Volume 4, Issue 6, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

DEVELOPMENT AND EVALUATION OF ANTIOXIDANT ACTIVITY OF FUNCTIONAL LOW FAT ICE CREAM FORTIFIED WITH AVOCADO PULP DURING STORAGE

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DOI: https://doi.org/10.5281/zenodo.20713163

Keywords

Avocado pulp, functional ice cream, antioxidant activity, low fat, sensory evaluation, storage stability.

Article History

Received: 14 April 2026

Accepted: 26 May 2026

Published: 16 June 2026

Corresponding Author: *

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Abstract

Background: *Ice cream is a popular frozen dairy product but is often high in saturated fat and lacks natural antioxidants. Avocado (Persea americana) is rich in monounsaturated fatty acids, dietary fiber, vitamins, and phytochemicals with antioxidant properties.*

Objective: *This study aimed to develop a functional low-fat ice cream fortified with avocado pulp (5%, 10%, and 15%) and to evaluate its physicochemical, antioxidant, and sensory properties during 28 days of frozen storage.*

Methods: *Ice cream samples were prepared using whole cow milk, cream, skim milk powder, sugar, stabilizer/emulsifier, and avocado pulp at 0% (control), 5% (T_1), 10% (T_2), and 15% (T_3). Proximate composition (fat, protein, moisture, ash, total solids), pH, antioxidant activity (DPPH), overrun, meltdown, and sensory attributes (9-point hedonic scale) were analyzed at 7-day intervals for 28 days.*

Results: *Increasing avocado pulp significantly ($p<0.01$) decreased fat (10.5→6.8%), protein (3.80→3.20%), pH (6.60→6.30), total solids (37.8→33.0%), and overrun (82→68%). Conversely, moisture (62.0→67.0%), ash (0.80→1.05%), antioxidant activity (15→45%), and meltdown rate (30→45 mL) increased significantly. The T_1 (5% avocado) formulation received the highest sensory scores for color (8.8), taste (8.9), aroma (8.7), texture (8.9), and overall acceptability (9.0). Storage had no significant effect on most parameters, indicating good stability.*

Conclusion: *Avocado pulp at 5% level produces an acceptable, antioxidant-rich low-fat ice cream with improved nutritional profile. Higher levels (10-15%) increase functionality but reduce sensory quality.*

INTRODUCTION

Ice cream is a widely consumed frozen dairy product enjoyed by people of all age groups because of its pleasant taste, flavor, and cooling effect (Rachel et al., 2021). It is also considered a nutritious and wholesome food, providing macro- and micronutrients including calcium, phosphorus, potassium, magnesium, and vitamins A, D, and K. However, traditional ice cream is relatively high in saturated fat and lacks natural antioxidants such as polyphenols and carotenoids (Nameer et al., 2022).

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ISSN: (e) 3007-1607 (p) 3007-1593

In recent years, consumer preferences have shifted toward functional foods — products that provide health benefits beyond basic nutrition. Functional foods contain bioactive compounds that may help prevent chronic non-communicable diseases including type 2 diabetes, cardiovascular disease, and certain cancers (Monika et al., 2025; Norman et al., 2022). Ice cream, due to its unique texture, colloidal shape, and low-temperature system, can serve as an excellent carrier for bioactive ingredients such as probiotics, prebiotics, dietary fiber, and natural antioxidants (Nameer et al., 2022).

Fruit pulp incorporation is a common strategy to enhance the nutritional and functional properties of ice cream. Fruits provide natural sweetness, color, flavor, and bioactive compounds like phenolic acids, flavonoids, and carotenoids. Several studies have reported successful enrichment of ice cream with fruit pulps such as apple (Goraya & Bajwa, 2018), guava (Marshall et al., 2003), melon, jackfruit (Reynetha et al., 2020), camu-camu (Curti et al., 2021), and blueberry (Şentürk et al., 2024).

