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RESEARCH ARTICLE

Egg-Based Mousse Ice Cream Incorporated with Lavulu [*Pouteria campechiana* (Kunth) Baehni] Flour as a Colorant and an Antioxidant

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ABSTRACT

This study aimed to produce egg-based mousse ice cream and to promote the food value of underutilized Lavulu (Pouteria campechiana (Kunth) Baehni) fruit. Lavulu flour (LF) was prepared by oven drying the ripened Lavulu fruit slices along with the peel at 60°C for 26 h (until moisture content reaches 5%) and grinding to a fine powder. Ice cream mix was prepared with constant levels of egg white foam (45%), whipped dairy cream (33%), sugar (18%) and varying levels of LF (0, 0.2, 0.4 and 0.6% w/w). LF was analyzed for total phenolics content, total flavonoids content, color, carotenoid profile, radical scavenging activity (DPPH assay), pH, water holding capacity, oil holding capacity, emulsifying activity, foaming activity, and proximate composition. The melting ratio, complete melting time, overrun, viscosity, hardness, total flavonoid content, total phenolic content, and sensory properties of ice cream samples were analyzed on day 2 of the frozen storage (-18°C). Radical scavenging activity (RSA), pH, color, and microbial analysis of ice cream samples were determined weekly during 1 month of frozen storage (-18°C). Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach was used to determine optimum LF incorporation level using sensory, RSA, and color data. Proximate analysis was carried out for the selected treatment (0.4% w/w LF). Sixteen carotenoid types were identified quantitatively and qualitatively in LF. Total carotenoid content and RSA of LF was 21.98 mg/g and 82.55±0.78%, respectively. Increasing LF percentage significantly increased ($p<0.05$) the viscosity, L value, and complete melting time of ice cream. Total phenolic content, total flavonoid content, and RSA were significantly ($p<0.05$) higher in LF incorporated samples compared to the control. The present study revealed that LF can be incorporated in ice cream as a rich source of antioxidants, along with color, flavor and texture enhancer.*

***Keywords**: Antioxidant, Carotenoid profile, Colorant, Ice cream, Pouteria campechiana (Kunth) Baehni*

INTRODUCTION

Lavulu (*Pouteria campechiana* (Kunth) Baehni), an underutilized tropical fruit, is recognized for its high nutritional and medicinal potential, yet remains largely unexplored in commercial food applications. The fruit has traditionally been valued by local communities for its therapeutic properties, attributed to its rich profile of bioactive compounds, including carotenoids, polyphenols, and flavonoids, which exhibit potent antioxidant activity (Pushpakumara, 2007; Do

et al., 2023). Lavulu fruit, particularly its pulp and peel, contains notable concentrations of carotenoids, ranging from 1.9 to 23.5 mg/g dry weight (De Lanerolle *et al.*, 2008). Furthermore, phenolic and flavonoid contents in the peel and pulp are substantial, with values reported as high as 2,304.7 mg gallic acid equivalent/100 g and 6,414.03 mg rutin equivalent/100 g, respectively (Kong *et al.*, 2013). These bioactive compounds not only contribute to the fruit's health benefits but also provide a natural source of antioxidants and colorants suitable for food applications.

Despite these promising attributes, Lavulu remains underutilized in the food industry, particularly in the development of functional food products. The application of Lavulu as a natural colorant and antioxidant in frozen desserts, for example, is largely unexplored. Utilizing Lavulu in such products could enhance their nutritional profile while appealing to the growing demand for natural food additives. This study addresses the research gap by evaluating the potential of Lavulu flour (LF) as both a colorant and antioxidant in an egg-based mousse ice cream formulation.

The objectives of this study were to: (i) elucidate the carotenoid profile of LF using different extraction solvents and different wavelength measurements using UV-visible spectrophotometer (ii) analyze the stability and acceptability of Lavulu fruit as a colorant and an antioxidant during frozen condition in an egg-based mousse ice cream.

MATERIALS AND METHODS

Lavulu fruit identification

According to the checklist of the flowering plants of Sri Lanka, which is published by National Science Foundation, there are four *Pouteria* varieties in Sri Lanka. *P. campechiana* (Kunth) Baehni is one of them. *P. campechiana* (Kunth) Baehni is nearly round, oval, ovoid, or spindle-shaped, 7.5-12.5 cm long and 5-7.5 cm wide. When unripe, the skin is green, and upon ripening turns yellow. The pulp is yellow with one to four hard seeds, and the flavor is sweet (Morton, 1987; Ma *et al.*, 2004).

Lavulu flour (LF) preparation

Lavulu fruits in same ripening stage were harvested from Badulla area and kept at room temperature (27ºC) until fully ripened since Lavulu contains sticky latex just after plucking and when they are raw (Ledesma *et al.*, 2015). Fruits were washed well, allowed to air dry and sliced up along with the peel since the peel contain high antioxidant content according to Kong *et al*. (2015). The slices were dried using drying oven (DHG-9146A, ZENITH LAB, China) at 60ºC for 26 h followed by grinding and sieving to obtain a fine powder. Prepared LF was stored in a cleaned dried airtight container at -10ºC.

