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Development of Functional Ice Cream by Incorporating Bael Fruit (*Aegele Marmelos*) Pulp and Evaluation of Its Quality Parameters

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Abstract- This study focuses on the production of bael fruit-formulated ice cream to utilize the benefits of bael fruit which is rich in medicinal and nutritional properties. Ice cream was developed under four treatments; T1 (control), T2, T3, and T4 with varying percentages of bael fruit pulp 0%, 25%, 50%, and 75%). A comprehensive analysis was conducted which included proximate analysis (protein, fat, ash, and moisture), sensory evaluation, and physicochemical property analysis (pH, hardness, cohesiveness, springiness and melting rate) of ice cream. Physicochemical properties were analyzed over 42 days to detect the storage duration. The results revealed that the T2 had the best sensory appeal which was even higher than the control. Protein, fat, and moisture contents were higher in T1 than the other treatments while ash content increased with the rate of bael fruit incorporation. The protein, fat, ash, and moisture contents (%) of T2 were recorded as 1.99±0.02, 1.69±0.01, 1.19±0.03, and 80.27±0.30 respectively. The pH, hardness, cohesiveness, springiness, and melting rate values of freshly produced ice cream with T2 were 5.53±0.03, 7.86±10.21, 0.25±0.01, 0.63±0.06, and 1.03±0.03 (mL/min) respectively. This study reveals that ice cream products with acceptable sensory and physicochemical attributes can be produced by incorporating the pulp of bael fruit, which is currently underutilized in the Sri Lankan context.

Keywords: Bael fruit, Functional ice cream, physicochemical properties

I. INTRODUCTION

Ice cream is a globally popular sweet frozen dessert food usually made from milk, and cream and comminute with fruits and, other ingredients (López-Martínez *et al.*, 2021). It contains different nutrients such as protein, sugar, fats, air, minerals, etc. There are many different types of ice cream due to differences in ingredients and production methods. When referred to the texture, ice cream is a complex colloidal food system. It is frozen by air cells, ice crystals, and moderately combined fat globules. It is distributed in a continuous freeze-concentrated aqueous phase. Typical ice cream is a high-caloric food with low nutritional density. It has lower contents of natural antioxidants and dietary fiber (López-Martínez *et al.*, 2021; Fungpaiboon & Kijroongrojana, 2017).

Nowadays, consumers are highly concerned about foods rich in dietary fibers, natural antioxidants, minerals, vitamins, natural colorants, low cholesterol, low calories, and free of artificial ingredients, focusing a better health. In recent years, special attention has been paid to the production of functional foods. The importance of "functional food" is to introduce microbes and beneficial compounds into the daily diet which provide therapeutic impacts on the human body (Pon *et al.*, 2015; Di Crisco et al., 2010). Underutilized fruits such as wood apples, bael fruit, and jamun are excellent in treating malnutrition. Popularizing the use of these fruits in the development of functional foods can help reduce some degenerative human diseases, increase the utilization of these fruits, and improve generated revenue for the country (Pon *et al.*, 2015).

Although there is a wide variety of ice cream formulations in the market, ice cream manufacturers focus on creating new formulations that are more appealing to consumers for further expansion of the market. Fruits are considered very important for innovative ice cream formulations due to their natural sweetness, desired flavor, and aroma (Karaman *et al.*, 2014; Nassef *et al.*, 2021). Some fruits are known to be rich in prebiotics, alternative sweeteners, dietary fibers, and natural antioxidants, as well as some favorable sensory properties to be used in producing confectionaries. Several conducted studies have shown that ice creams are a successful matrix for a combination of ingredients like fruit extracts with functional properties (Lima et al., 2016)

Bael fruit (*Aegele marmelos*) is an underutilized fruit in Sri Lanka that is rich in nutritive value. It contains 1.6g of protein, 0.2g of fat, 1.9g of minerals, 2.9g of dietary fiber, 85mg of calcium, 0.5mg of iron, and 1.19mg of riboflavin, per 100g of edible portion (Sharma et al, 2007). No other fruits have such a high content of riboflavin as bael fruits (Viswanath *et al.*, 2018). Also, bael fruit is a good source of vitamin A, C and B group vitamins (Sharma et al, 2007). Bael fruit contains countless amounts of phytochemicals and bioactive compounds like phenolics, alkaloids, carotenoids, flavonoids, coumarins, pectin, phytosterols, tannins, and terpenoids. (Choudhary & Pogonia, 2018; Reddy *et al.*, 2022; Hemakumar, *et al*, 2023). Due to its relatively strong antioxidant activity the fruit attracts a lot of attention (Hemakumar *et al.*, 2023).