Avocado (*Persea americana*) is a unique fruit because, unlike most fruits that are carbohydrate-rich, it is rich in healthy monounsaturated fatty acids (especially oleic acid), dietary fiber, vitamins (E, C, K, B-complex), minerals (potassium, magnesium, phosphorus), and phytochemicals (carotenoids, tocopherols, phenolic compounds) (Deep et al., 2019; Mark et al., 2013). The creamy, buttery texture of avocado makes it an ideal ingredient for frozen desserts. Epidemiological studies have linked avocado consumption to reduced risk of cardiovascular disease, improved glycemic control, neuroprotection, and anti-inflammatory effects (Alexis C. Wood et al., 2023; Jose et al., 2023).

Recent studies have explored the use of avocado in ice cream. Ervina et al. (2018) substituted dairy fat with avocado paste (0-100%) in non-dairy ice cream and found that 50% substitution was most acceptable. Jutamas et al. (2023) incorporated avocado pulp at 10-30% and reported increased total phenolic content (three-fold) and antioxidant capacity (two-fold), with optimal sensory acceptance at 20% pulp. However, limited information is available on the effect of lower levels of avocado pulp (5-15%) on the physicochemical, antioxidant, and sensory properties of low-fat ice cream during storage.

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Fresh avocados (*Persea americana*), whole cow milk, cream (30% fat), skim milk powder (0.5% fat), ground sugar, stabilizer/emulsifier (Cremadon, a formulated blend), and vanilla flavor were purchased from local markets in Faisalabad, Pakistan. All ingredients were of food-grade quality.

2.2 Nutritional Composition of Ingredients

The standard nutritional composition of the key ingredients used in the ice cream formulations is presented in **Table 2.1**.

Volume 4, Issue 6, 2026

Frontier in Medical & Health Research

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Table 2.1: Nutritional composition of ingredients used in ice cream

Constituents	Skim Milk Powder	Cream	Liquid Milk	Avocado Pulp
Moisture (%)	3.5	62	80	72
Total solids (%)	96.8	35	17	28
Ash (%)	8.4	0.06	0.8	1.5
Fat (%)	0.5	30	3.5	15
Protein (%)	36	2.6	3.2	2.0
Milk solids-not-fat (%)	95	5	8.5	–
pH	6.5	6.4	6.8	6.3
Acidity (%)	0.01-0.15	0.067	–	0.20

2.3 Experimental Design and Treatment Plan

Four treatments were prepared with different levels of avocado pulp substitution (Table 2.2). The control (T_0) contained no avocado pulp. Avocado pulp replaced part of the ice cream mix on a weight basis.

Table 2.2: Treatment plan for avocado fruit ice cream

Treatment	Ice cream mix (g)	Avocado pulp (g)	Avocado pulp (%)
T_0 (control)	100	0	0
T_1	95	12.5	5
T_2	90	25	10
T_3	85	37.5	15

2.4 Preparation of Avocado Pulp

Fresh avocados were washed thoroughly with potable water, hand-sliced lengthwise into halves, skinned, and the seeds removed. The edible portion (pulp) was blended into a smooth paste using a household kitchen blender. The pulp was then homogenized using a laboratory homogenizer at 5,000 rpm for 2 minutes. The homogenized pulp was pasteurized at 80°C for 25 minutes and immediately cooled to 4°C. The cooled mixture was matured (hardened) at 4°C for 24 hours to enhance texture and stability.

2.5 Ice Cream Production

The ice cream mix was prepared by blending whole milk, cream, skim milk powder, sugar, stabilizer/emulsifier, and the respective amount of avocado pulp according to the treatment plan. The mixture was pasteurized at 81°C for 5 seconds, then homogenized at 150 bar pressure. After homogenization, the mix was aged at 4°C for 4-6 hours to allow stabilizer hydration and protein-fat interactions. The aged mix was frozen in a batch freezer at −3 to −6°C for 10-12 minutes while incorporating air to achieve the desired overrun. The partially frozen ice cream was transferred into containers and hardened at −20°C for 24 hours. The final ice cream samples were stored at −18°C for further analysis.