Analysis of Lavulu flour (LF)

Carotenoid profile analysis

The carotenoid profile of LF was elucidated using different extraction solvents and different wavelength measurements using UV-visible spectrophotometer as described by Wrolstad *et al*. (2003). Carotenoid were extracted from known weight of LF to ethanol and petroleum ether using Soxhlet extraction according to Kodal and Aksu (2017). Then, quantification was done from the properly diluted ethanolic and petroleum ether extracts using UV spectrophotometer (630136 S/N, Thermo Fisher Scientific, Spain) at the maximum wavelengths of different carotenoid types in relevant solvent according to the method described by Wrolstad *et al*. (2003). Neoxanthin and Violaxanthin were measured from ethanolic extract using their maximum wavelength by UV spectrophotometer using Ethanol as the blank. Other carotenoid types were measured using extract in ether by taking petroleum ether as blank. Calculation was carried out using the following formula (Wrolstad *et al*., 2003):

$$\text{Carotenoid content}\left(\frac{\mu g}{g}\right) = \left(\frac{A \times V \times 10^4}{E \times W}\right)$$

A = Absorbance; V = Total extract volume (mL); W = sample weight (g); E is the absorption coefficient of the carotenoid in the solvent used to 1 cm path length.

Extraction of antioxidant

Antioxidants of LF were extracted following the method previously described by Kong *et al*. (2013). A one-gram sample in 20 mL of 70% (v/v) ethanol containing 5% (v/v) 1.2 M HCl was kept in a shaking water bath at 200 rpm and 60°C for 2 h. After extraction, the extract was filtered through Whatman paper No. 4.

Determination of total phenolic content (TPC)

TPC was determined following the method described by Kong *et al*. (2013) using UV spectrophotometer (6235GI403469, Eppendorf, Germany). Firstly, a stock gallic acid solution was made up by dissolving 25 mg of Gallic acid in 100 mL of 70% methanol. Then, to make up the standard working solutions, 0, 1, 2, 3, and 4 mL aliquots of a stock Gallic acid solution (250 mg/L) was separately pipetted into a 10 mL volumetric flask and subsequently diluted to volume with 70% methanol. For the TPC assay, 2 mL from each standard solution was transferred to a 10 mL volumetric flask, followed by the addition of 1 mL of Folin-Ciocalteu reagent. The mixtures were incubated for 5 min, after which 4 mL of saturated sodium carbonate solution (60 g/L) was added. The final volume was adjusted to 10 mL using distilled water. The mixtures were then kept in the dark for 2 h. Absorbance readings were taken at 760 nm using a UV spectrophotometer (Model 6235GI403469, Germany), with distilled water serving as the blank. TPC of the samples was calculated using a standard curve and expressed as gallic acid equivalents (GAE) per 100 g of dry sample weight (Ozkok *et al*. 2010).

Determination of total flavonoid content (TFC)

TFC was determined according to the method described by Kong *et al*. (2013) using UV spectrophotometer (6235GI403469, Eppendorf, Germany). A standard curve of known concentrations of rutin was generated by preparing and testing five concentrations of rutin standard solution, which were 0, 25, 50, 75, and 100 mg/L according to Ozkok *et al*. (2010). An appropriately diluted sample (2 mL) was mixed with 0.2 mL of 5% $NaNO_2$. After 5 min of incubation, 0.2 mL of 10% $AlCl_3$ were added to the mixture and allowed to stand for 6 min. Then, 2 mL of 1 M NaOH were added, and the reaction mixture was made up to a total volume of 5 mL using distilled water. Absorbance was measured at 510 nm against distilled water as blank. TFC of the samples were calculated using standard curve of rutin and expressed as rutin equivalent (RE) per 100 g sample in dry weight.

Determination of DPPH radical scavenging activity

DPPH radical scavenging activity was measured following the method in Kong *et al*. (2013) using UV spectrophotometer (6235GI403469, Eppendorf, Germany). Sample extract (0.1 mL) was added with 3.9 mL of 100 μM 2,2-diphynyl-1-picrylhydrazyl (DPPH) solution in ethanol. After 30 min of incubation, absorbance of the reaction mixture was read at 515 nm against ethanol as blank. The results were expressed as percentage (%) of DPPH radical scavenging activity.

Total sugar content determination

Total sugars content was determined by the phenol-sulphuric acid method according to Agrawal *et al*. (2015). LF (100 mg) was weighed and added with HCl (15 mL) and kept in water bath for 3 h. After cooling it was neutralized by adding solid sodium carbonate until effervescence ceases. Then final volume was made to 100 mL by adding distill water and centrifuged (4,500 rpm, 15°C, 15 min). Supernatant was used as sample extract in further process. Then, 0.2, 0.4, 0.6, 0.8 and 1 mL of working standard (0.1 mg/mL) of glucose were taken in boiling tubes and the final volumes of each tube was made to 1 mL by adding distilled water. After that, 1 mL of 5% phenol and 5 mL of 96% H_2SO_4 were added one by one in each tube and shaken well so that the phenol and H_2SO_4 get mixed thoroughly with working standard. After 10 min, all the tubes were placed in water bath at 25-30°C for 15 min. Absorbance was then taken at 490 nm using UV spectrophotometer (630136 S/N, Thermo Fisher Scientific, Spain) against distilled water as blank.