Bael fruit is rich in medicinal properties. This fruit is used in Ayurvedic medicine as a remedy for diarrhea, dryness of the eye, and the common cold. It is used to treat constipation, as is considered a laxative, and stops bleeding. When the fruit starts to ripen, its medicinal value increases but both ripen and unripe fruits are used for medicinal purposes. (Ahirwar, 2021). It has also been evaluated for pharmacological activity anti-inflammatory, analgesic, antidiarrheal, antidiabetic, antifungal, entity-hyperlipidemic, antimicrobial, antiparasitic, anticancer, hepatoprotective, anti-colitis, and cardioprotective activities (Lamia, et al, 2018; Rakulini and Sounthararajan, 2019).

The ice cream industry faces challenges in meeting consumer demands for healthier and more functional ice cream products. To address this, research studies

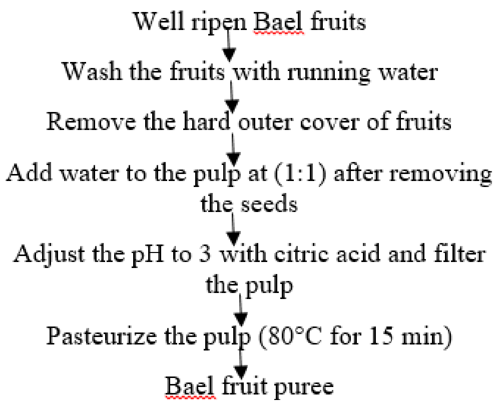

Figure 1: Extraction process of bael fruit puree

Fresh milk (1L) was heated to 50°C and skim milk powder (40g) was added to increase the dry matter (DM) content of the ice cream mix. Whipping cream (90g) and table sugar (190g) were incorporated at 60 and 70°C, respectively. After the addition of the emulsifier and stabilizers (0.5%), the ice cream mix

using natural beneficial active ingredients in ice cream formulations are highly interesting. Various fruits have been studied so far for their potential to be used in ice cream preparation. In Sri Lanka, the bael fruit is considered an underutilized fruit and hence there are not many value-added food products produced using this fruit. During fruiting season, it can be seen that a large number of this nutritious fruit is being wasted. However, Bael fruit which is rich in nutrients and various bioactive compounds has the potential as a functional ingredient in ice cream production. However, there is a lack of research on the quality stability of bael fruit-incorporated ice cream, including its physicochemical and chemical properties, as well as the effect of various processes. Thus, this study was designed to develop a production process and formulation of a functional ice cream incorporating bael fruit pulp and to evaluate its sensory, nutritional, and physicochemical properties.

II. METHODOLOGY

A. Research Location

This research was conducted in the technology faculty laboratory of the South Eastern University of Oluvil Sri Lanka. Raw materials such as cow's milk, skim milk powder, sugar, whipping cream, and cremodan stabilizer were purchased from the local market. Fresh bael fruits were harvested from the home garden. The method for Ice cream preparation was done according to Makwana, *et al.* (2017).

B. Ice cream-making process

Bael puree was prepared according to the method given in Figure 1.

was pasteurized at 85°C for 5 min and then rapidly cooled to 50°C. At this stage, prepared bael fruit puree was added to the ice cream mix at 54ºC in different concentrations: T1:0%, T2:25%, T3:50% and T4:75% (wt/wt). The ice cream mixes enriched with bael puree were aged at 4°C for 24 h. After the aging process, the samples were frozen using an ice cream maker (Simac II Gelataio GC 6000; Simac, Treviso, Italy), rapidly hardened at −18°C, and stored. The proximate analysis was carried out for the ice cream papered. Physicochemical properties, microbial and sensory quality were evaluated during the storage at 14-day intervals.

C. Sensory Evaluation

Color, smell, texture, taste, and overall acceptability of ice cream prepared following four treatments were tested by a panel of 30 semi-trained members with a five-point hedonic scale to identify the treatment with the best sensory appeal. The results were analyzed according to the Friedmann test at a 95% level of significance using MiniTab19 statistical software.