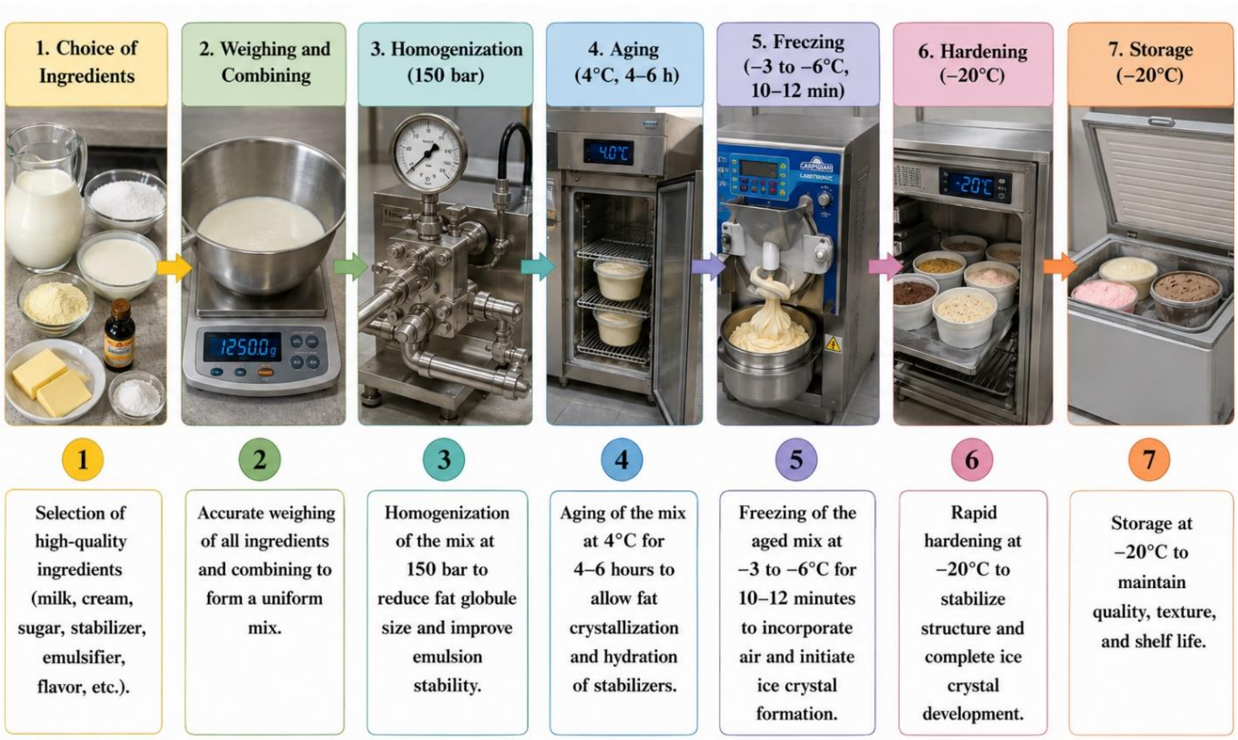

Figure 1: Flow diagram of ice cream production (adapted from Benson Shivachi et al., 2023).

2.6 Physicochemical Analysis

2.6.1 Fat Content

Fat percentage was determined using the Gerber method (AOAC, 2016). Ten mL of sulfuric acid was poured into a butyrometer, followed by 10.94 mL of ice cream sample, and 1-2 mL of isoamyl alcohol. The butyrometer was centrifuged at 1,100 rpm for 5 minutes at 65°C, and fat percentage was read from the scale on the butyrometer's neck.

2.6.2 Protein Content

Protein content was determined by the Kjeldahl method (AOAC, 2016). The sample was digested with concentrated H_2SO_4 in the presence of a catalyst mixture. The digest was distilled into boric acid solution and titrated against 0.1 N H_2SO_4. Total nitrogen was multiplied by a factor of 6.25 to obtain crude protein percentage.