Water holding capacity

Water holding capacity (WHC) was measured by the method of Ghribi *et al*. (2015). Briefly, LF sample (3.0 g) was dispersed in 25 mL of distilled water and placed in centrifuge tubes. The dispersions were stirred after the interval of 5 min, held for 30 min, followed by centrifugation for 25 min at 3,000 *g*. The supernatant was eliminated, and excess of water was removed by draining for 25 min at 50°C and the sample was reweighed.

Oil holding capacity

To determinate oil holding capacity (OHC), the method of Ghribi *et al*. (2015) was followed. Briefly, the LF samples (0.5 g) were mixed with 6 mL of oil. The contents were stirred for 1 min to disperse the sample in the oil. After a holding period of 30 min, the tubes were centrifuged for 25 min at 3,000 *g*. The separated oil was then removed with a pipette and the tubes were inverted for 25 min to drain the oil prior to reweighing. The water and oil holding capacities were expressed as grams of water or oil bound per 100 g of the sample on a dry basis.

Foaming capacity

Foaming capacity was determined according to the method of Ghribi *et al*. (2015). Briefly, 50 mL of 3% (w/v) dispersions of LF sample in distilled water were homogenized at rapid speed for 3 min in a graduated cylinder. The volume was recorded before and after whipping. Foaming capacity was expressed as the volume (%) increase due to whipping and was calculated using the following equation:

$$\text{Volume increase}(\%) = \left(\frac{V_2 - V_1}{V_1}\right) \times 100$$

Where, V1= initial volume of solution (mL); V2= volume of solution after homogenizing (mL)

Emulsifying activity determination

Emulsifying activity (EA) was determined according to the methods of Neto *et al*. (2001). Briefly, 5 mL of LF was dispersed in distilled water (10 mg/mL) and was homogenized (1 min) with 5 mL of oil. The emulsions were centrifuged (1,100 *g*, 5 min) and the height of the emulsified layer and the total contents in the tube was determined. The emulsifying activity was calculated using the following formula:

$$\text{Emulsifying activity}\ (\%) = \left(\frac{\text{Height of the emulsified layer}}{\text{Height of the total content}}\right) \times 100$$

Determination of moisture content

Moisture content was analyzed using a moisture analyzer (AGS120/T250N, AXIS, Poland).

Color analysis

L*, a*, and b* values were analyzed using a colorimeter (B 8408579, Konica Minolta, Japan).

Determination of pH

The pH value was measured from an aliquot of 10 g of flour blended with 100 mL distilled water (AOAC, 2016) using a pH meter (ELE 511, Lab Kits, China).

Proximate analysis

Crude fat content was analyzed using the Soxhlet method as described in AOAC (2016). Total ash content was analyzed as described in AOAC (2016). The crude fiber was analyzed according to the method in AOAC (2005) using a fiber analyzer (400623, Selecta, Spain).

Development of egg-based mousse ice cream

Egg-based mousse ice cream was prepared according to the process flow chart as given in Figure 1. Electric beater was used for the beating process.

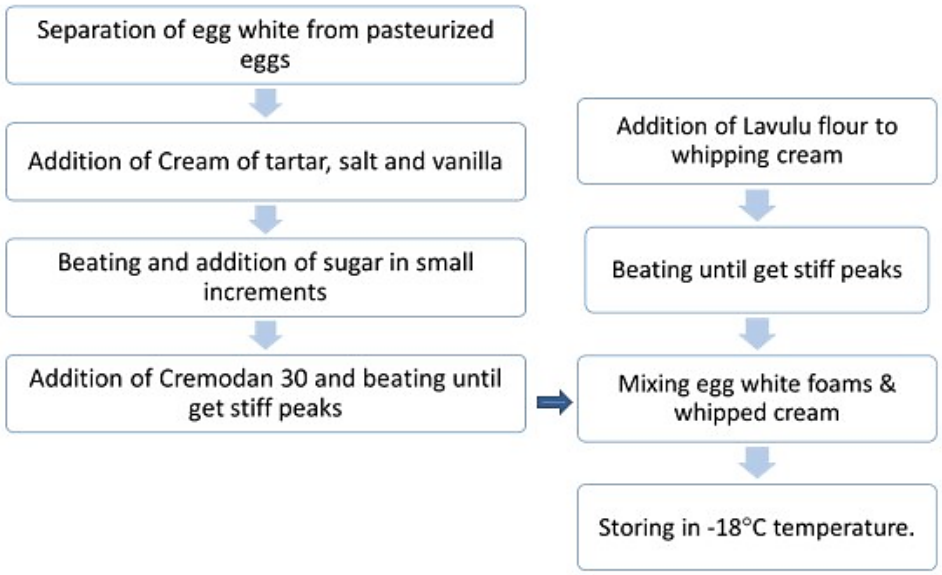

Figure 1: Procedure of egg-based mousse ice cream production

Four treatments of mousse ice creams were prepared using different level of LF keeping all other ingredients at constant levels according to Table 1.