D. Evaluation of physicochemical properties

The acidity of the ice cream samples was measured using the methods of Ranganna (2014). The textural properties of ice cream were analyzed using the AMETEK Brookfield CT3 texture analyzer. The color of the developed ice cream samples were evaluated by using a Chromameter (B2015081, Japan). The melting time of ice cream was estimated by the method described by Rajor and Gupta, (1982). All parametric data were analyzed using SAS statistical software at a 95% level of significance.

III. RESULT AND DISCUSSION

A. Sensory analysis

Table 1 shows the result of the sensory evaluation of different formulations of Bael fruit ice cream just after the production. The results pointed out that there was a significant difference between the ratings given to the four ice cream samples. There was a significant difference ($p<0.05$) related to all tested properties between the treatments. Nevertheless, according to the scores received by panelists, T3 had the most preferred color, followed by T2, T4, and T1. But, in terms of texture, smell, and taste, T2 was the best. Also, the overall acceptability was best in T2. Sensory investigation revealed that various treatments had variable effects on the sensory characteristics and overall the ice cream T2 with 25% Bael fruit pulp had the best sensory acceptability.

Table 1 Friedman test results for sensory parameters of bael fruit incorporated ice cream

Parameters	Overall rank of the sensory evaluation (day 1)			
	T1	T2	T3	T4
Color	2.27^{a}	2.62^{b}	2.72^{b}	2.40^{a}
Texture	2.60^{a}	2.97^{b}	1.95^{c}	2.48^{a}
Smell	2.50^{a}	2.85^{b}	2.25^{a}	2.40^{a}
Taste	2.42^{a}	3.40^{b}	1.78^{c}	2.40^{a}
Overall Acceptability	2.53^{a}	3.28^{b}	1.68^{c}	2.57^{a}

Values denoted with different letters in superscript were significantly different ($p<0.05$) according to the Mann-Whitney test when compared between treatments

B. Physiochemical Analysis

a. pH

Table 2 table explains the result of the pH, changes over the storage period, There were not significant pH differences across the treatments and storage durations, as indicated by the statistical significance of the p-values for all comparisons ($p>0.05$). After analyzing the pH data, it became clear that pH values for all treatments decreased over time, showing a general pattern of rising acidity during storage. Several factors, such as microbial activity, enzymatic activities, and the breakdown of organic molecules in the samples, might be the reasons for this pH drop (Makwana et al., 2017; Trivana et al., 2023).

B. Texture Profile

Table 2 shows the results of textural properties (hardness, springiness, and cohesiveness) of ice cream samples with 0, 14, 28, and 42 days time intervals. "Hardness of ice cream is measured as the resistance of the ice cream to deformation when an external force is applied." (Muse and Hartel, 2004). The hardness of the ice cream samples slightly increased from T2 to T4 as the concentration of bael fruit pulp increased. T1 which did not include bael fruit pulp consistently exhibited the lowest hardness values among every sample. All samples revealed lower hardness on the first day of storage compared to the last day, and hardness increased over storage. Whatever the pulp concentration, the values for hardness continue to fluctuate over time for all samples. Changes in moisture loss, freeze-thaw cycles, overrun, ice crystal size, ice phase volume, and extent of fat destabilization during storage may be responsible for this increase in the hardness of ice cream (Muse and Hartel, 2004; Pon et al., 2015). Usually, when larger ice crystals are grown or the level of destabilized fat increases, the hardness of ice cream increases (Muse and Hartel, 2004). T2 which had the best sensory acceptability had a hardness value ranging from 77.86±10.21 to 122.5±16.847 over the storage life of 42 days.

The cohesiveness values of all treatments decreased with the storage period. Treatments with bael fruit pulp had lower cohesiveness values compared to the control. Also, the cohesiveness of the ice cream samples considerably decreased from T2 to T4 as the concentration of bael fruit pulp increased. T2 which had the best sensory acceptability had a cohesiveness value ranging from 0.25±0.01 to 0.18±0.01 over the storage life of 42 days. Due to the water content of the Bael fruit pulp, these ice creams' cohesiveness may be affected (Muse and Hartel, 2004). Although it depends on other elements like the ice cream base and stabilizers used, the cohesiveness may initially be relatively high (Iqbal et al., 2022). Due to the water concentration in Bael fruit pulp, more ice crystals can develop over time and the texture could change. As a result of that, the ice cream could become harder and its cohesiveness could decrease.