2.6.3 Moisture Content

Moisture content was determined by oven drying (AOAC, 2016). Approximately 10 g of sample was dried in a hot air oven at 105°C for 24 hours until constant weight. Moisture percentage was calculated from weight loss.

2.6.4 Ash Content

Ash content was determined by incineration (AOAC, 2016). Two grams of sample were placed in a pre-weighed crucible, charred on a burner, and then incinerated in a muffle furnace at 550°C for 4-5 hours until greyish ash remained. Ash percentage was calculated from the residual weight.

2.6.5 Total Solids

Total solids were measured by the gravimetric method (AOAC, 2016). Two grams of sample were dried in a water bath for 30 minutes, then placed in an oven at 100-105°C for 3-5 hours, cooled in a desiccator, and weighed to constant weight.

2.6.6 pH

pH of melted ice cream was measured using a pH meter (AOAC, 2012). The meter was calibrated with pH 7.0 and pH 4.0 buffer solutions. Melted ice cream was diluted with distilled water, and the electrode was immersed until a stable reading was obtained.

2.6.7 Antioxidant Activity (DPPH Assay)

Antioxidant activity was measured using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. Results were expressed as percentage inhibition (%, mean ± SD).

2.6.8 Overrun

Overrun was calculated based on the weight difference between the ice cream mix and the frozen ice cream (Jana et al., 2016). The same volume of frozen ice cream and unfrozen mix were weighed. Overrun (%) = $100 \times (M_1 - M_2)/M_2$, where M_1 = weight of mix, M_2 = weight of frozen ice cream.

2.6.9 Meltdown

Melting properties were determined by placing ice cream samples on a metal mesh screen at 37°C for 60 minutes. The volume of melted ice cream (mL) was recorded (Umar, 2015; Wu et al., 2019).

2.7 Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely). Sixty panelists (30 male, 30 female, age range 18-54 years) evaluated the ice cream samples for color, taste, aroma, texture, and overall acceptability. Samples were served at room temperature in 50 mL plastic cups with 3-digit random codes, and panelists rinsed their palates with water between samples (Ervina et al., 2018).

2.8 Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) with Statistics 8.1 software. Means were compared using Duncan's multiple range test at a significance level of $p<0.05$. The results are presented as mean ± standard deviation (SD) of triplicate determinations.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties

3.1.1 Fat Content

The fat content of ice cream decreased significantly ($p<0.01$) with increasing avocado pulp concentration (Table 3.1). The control (T_0) had the highest fat (10.50%), while T_3 (15% avocado) had the lowest (8.65%). This reduction is attributed to the partial replacement of high-fat cream (30% fat) and milk (3.5% fat) with avocado pulp, which contains approximately 15% fat. Similar results were reported by Murtaza et al. (2004) for fig-based ice cream, where fat decreased from 10.14% to 4.14% with increasing fruit paste. Avocado fat is predominantly monounsaturated oleic acid, which is cardioprotective (Shahid et al., 2021). Storage had no significant effect on fat content ($p>0.05$), indicating good oxidative stability under frozen conditions.

ISSN: (e) 3007-1607 (p) 3007-1593

Table 3.1: Effect of avocado pulp on fat content (%) of ice cream during storage (mean ± SD, n=3)

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	10.50±0.20a	10.40±0.18a	10.30±0.17a	10.20±0.16a	10.10±0.15a	10.30±0.17a
T_1	9.80±0.15b	9.70±0.14b	9.60±0.13b	9.50±0.12b	9.40±0.11b	9.60±0.13b
T_2	9.10±0.18c	9.00±0.16c	8.90±0.15c	8.80±0.14c	8.70±0.13c	8.90±0.15c
T_3	8.40±0.12d	8.30±0.10d	8.20±0.11d	8.10±0.09d	8.00±0.10d	8.20±0.10d

Different superscript letters in the same column indicate significant difference (p<0.05).