Determination of overrun

Overrun was measured in four treatments using the method in Banupriya *et al.* (2016). The weight of 20 mL mix before beating was taken (W1). Then, the weight of same volume after beating was measured (W2). Following formula was used to measure the overrun:

$$\text{Overrun}\% = \left(\frac{\text{W1} - \text{W2}}{\text{W2}}\right) \times 100\%$$

Table 1: Compositions of developed mousse ice cream treatments (w/w%)

Ingredient	Treatments with different LF %			
	T 1 (0)	**T 2 (0.2)**	**T 3 (0.4)**	**T 4 (0.6)**
Egg white	45	45	45	45
Whipping cream	33	33	33	33
Sugar	18	18	18	18
Vanilla	3	3	3	3
Salt	0.2	0.2	0.2	0.2
Cream of tartar	0.3	0.3	0.3	0.3
Cremodan®	0.5	0.5	0.5	0.5
Lavulu flour	0	0.2	0.4	0.6

Sensory evaluation

Untrained panelists (30) were participated for the sensory evaluation. Mousse ice cream samples were evaluated using a nine-point hedonic scale for color, odor, flavor, texture/mouthfeel, resistance to melting and overall acceptability.

Analysis of egg-based mousse ice cream

Total phenolic content, total flavonoid content and radical scavenging activity analysis of ice cream

TPC, TFC, and radical scavenging activity were determined according to the method described by Kong *et al*. (2013).

Viscosity analysis

Viscosity was measured using viscometer (RP-2-L, Raypa, Spain) equipped with L model 4 probe at 20°C temperature.

Determination of melting ratio and complete melting time

The melting ratio and complete melting time were determined according to the procedure described by Guven and Karaca (2002). A 25 g sample was subjected to melting, keeping on a stainless-steel wire mesh at a constant temperature (25°C). The melting ratio after 30 min was recorded, and the complete melting time (S) was determined.

Hardness analysis

Hardness of all four treatments were analyzed using a texture analyzer (M08-372-E0315, Brookfield, USA) equipped with TA4/1000 probe.

Color analysis

Color (L*, a* and b* value) was measured using colorimeter (B 8408579, Konica Minolta, Japan) weekly in all four treatments.

pH analysis

The pH value was measured weekly from an aliquot of 10 g of ice cream blended with 100 mL distilled water (AOAC, 2016) using pH meter (ELE 511, Lab Kits, China).

Microbiological analysis

Total plate count, yeast and mold count, coliform and salmonella were enumerated weekly for all four treatments according to the method in FDA (2001), using spread plate method utilizing selective agar plates of total plate count agar, potato dextrose agar, MacConkey agar and XLD agar, respectively.

Technique for order preference by similarity to ideal solution (TOPSIS) approach

TOPSIS approach was carried out to select the best treatment according to the sensory data and instrumental data (Karaman *et al*., 2013). First, all the data were normalized, and weights were given to each criterion as shown in Table 2. Then, the ranking of treatments was obtained using TOPSIS approach.

Total sugar content analysis

Total sugar content was analyzed in selected treatment (0.4%) using phenol sulfuric method according to Agrawal *et al*. (2015).

Table 2: List of parameters and the weights given under TOPSIS approach.

Criteria	Weights
Radical scavenging activity (%)	0.2
Colorimeter values (b* value)	0.2
Color	0.2
Odor	0.1
Flavour	0.1
Mouthfeel	0.1
Resistance to melting	0.1

Protein content determination

Protein content was determined using Kjeldhal method (AOAC, 2016) and Biuret method (Layne, 1957).

Fat content determination

Fat content was determined using Soxhlet method (AOAC, 2016), Gerber method (Moore and Morse, 1926), and Rose Gottlieb method (Pearson, 1976).

Moisture content determination

Moisture content of selected ice cream sample (0.4%) was determined according to the method in Pearson (1976) using drying oven at 100°C for 2-3 h. Total solid content was calculated by reducing the moisture content.

Total ash content determination

Total ash content was determined using the method in AOAC (2016) for the selected treatment (0.4%).

Statistical analysis

All measurements were carried out in triplicate (n=3). Data was analyzed using one-way ANOVA (p=0.05) and means were compared using Tukey's test (p=0.05). Sensory data was analyzed using Friedman test. Minitab version 17 was used for the data analysis.

RESULTS AND DISCUSSION

Chemical composition of Lavulu flour

The chemical composition of LF is given in Table 3. TPC and TFC values of LF were comparable with the values in Kong *et al*. (2013). But there was a slight increment of TPC and TFC values. Processing the flour without peeling could be the reason since the peel also has high TPC and TFC values. Crude fat, crude fiber, ash, and total sugar contents were comparable with the values reported by Pushpakumara (2007).

Table 3: Chemical composition of Lavulu flour

Parameter	Value
Moisture (%) (w/w)	6.22±0.20
Crude fat (%) (w/w)	2.97±0.29
Crude fiber (%) (w/w)	0.15±0.03
Ash (%) (w/w)	1.95±0.00
Total flavonoid content (mg RE/100g dw)	10,358±266
Total phenolic content (mg GAE/100g dw)	2164±72
Total sugar content % (w/w)	45.27±0.01
Radical scavenging activity (%)	82.55±0.78

Physicochemical properties of Lavulu flour

Physicochemical properties of LF are shown in Table 4. The positive a* and b* value showed that the flour has the color towards yellow. The flour did not show foaming activity. However, LF had slight emulsifying activity.