For the springiness of ice creams, there was an obvious effect of the percentage of Bael fruit pulp. From T2 to T4, there was a detectable loss of springiness, revealing that increasing pulp concentrations resulted in less elastic and resistant ice creams. The highest springiness (0.93±0.06) was observed in T1 which was the control. The springiness values of all treatments decreased with the storage period. These variations might be explained by things including the interactions of the ingredients, the development of ice crystals, and temperature changes during storage (Muse and Hartel, 2004). T2 which had the best sensory acceptability had a springiness value ranging from 0.63±0.06 to 0.3±0.09 over the storage life of 42 days. Texture analysis results demonstrate that the texture of the ice cream fluctuates when the Bael fruit pulp is included

Table 2: Physicochemical properties of ice cream with time

Treatment	Physicochemical properties	Time interval			
		0 days	14 days	28 days	42 days
T1	Hardness	57.86±10.21	66.73±13.47	78.33±12.91	96.16±16.84
	Cohesiveness	0.33±0.01	0.28±0.01	0.27±0.03	0.2±0.01
	Springiness	0.93±0.06	0.70±0.05	0.53±0.12	0.53±0.09
	pH*	6.15±0.03^a	5.96±0.01^a	5.87±0.02^a	5.63±0.01^b
T2	Hardness	77.86±10.21	83.66±13.47	90.83±12.91	122.5±16.847
	Cohesiveness	0.25±0.01	0.23±0.01	0.21±0.03	0.18±0.01
	Springiness*	0.63±0.06^a	0.46±0.05^b	0.41±0.12^b	0.39±0.09^b
	pH	5.53±0.03	5.45±0.01	5.23±0.02	4.93±0.01
T3	Hardness	92.50±10.21	100.23±13.47	104.4±12.91	167.5±16.84
	Cohesiveness	0.22±0.01	0.17±0.01	0.16±0.03	0.12±0.01
	Springiness*	0.5±0.06^a	0.3±0.052^b	0.23±0.12^b	0.2±0.09^b
	pH	5.36±0.03	5.31±0.01	5.28±0.02	5.13±0.01
T4	Hardness	300.66±10.21	321.83±13.47	415.66±12.91	450±16.84
	Cohesiveness	0.17±0.01	0.11±0.01	0.9±0.03	0.06±0.01
	Springiness	0.30±0.06	0.26±0.05	0.1±0.12	0.1±0.09
	pH*	5.34±0.03^a	5.23±0.01^a	4.93±0.02^b	4.83±0.01^b

Superscript asterisk (*) denotes that statistically significant differences were recorded relevant to the considered property. Distinct characters following the same rows means±standard deviation indicates statistically significant differences at $p<0.05$ on Tukey's test under Friedman test

C. *Color determination*

Table 3 summarizes the results of colorimetric values obtained for each developed ice cream sample. The concentration of Bael fruit pulp had an apparent effect on the ice cream samples' L-value (lightness). The L-value continues to decrease from T2 to T4, exhibiting that the ice cream gets darker as the Bael fruit pulp content increases. Additionally, lightness tends to change over time while being stored. This might be due to consequences of oxidation, interactions between ingredients, or additional changes to the product's process (Silva et al., 2011). In colorimetry, the a-value shows greenness to redness while the b-value shows blueness to yellowness. The concentration of Bael fruit pulp has an apparent effect on the ice cream samples' a-value and b-value according to the readings.

Table 3: Values of colorimetric parameters L, a^*, and b^* of the samples with time interval

Treatment	Factor	Time interval			
		0	14	28	42
T1	L	89.43±4.73	84.96±5.41	84.76±4.85	86.53±5.96
	a^*	-0.93±0.69	-0.60±0.95	0.00±1.24	-0.03±0.78
	b^*	3.70±2.33	2.36±2.21	3.70±2.66	2.96±3.98
T2	L	69.63±4.73	70.73±5.41	71.83±4.85	70.06±5.96
	a^*	1.93±0.69	1.40±0.95	3.60±1.24	2.23±0.78
	b^*	13.03±2.33	15.06±2.21	16.00±2.66	16.33±3.98
T3	L	75.06±4.73	66.26±5.41	75.76±4.85	68.26±5.96
	a^*	2.02±0.69	1.80±0.95	0.80±1.24	1.06±0.78
	b^*	16.60±2.33	14.10±2.21	28.60±2.66	9.23±3.98
T4	L	66.43±4.73	66.76±5.41	62.06±4.85	65.40±5.96
	a^*	2.30±0.69	3.23±0.95	3.96±1.24	4.76±0.78

