhibited superior acceptability in terms of all attributes by using a 9 point Hedonic scale. Physicochemical analysis confirmed that optimized sample exhibited a balanced nutritional composition with moderate fat (8.2%) and calories (186.2 kcal/100g) and slight improvement in protein (3.6%) and fiber content (0.8%) compared to control sample. It demonstrated enhanced viscosity (2550 cP) and standard overrun (45%) which are crucial components for product stability. Microbial analysis confirmed the quality and safety of the developed ice cream sample in which the Total viable count (TVC), Yeast & Mold levels are within the standard FSSAI limits. Affirming the absence of E. coli and Enterobacteriaceae indicates the microbiological safety of the developed Dairy- free ice cream. Finally, this research study highlights the potential of integrating underutilized tropical fruits and plant based milk alternatives in ice cream formulations which increases the innovation in functional and health oriented food products. And also it offers a nutritious and attractive substitute to conventional dairy based ice cream for lactose intolerant, vegan diets and health conscious consumers.

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