Table 4: Physicochemical properties of Lavulu flour

Parameter		Value
Color	L* value	75.05±0.39
	a* value	15.70±0.18
	b* value	69.93±0.46
pH		6.52±0.00
Water holding capacity (%)		37.23±1.75
Oil holding capacity (%)		91.39±1.13
Emulsifying activity (%)		11.11±0.64
Foaming activity		0

Carotenoid profile of Lavulu flour

Carotenoid types which were measured using maximum wavelengths in the relevant solvent extract are shown in Table 5.

Table 5: Carotenoid profile of Lavulu flour

Carotenoid type	Content (µg/g)
Bixin	979.10±0.21
Canthaxanthin	2,603.81±0.62
α-Carotene	1,943.24±0.55
β-Carotene	1,725.06±0.71
δ-Carotene	1,203.52±0.32
γ-Carotene	1,569.82±0.68
Crocetin	972.68±0.46
β-Cryptoxanthin	1,968.08±0.57
Echinenone	1,988.78±0.95
Neoxanthin	564.13±0.33
Phytoene	0
Phytofluene	272.69±0.73
Rubixanthin	1,714.11±0.41
Violaxanthin	519.27±0.88
Zeaxanthin	2,164.36±0.86
α-Zeacarotene	1,803.06

According to the results, LF contained high Canthaxanthin content measured at 456 nm wavelength using extract in ether by taking petroleum ether as blank. The summation of all the carotenoid types was 21.98 mg/g. Total carotenoid content was comparable with that in Lavulu (23.5 mg/g) reported by De lanerolle *et al*. (2008).

Total flavonoid content of ice cream

Since the mean values were significantly different at $p<0.05$ in four treatments (Figure 2), it revealed that there is an effect of adding LF on total flavonoid content of ice cream. The TFCs of ice creams incorporated with 0, 0.2, 0.4, and 0.6% of LF were 28,101±289, 29,418±381, 31,409±419, and 32,705±421 mg RE/100 g dw, respectively. Accordingly, LF incorporation had increased the TFC of ice cream.

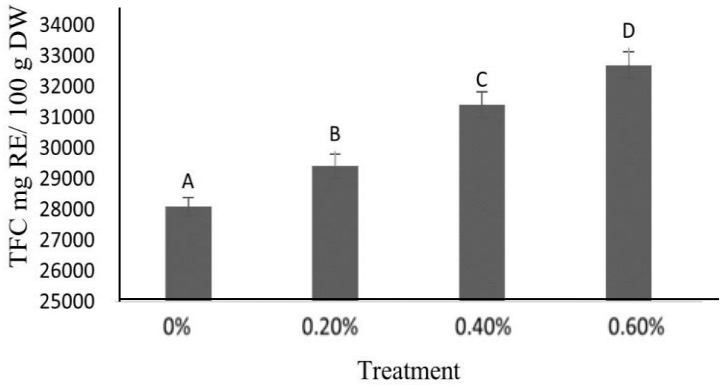

Figure 2: Total flavonoid content of ice cream incorporated with different levels of Lavulu flour (LF). Means with different uppercase letters are significantly different at $p<0.05$

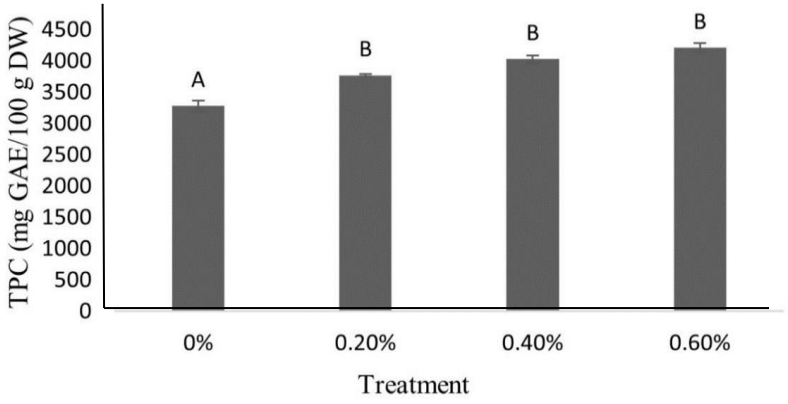

Figure 3: Total phenolic content of ice cream incorporated with different levels of Lavulu flour (LF). Means with different uppercase letters are significantly different at $p<0.05$

Total phenolic content of ice cream

Same as in the TFC content, the TPCs were significantly different at $p<0.05$ among the four treatments (Figure 3). It showed that there was an effect of adding LF on TPC of ice cream. The TPCs of ice creams incorporated with 0, 0.2, 0.4, and 0.6% were 3,284±83.9, 3,773±16.3, 4,032±57.7, and 4,212±71.2 mg GAE/100 g DW, respectively. Accordingly, TPC of ice cream had increased with the LF incorporation.