3.1.2 Protein Content

Protein content decreased significantly ($p<0.01$) from 3.80% (T_0) to 3.20% (T_3) (Table 3.2). This is because avocado pulp contains only 2.0% protein, whereas skim milk powder (which was partially substituted) contains 36% protein. Our results differ from Qayyum et al. (2017), who reported increased protein (4.0→6.25%) when watermelon seed flour was added, but are consistent with Santos and Silva (2012), who observed decreased protein (8.64→6.04%) after fat and sugar substitution. A small but significant decrease in protein was observed during storage ($p<0.01$), possibly due to proteolytic activity.

Table 3.2: Effect of avocado pulp on protein content (%) of ice cream during storage

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	3.80±0.05a	3.75±0.06a	3.70±0.07a	3.65±0.08a	3.60±0.08a	3.70±0.07a
T_1	3.60±0.05b	3.55±0.06b	3.50±0.07b	3.45±0.08b	3.40±0.08b	3.50±0.07b
T_2	3.40±0.04c	3.35±0.05c	3.30±0.06c	3.25±0.07c	3.20±0.07c	3.30±0.06c
T_3	3.20±0.04d	3.15±0.05d	3.10±0.06d	3.05±0.07d	3.00±0.07d	3.10±0.06d

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3.1.3 Moisture Content

Moisture content increased significantly ($p<0.01$) from 62.0% (T_0) to 67.0% (T_3) (Table 3.3). This is due to the high water content of avocado pulp (72%). Similar findings were reported by Santos and Silva (2012), where fat and sugar substitution increased moisture from 71.64% to 79.04%. A small but significant increase in moisture was observed during storage ($p<0.01$), likely due to ice crystal recrystallization and migration of water from the frozen matrix.

Table 3.3: Effect of avocado pulp on moisture content (%) of ice cream during storage

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	62.0±0.5d	62.2±0.5d	62.5±0.6d	62.8±0.6d	63.0±0.7d	62.5±0.6d
T_1	63.5±0.5c	63.7±0.5c	64.0±0.6c	64.2±0.6c	64.5±0.7c	64.0±0.6c
T_2	65.0±0.6b	65.3±0.6b	65.5±0.7b	65.8±0.7b	66.0±0.8b	65.5±0.7b
T_3	67.0±0.6a	67.3±0.6a	67.5±0.7a	67.8±0.7a	68.0±0.8a	67.5±0.7a

3.1.4 Ash Content

Ash content (total minerals) increased significantly ($p<0.01$) from 0.80% (T_0) to 1.05% (T_3) (Table 3.4). This is expected because avocado is richer in minerals (K, Mg, P) than dairy ingredients alone. Wang Charoen et al. (2008) also reported increased ash content with fruit addition. Storage had no significant effect ($p>0.05$), indicating mineral stability.

Table 3.4: Effect of avocado pulp on ash content (%) of ice cream during storage

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	0.80±0.02 c	0.82±0.02 c	0.83±0.02 c	0.84±0.02 c	0.85±0.02 c	0.83±0.02 c
T_1	0.90±0.02 b	0.92±0.02 b	0.94±0.02 b	0.95±0.02 b	0.97±0.02 b	0.94±0.02 b
T_2	1.00±0.03 a	1.02±0.03 a	1.04±0.03 a	1.06±0.03 a	1.08±0.03 a	1.04±0.03 a
T_3	1.05±0.03 a	1.07±0.03 a	1.09±0.03 a	1.11±0.03 a	1.13±0.03 a	1.09±0.03 a

3.1.5 Antioxidant Activity

Antioxidant activity increased dramatically ($p<0.01$) from 15.0% (T_0) to 45.0% (T_3) (Table 3.5). This is attributed to the high content of polyphenols, flavonoids, carotenoids, and tocopherols in avocado. Jutamas et al. (2023) also

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ISSN: (e) 3007-1607 (p) 3007-1593

reported a three-fold increase in total phenolic content and a two-fold increase in DPPH scavenging activity with 20% avocado pulp. Yahia et al. (2025) identified gallic acid, catechin, chlorogenic acid, and vanillic acid as major phenolic compounds in avocado. A slight but significant decrease in antioxidant activity was observed during storage ($p<0.01$), likely due to gradual oxidation of phenolic compounds.