*b**	31.23±2.33	30.26±2.21	28.60±2.66	29.90±3.98

Data represent the mean±standard error of L (lightness), *a** (greenness to redness), and *b** (yellowness to blueness) values in colorimetric readings

D. Melting rate

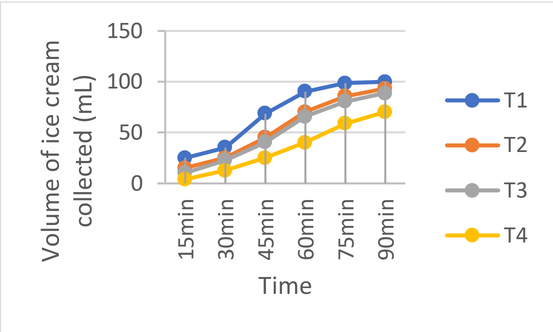

Figure 2 Melting kinetics of ice cream with bael fruit

Figure 2 results indicate that the addition of Bael fruit pulp has a significant impact on the melting rate of ice cream. The average melting rate (mL/min) for T1, T2, T3, and T4 were 1.11±0.02, 1.03±0.03, 0.98 ±0.02, and 0.78±0.03. For all ice creams with bael fruit pulp, the melting rate was lower than that of the control. The control showed a different behavior and moved through the melting process more quickly. This behavior was caused by the high air incorporation and lack of pulp. The natural thickeners and stabilizers found in Bael fruit, which contribute to the fruit's better texture and resistance to melting, are responsible for this (Silva et al., 2011). However, T4 showed the slowest thawing of the ice creams, the lowest melting, and the best melt resistance due to its increased pulp content.

E. Proximate analysis

Table 5 shows the protein, fat, ash, and moisture content in each ice cream sample. It was noted that there was not a significant difference ($p>0.05$) in protein and moisture content between treatments. Nevertheless, the highest protein, fat, and moisture contents were recorded in the control. Fat content was significantly higher ($p<0.05$) in the control compared to the other treatments and the fat content decreased with the increased rates of bael fruit pulp content indicating that the incorporation of bael fruit pulp can significantly lower the fat content in ice cream. The Ash content of ice creams increased with the increased levels of bael fruit incorporated. Also, the ash content was significantly higher ($p<0.05$) in bael fruit-incorporated ice creams than in the control.

Table 6 Nutritional composition of bael fruit ice cream

Treatment		Nutrient content (g/100g)
T1	Protein	2.18±0.02
	Fat	2.34±0.01[a]
	Ash	0.84±0.03[c]
	Moisture	82.53±0.30
T2	Protein	1.99±0.02
	Fat	1.69±0.01[b]
	Ash	1.19±0.03[d]
	Moisture	80.27±0.30
T3	Protein	1.99±0.02
	Fat	1.65±0.01[b]
	Ash	1.26±0.03[d]
	Moisture	79.32±0.30[a]
T4	Protein	1.93±0.02
	Fat	1.61±0.01[b]
	Ash	1.34±0.03[d]
	Moisture	78.23±0.30

Values represent the mean±standard error of the three replicates.

[a,b]Denote significant differences in fat content among ice cream developed with four different treatments according to Tukey's test

[c,d]Denote significant differences in ash content among ice cream developed with four different treatments according to Tukey's test

IV. CONCLUSION

This study concluded that the ice cream produced incorporating 25% bael fruit (T2) was the formulation with the best sensory acceptability, which was more acceptable than the ice cream without bael fruit pulp. According to the colorimetric evaluation, the lightness of the ice cream is decreased while yellowness is increased when the rate of bael fruit pulp incorporated is increased. The pH, hardness, cohesiveness, and springiness values of freshly produced ice cream with T2 were 5.53±0.03, 7.86±10.21, 0.25±0.01, and 0.63±0.06 respectively. The average melting rate (mL/min) for T2 was 1.03±0.03. The protein, fat, ash, and moisture contents (%) of T2 were recorded as 1.99±0.02, 1.69±0.01, 1.19±0.03, and 80.27±0.30 respectively. The incorporation of bael fruit could significantly lower the fat content and increase the ash content in ice creams. Overall, this study reveals the requirement for further research on producing ice cream by incorporating bael fruit pulp which investigates the antioxidant potential and microbial quality.

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