Radical scavenging activity

The RSA of different treatments were significantly different at $p<0.05$ as presented in Table 6. It showed that there was a positive impact of LF incorporation on the RSA of ice cream.

Table 6: Radical scavenging activity of ice cream incorporated with different levels of Lavulu flour (LF) during storage

Week	LF (%)			
	0	**0.2**	**0.4**	**0.6**
1	13.27 ± 0.23^{Ap}	20.89 ± 0.10^{Apq}	22.33 ± 0.63^{Aq}	24.04 ± 0.41^{Ar}
2	9.24 ± 0.16^{Bp}	10.29 ± 0.23^{Bpq}	11.07 ± 0.04^{Bq}	15.51 ± 0.42^{Br}
3	7.29 ± 0.10^{Cp}	7.94 ± 0.04^{Cq}	8.75 ± 0.23^{Cqr}	10.07 ± 0.08^{Cr}
4	6.38 ± 0.02^{Dp}	6.98 ± 0.22^{Dq}	8.58 ± 0.05^{Cr}	8.63 ± 0.19^{Ds}

Data represented as the mean± standard error of mean (n=3). Mean values with different uppercase letters within the same column are significantly different at $p<0.05$. Mean values with different lowercase letters within the same row are significantly different at $p<0.05$.

When comparing the weekly results, RSA had decreased with the storage period in all four treatments due to the deterioration of RSA of LF with the storage time and conditions. Though several authors reported the antioxidant activity of Lavulu fruit (Kong *et al*., 2013), (Ma *et al.*, 2004), there is no report on the RSA variation of Lavulu fruit with the storage time and conditions.

Colorimeter values of ice cream

L* value (lightness) ice cream samples had reduced with the LF incorporation, while increasing a* (+ value indicates redness) and b* (yellowness) values. In the carotenoid profile (Table 7), LF contained high canthaxanthin and zeaxanthin contents. Canthaxanthin is a reddish orange color carotenoid type and zeaxanthin is a yellow color carotenoid type. This revealed that the canthaxanthin and zeaxanthin content of LF was the reason for the increment of red and yellow color of ice cream samples.

According to the results, the color of ice cream samples was significantly affected by the storage time. According to Metzger *et al.* (2000), color is influenced by

several factors that include light scattering by fat and protein particles, when the protein and fat denature the color also can be changed with storage time.

Hardness, viscosity, melting ratio and complete melting time of ice cream

According to Table 8, hardness, viscosity, and complete melting time increased with the LF incorporation. Melting ratio decreased with the increment of level of LF. According to Syed *et al*. (2018), fibre and emulsifying properties can increase the hardness of the ice cream and decrease the flow rate. Similarly, fibre and emulsifying property of LF reduced the flow rate of ice cream and that cause for the high viscosity and hardness in this study. Due to the hardness and high viscosity, melting ratio reduced and complete melting time increased.

Table 7: Weekly measured colorimeter values of ice creams incorporated with different levels of Lavulu flour (LF)

LF (%)		Week 1	Week 2	Week 3	Week 4
0	L*	97.09 ± 0.12^{Ap}	95.67 ± 0.28^{Ap}	93.76 ± 0.14^{Bq}	95.76 ± 0.96^{ABp}
	a*	-0.43 ± 0.01^{Ap}	-0.52 ± 0.02^{Br}	-0.52 ± 0.01^{Br}	-0.64 ± 0.00^{Cr}
	b*	6.55 ± 0.00^{Bs}	6.53 ± 0.03^{Bs}	7.43 ± 0.06^{As}	7.51 ± 0.10^{As}
0.2	L*	96.93 ± 0.15^{Ap}	94.78 ± 0.24^{Bp}	94.23 ± 0.68^{Bpq}	94.33 ± 0.51^{Bpq}
	a*	-0.75 ± 0.02^{Cs}	-0.39 ± 0.00^{Bq}	-0.33 ± 0.01^{ABq}	-0.25 ± 0.03^{Aq}
	b*	11.51 ± 0.06^{Cr}	13.48 ± 0.06^{Bq}	13.50 ± 0.08^{Br}	11.99 ± 0.06^{Ar}
0.4	L*	97.85 ± 0.62^{Ap}	93.97 ± 0.08^{BCp}	94.5 ± 0.28^{ABp}	92.42 ± 0.52^{Cq}
	a*	-0.58 ± 0.01^{Cr}	-0.53 ± 0.02^{Cr}	-0.36 ± 0.03^{Bq}	-0.11 ± 0.05^{Aq}
	b*	14.54 ± 0.07^{Bq}	14.06 ± 0.04^{Cr}	15.65 ± 0.16^{Aq}	15.79 ± 0.40^{Aq}
0.6	L*	95.12 ± 0.30^{Ap}	94.99 ± 0.13^{Ap}	93.38 ± 0.29^{Apq}	93.6 ± 0.39^{Apq}
	a*	-0.51 ± 0.00^{Dq}	-0.11 ± 0.00^{Cp}	0.15 ± 0.05^{Bp}	0.2867 ± 0.02^{Ap}
	b*	17.53 ± 0.26^{Bp}	16.62 ± 0.13^{Cp}	18.62 ± 0.13^{Ap}	18.09 ± 0.05^{ABp}