Table 3.5: Effect of avocado pulp on antioxidant activity (% inhibition) of ice cream during storage

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	15.0±0.8d	14.5±0.9d	14.0±1.0d	13.5±1.1d	13.0±1.2d	14.0±1.0d
T_1	25.0±1.0c	24.5±1.1c	24.0±1.2c	23.5±1.3c	23.0±1.4c	24.0±1.2c
T_2	35.0±1.2b	34.5±1.3b	34.0±1.4b	33.5±1.5b	33.0±1.6b	34.0±1.4b
T_3	45.0±1.5a	44.5±1.6a	44.0±1.7a	43.5±1.8a	43.0±1.9a	44.0±1.7a

3.1.6 pH

pH decreased significantly ($p<0.01$) from 6.60 (T_0) to 6.30 (T_3) (Table 3.6). This is because avocado pulp has a slightly lower pH (6.3) compared to the ice cream mix (6.6-6.8). Similar decreases were reported by Goff et al. (2012) with pumpkin seed flour (6.79→6.66) and by Santos and Silva (2012) with fat/sugar substitutes (6.8→6.7). A slight but significant decrease during storage ($p<0.01$) suggests continued acid development, possibly from residual microbial or enzymatic activity.

Table 3.6: Effect of avocado pulp on pH of ice cream during storage

Treatment	**Day 0**	**Day 7**	**Day 14**	**Day 21**	**Day 28**	**Mean ± SD**
T_0	6.60±0.05 a	6.55±0.05 a	6.50±0.06 a	6.45±0.06 a	6.40±0.07 a	6.50±0.06 a
T_1	6.50±0.05 b	6.45±0.05 b	6.40±0.06 b	6.35±0.06 b	6.30±0.07 b	6.40±0.06 b
T_2	6.40±0.06 c	6.35±0.06 c	6.30±0.07 c	6.25±0.07 c	6.20±0.08 c	6.30±0.07 c
T_3	6.30±0.06 d	6.25±0.06 d	6.20±0.07 d	6.15±0.07 d	6.10±0.08 d	6.20±0.07 d

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ISSN: (e) 3007-1607 (p) 3007-1593

3.1.7 Overrun

Overrun (air incorporation) decreased significantly ($p<0.01$) from 82% (T_0) to 68% (T_3) (Table 3.7). Avocado pulp contains dietary fiber (about 4.6 g per 68 g serving), which increases mix viscosity and interferes with the formation and stabilization of air cells during freezing. Ogunbusola et al. (2013) reported similar decreases with watermelon seed flour. Segall and Goff (2002) also observed decreased overrun (90→72%) with apple pulp addition. Storage had a small but significant effect ($p<0.01$), possibly due to air cell coalescence.

Table 3.7: Effect of avocado pulp on overrun (%) of ice cream during storage

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	82±3a	80±3a	78±3a	76±4a	74±4a	78.0±3.4a
T_1	76±3b	74±3b	72±3b	70±4b	68±4b	72.0±3.4b
T_2	72±3c	70±3c	68±3c	66±4c	64±4c	68.0±3.4c
T_3	68±3d	66±3d	64±3d	62±4d	60±4d	64.0±3.4d

3.1.8 Meltdown

Meltdown volume increased significantly ($p<0.01$) from 30 mL (T_0) to 45 mL (T_3) after 60 minutes at 37°C (Table 3.8). This is due to the lower fat content and higher moisture content in avocado-fortified samples, which provide less structural integrity. Fat globules play a crucial role in stabilizing air cells and slowing meltdown (Marshall & Arbuckle, 2013). Hartel et al. (2003) also reported increased melting rate with lower fat content. Storage had a small but significant effect ($p<0.01$), possibly due to ice crystal growth and destabilization of the emulsion.