Data represented as the mean± standard error of mean (n=3). Mean values with different uppercase letters within the same column for same color are significantly different at $p<0.05$. Mean values with different lowercase letters within the same row for the same color are significantly different at $p<0.05$

Table 8: Hardness, viscosity, melting ratio and complete melting time of ice creams incorporated with different levels of Lavulu flour (LF)

LF (%)	Hardness (g)	Viscosity (mPas)	Melting ratio	Complete melting time (min)
0	22.33 ± 3.38^{D}	2485 ± 63.0^{D}	0.40 ± 0.003^{A}	15.00 ± 1.73^{B}
0.2	380.70 ± 19.70^{C}	3420 ± 69.8^{C}	0.36 ± 0.008^{A}	27.33 ± 0.33^{A}
0.4	651 ± 74.70^{B}	4155 ± 17.1^{B}	0.32 ± 0.008^{B}	29.00 ± 0.58^{A}
0.6	1299.3 ± 76.3^{A}	6470 ± 148.0^{A}	0.18 ± 0.010^{C}	32.33 ± 1.45^{A}

Data represented as the mean± standard error of mean. Mean values with different uppercase letters within the same column are significantly different at $p<0.05$.

pH value of ice cream

The pH value of ice creams added with different levels of LF reduced with the storage time and control sample had a higher reduction of pH according to the results in Table 9.

Table 9: pH variation of ice creams incorporated with different levels of Lavulu flour (LF) during storage

Week	0%	0.2%	0.4%	0.6%
1	7.72 ± 0.29^{Dp}	7.75 ± 0.08^{Bp}	7.61 ± 0.01^{Cp}	7.63 ± 0.07^{Cp}
2	7.58 ± 0.04^{Cq}	7.69 ± 0.09^{Aqr}	7.58 ± 0.02^{Ap}	7.61 ± 0.07^{Br}
3	7.35 ± 0.07^{Ap}	7.53 ± 0.02^{Aq}	7.52 ± 0.02^{ABq}	7.53 ± 0.06^{Aq}
4	7.07 ± 0.04^{Bp}	7.18 ± 0.04^{Ar}	7.26 ± 0.03^{Bq}	7.28 ± 0.02^{Aq}

Data represented as the mean± standard error of mean. Mean values with different uppercase letters within the same column are significantly different at $p<0.05$. Mean values with different lowercase letters within the same row are significantly different at $p<0.05$

Microbiological analysis

Salmonella and Coliform were not detected in all four treatments. Total plate count increased with the storage time and control sample had a higher total plate count when compared to other treatments (Figure 4).

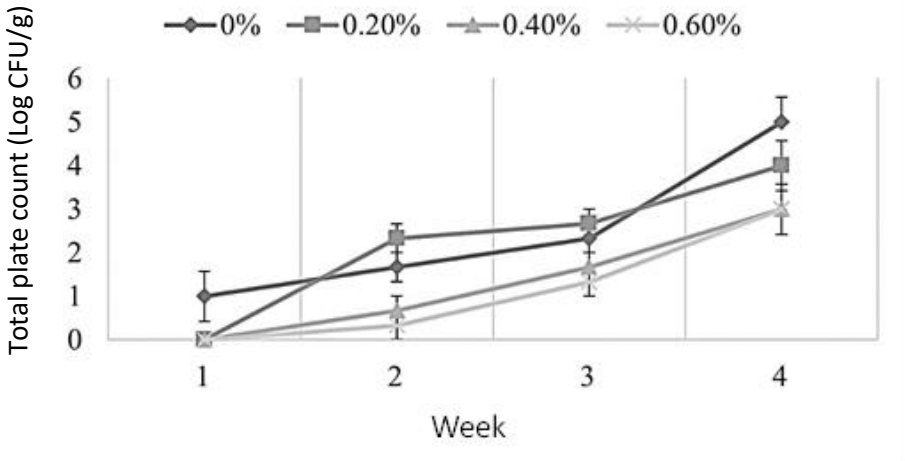

Figure 4: Total plate counts (Log CFU/g) of ice cream incorporated with different levels of Lavulu flour (LF) during frozen storage

It revealed that LF has an antimicrobial activity since the increment of LF percentage decreased the plate count. According to Ito *et al*. (2005), Lavulu fruit has antibacterial activity. The maximum total plate count that can be accepted in an ice cream is 10^5 Log CFU/g according to European microbiological regulation. In the 4^{th} week, total plate count had arisen up to the acceptable level.

Therefore, it is good to consume this ice cream within a month of production or can add suitable preservative to increase the shelf life. There is no prescribed standard for yeast and mold in ice cream. The highest yeast and mold values were around 2 Log CFU/g at week 4 for all the treatments.

Sensory evaluation

According to the sensory evaluation data given in Figure 5, ice cream added with 0.4% of LF had the highest sensory scores.

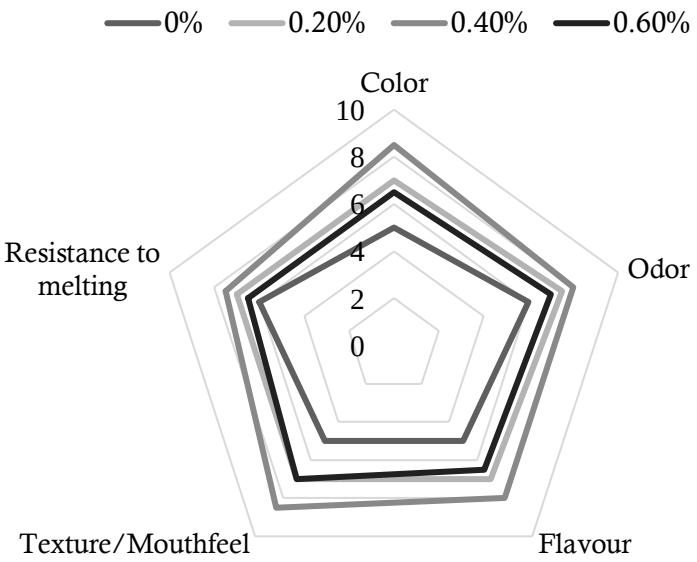

Figure 5: Radar diagram for the sensory evaluation of ice cream incorporated with different levels of Lavulu flour (LF)

Further, the panelists' comments revealed that the odor of LF reduced the scores for the treatment with LF at 0.6%. TOPSIS approach was carried out to combine the instrumental values and sensory values to select the best LF percentage as an antioxidant and colorant.

TOPSIS approach

Sensory data and selected instrumental data were normalized and weighted as shown in Table 10. The final ranking was then carried out according to the closeness coefficient as given in Table 11. According to TOPSIS approach, ice cream added with 0.4% of LF was selected as the best treatment.

Properties of the selected treatment (ice cream with LF at 0.4%)

Protein content

The protein contents of ice cream incorporated with 0.4% of LF were 7.54±0.52 (Biuret method) and 5.59±0.32 (Kjeldahl method) as a percentage (w/w). According to FDA, a good source of protein is those products that contain 5 to 9 g protein per serving. Hence, this product can be called as a good protein source but not a high protein source as high protein source should contain more than 10 g protein per serving according to FDA.

Table 10: Weighted normalized decision matrix for TOPSIS approach

LF (%)	RSA (%)	b* value (yellowness)	Sensory properties				
			Color	Odor	Flavor	Mouthfeel	RM[#]
0	0.141	0.050	0.077	0.045	0.038	0.037	0.044
0.2	0.098	0.087	0.091	0.047	0.048	0.048	0.048
0.4	0.077	0.110	0.120	0.055	0.060	0.060	0.055
0.6	0.068	0.133	0.106	0.052	0.051	0.053	0.052

[#]RM, Resistance to melting

Table 11: Final ranking of ice creams incorporated with different levels of Lavulu flour (LF) according to TOPSIS approach

LF (%)	Closeness coefficient	Ranking
0	0.4232	4
0.2	0.4246	3
0.4	0.5494	1
0.6	0.5469	2

Fat content

The fat content of ice cream incorporated with 0.4% of LF was reported as 11.33±0.88% (w/w) (Gerber method), 15.90±0.45% (w/w) (Rose Gottlieb method), and 14.90±0.41% (w/w) (Soxhlet method). Fat content of a regular ice cream is 11%. The fat content of the developed mousse ice cream was falling around that of regular ice cream and was slightly high due to the addition of whipping cream.

Total sugar content

The total sugar content of ice cream incorporated with 0.4% of LF was 24.77±1 as a percentage (w/w) and comparable to the sugar content of a regular ice cream.

Overrun

The total overrun of ice cream incorporated with 0.4% of LF was 420±5% (w/w). Egg white increases six to eight times in volume when beaten to a foam according to Vaclavik and Christian (2008). Overrun of whipping cream depends on the brand. The overrun of the developed product was compatible with the statement of Vaclavik and Christian (2008).

Moisture, total solid, and ash contents

The moisture, total solid, and ash contents of the ice cream incorporated with 0.4% of LF were 37.62±1.21, 63.44±0.88, and 0.00059±0.003% (w/w).

CONCLUSION

Mousse ice cream can be successfully prepared using high percentage of egg white foams. It is a healthy alternative for the regular ice creams which has high carbohydrate content and low protein content. Lavulu flour incorporation increased the redness and yellowness of the product as a colorant. Lavulu flour incorporation even at low level significantly increased the radical scavenging activity, total phenolic content and total flavonoid content of the product, revealing its high antioxidant potential. Lavulu flour incorporation at 0.4% (w/w) was selected as the best treatment considering the sensory and bioactive properties. It is to be noted that a high percentage of Lavulu flour could not be incorporated due to its associated strong flavor. Further studies are suggested to reduce the intensity of the flavor. In addition, Lavulu flour indicated emulsifying and antibacterial properties. Furthermore, Lavulu flour incorporation showed a positive correlation with the viscosity, hardness, and complete melting time Additionally, further research can be conducted on the carotenoid profile, deterioration of antioxidant activity during storage, compounds contributing to the strong flavor, antibacterial activity, emulsifying properties, and colorant potential of Lavulu flour.

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