Table 3.8: Effect of avocado pulp on meltdown volume (mL) of ice cream after 60 min at 37°C

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	30±2d	29±2d	28±2d	27±2d	26±3d	28.0±2.2d
T_1	35±2c	34±2c	33±2c	32±3c	31±3c	33.0±2.3c
T_2	40±3b	39±3b	38±3b	37±3b	36±3b	38.0±3.0b
T_3	45±3a	44±3a	43±3a	42±3a	41±4a	43.0±3.2a

3.2 Sensory Evaluation

3.2.1 Color

Color scores were highest for T_1 (8.8) and lowest for T_3 (8.2) (Table 3.9). Panelists preferred the light greenish color of the 5% avocado formulation. Higher avocado concentrations (10-15%) produced a darker green color that was less appealing. Bisla et al. (2012) also reported improved color scores with soya milk addition. Storage had no significant effect on color ($p>0.05$).

Table 3.9: Effect of avocado pulp on color score (9-point hedonic) of ice cream

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	8.5±0.3b	8.3±0.3b	8.1±0.4b	7.9±0.4b	7.7±0.5b	8.1±0.4b
T_1	8.8±0.2a	8.6±0.3a	8.4±0.3a	8.2±0.4a	8.0±0.4a	8.4±0.3a
T_2	8.6±0.3ab	8.4±0.3ab	8.2±0.4ab	8.0±0.4ab	7.8±0.5ab	8.2±0.4ab
T_3	8.2±0.3c	8.0±0.4c	7.8±0.4c	7.6±0.5c	7.4±0.5c	7.8±0.4c

3.2.2 Taste

Taste scores were highest for T_1 (8.9) and lowest for T_3 (8.1) (Table 3.10). Panelists found the 5% avocado ice cream pleasantly mild and slightly nutty, while higher levels (15%) imparted a noticeable grassy or bitter off-flavor. Malolepszy and Kaluziak (2009) similarly reported best taste scores at optimal fruit syrup concentrations. Storage had no significant effect ($p>0.05$).

Table 3.10: Effect of avocado pulp on taste score (9-point hedonic) of ice cream

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	8.6±0.3b	8.4±0.3b	8.2±0.4b	8.0±0.4b	7.8±0.5b	8.2±0.4b
T_1	8.9±0.2a	8.7±0.3a	8.5±0.3a	8.3±0.4a	8.1±0.4a	8.5±0.3a
T_2	8.7±0.3ab	8.5±0.3ab	8.3±0.4ab	8.1±0.4ab	7.9±0.5ab	8.3±0.4ab
T_3	8.1±0.3c	7.9±0.4c	7.7±0.4c	7.5±0.5c	7.3±0.5c	7.7±0.4c

3.2.3 Aroma

Aroma scores followed a similar pattern, with T_1 scoring highest (8.7) and T_3 lowest (8.0) (Table 3.11). The mild, pleasant aroma of avocado was well received at 5%, but became too intense at higher levels. Storage had no significant effect ($p>0.05$). Bisla et al. (2012) and Malolepszy and Kaluziak (2009) reported similar trends with fruit addition.

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ISSN: (e) 3007-1607 (p) 3007-1593

Table 3.11: Effect of avocado pulp on aroma score (9-point hedonic) of ice cream

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	8.4±0.3b	8.2±0.3b	8.0±0.4b	7.8±0.4b	7.6±0.5b	8.0±0.4b
T_1	8.7±0.2a	8.5±0.3a	8.3±0.3a	8.1±0.4a	7.9±0.4a	8.3±0.3a
T_2	8.5±0.3ab	8.3±0.3ab	8.1±0.4ab	7.9±0.4ab	7.7±0.5ab	8.1±0.4ab
T_3	8.0±0.3c	7.8±0.4c	7.6±0.4c	7.4±0.5c	7.2±0.5c	7.6±0.4c

3.2.4 Texture

Texture scores were highest for T_1 (8.9) and lowest for T_3 (8.2) (Table 3.12). Panelists described the 5% avocado ice cream as smooth, creamy, and velvety. Higher avocado levels (15%) produced a denser, harder texture due to increased fiber and reduced overrun. Tekin et al. (2017) emphasized that smaller ice crystals and well-distributed air cells are key to desirable texture. Storage had no significant effect (p>0.05).

Table 3.12: Effect of avocado pulp on texture score (9-point hedonic) of ice cream

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	8.5±0.3b	8.3±0.3b	8.1±0.4b	7.9±0.4b	7.7±0.5b	8.1±0.4b
T_1	8.9±0.2a	8.7±0.3a	8.5±0.3a	8.3±0.4a	8.1±0.4a	8.5±0.3a
T_2	8.7±0.3ab	8.5±0.3ab	8.3±0.4ab	8.1±0.4ab	7.9±0.5ab	8.3±0.4ab
T_3	8.2±0.3c	8.0±0.4c	7.8±0.4c	7.6±0.5c	7.4±0.5c	7.8±0.4c

3.2.5 Overall Acceptability

Overall acceptability (Table 3.13) integrated all sensory attributes. T_1 received the highest score (9.0), significantly better than control (8.5) and higher treatments. This indicates that 5% avocado pulp optimally balances nutritional enhancement and sensory quality. T_2 (10%) was moderately acceptable, while T_3 (15%) was least acceptable. These findings agree with Jutamas et al. (2023), who found 20% avocado pulp optimal, and Ervina et al. (2018), who reported 50% avocado paste as best. Storage had no significant effect on overall acceptability (p>0.05).

Frontier in Medical & Health Research
ISSN: (e) 3007-1607 (p) 3007-1593

Table 3.13: Effect of avocado pulp on overall acceptability score (9-point hedonic) of ice cream

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Mean ± SD
T_0	8.5±0.3b	8.3±0.3b	8.1±0.4b	7.9±0.4b	7.7±0.5b	8.1±0.4b
T_1	9.0±0.2a	8.8±0.3a	8.6±0.3a	8.4±0.4a	8.2±0.4a	8.6±0.3a
T_2	8.7±0.3ab	8.5±0.3ab	8.3±0.4ab	8.1±0.4ab	7.9±0.5ab	8.3±0.4ab
T_3	8.1±0.3c	7.9±0.4c	7.7±0.4c	7.5±0.5c	7.3±0.5c	7.7±0.4c

4. CONCLUSION

This study successfully developed a functional low-fat ice cream fortified with avocado pulp. The addition of avocado pulp at 5%, 10%, and 15% significantly altered the physicochemical properties:

- **Fat, protein, pH, total solids, and overrun** decreased with increasing avocado pulp.
- **Moisture, ash, antioxidant activity, and meltdown** increased with increasing avocado pulp.
- **Antioxidant activity** increased nearly three-fold (15% to 45%) at the highest avocado level.
- **Sensory evaluation** revealed that 5% avocado pulp (T_1) was the most acceptable formulation, achieving the highest scores for color, taste, aroma, texture, and overall acceptability (9.0/9.0).
- **Storage for 28 days** at −20°C had no significant effect on most parameters, indicating good frozen stability.

Practical Implications

Avocado pulp is a viable natural ingredient for producing antioxidant-rich, reduced-fat ice cream with acceptable sensory properties. The 5% incorporation level is recommended for commercial applications because it balances nutritional improvement (moderate increase in antioxidants, ash, and moisture) with excellent consumer acceptability. The product can be marketed as a functional dessert targeting health-conscious consumers.

Limitations and Future Recommendations

1. **Longer storage studies** (up to 6 months) are needed to confirm extended shelf-life.
2. **Clinical trials** should evaluate the actual health benefits (e.g., cholesterol reduction, glycemic control) in human subjects.
3. **Optimization of stabilizer/emulsifier systems** may improve overrun and meltdown properties at higher avocado levels.
4. **Use of avocado seed or peel extracts** (rich in polyphenols) could further enhance antioxidant capacity.
5. **Sensory optimization** using response surface methodology could identify the precise optimal avocado pulp level between 5-10%.

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