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Technological and nutritional aspects of fresh purslane (*Portulaca oleracea* L.) in ice cream production

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Abstract: Purslane (*Portulaca oleracea* L.) is rich in ω-3 fatty acids, antioxidants, and minerals, and has notable neuroprotective, anti-inflammatory, antimicrobial, antidiabetic, antioxidant, anticancer, and antihypertensive properties. This research evaluated the effect of fresh purslane (FP) on the physicochemical and nutritional properties of ice cream, including α-linolenic acid (ALA; 18:3; ω-3), mineral content, and antioxidant properties, along with sensory characteristics. FP was added at 0, 5, 10, and 15% (w/w) levels. The addition of FP significantly increased the iron (Fe), calcium (Ca), copper (Cu), sodium (Na), oleic acid (OA), and ALA contents ($P < 0.05$). FP also increased the first dripping and complete melting times, while decreasing overrun and viscosity. Total antioxidant capacity (TAC) remained unchanged ($P > 0.05$), but total phenolic content (TPC) and 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical scavenging activity significantly increased ($P < 0.01$). Thirty-one volatile compounds were identified, with increases in octadecane, dodecane, and 2-hexenal concentrations due to FP addition. Although the addition of FP improved the ALA content and antioxidant properties, sensory results showed that FP over 5% (w/w) lowered taste and general acceptability scores. Thus, using 5% of FP in ice cream is optimal for enhancing nutritional properties.

Keywords: antioxidants; mineral content; omega-3 fatty acids; phenolics; *Portulaca oleracea* L

Dairy products are widely available and increasingly enriched with plant components (Babukhadia et al. 2020). Ice cream, for instance, contains calcium, vitamins A, D, E, fats, carbohydrates, and proteins but lacks dietary fibre and natural antioxidants (Ismail et al. 2020).

Portulaca oleracea L. (purslane) offers high nutritional and medicinal benefits. Its leaves and stems are rich in ω-3 fatty acids, vitamins A, C, E, and minerals like potassium, calcium, and magnesium (Uddin et al. 2014). Purslane is among the richest plants in fatty acids and can be a functional food (Petropoulos et al. 2015), providing fibre, carbohydrates, chlorophyll, antioxidants, and phenolic compounds (Fukalova et al. 2022). Purslane has various health benefits, including hypoglycaemic, lipid-lowering, antioxidant, anti-inflammatory, antibacterial, and antitumor effects (Chen et al. 2019). It is also used in herbal medicine for treating conditions like osteoporosis and psoriasis (Uddin et al. 2014), and its nutrient content helps reduce chronic disease risks (Nemzer et al. 2020).

Purslane has been used to enhance micro and macro nutrients of foods: 2% purslane extract improved yogurt functional properties (Salehi et al. 2021) and 5% dry purslane flour added to bread increased bioactive compounds (Melilli et al. 2020a). Purslane extracts have been used to maintain pork meat quality (Fan et al. 2019), stabilize oils (Shanker and Debnath 2019), prevent browning in potato slices (Liu et al. 2019), and enhance pasta (Melilli et al. 2020b). Drying methods significantly reduce purslane beta-carotene, flavonoids, and phenolics (Binici et al. 2021), whereas fresh extracts show higher antioxidant activity (Sicari et al. 2018). Adding fresh

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purslane (FP) to ice cream could boost phenolic content, colour, and antioxidants. This study aims to evaluate the effects of adding 0%, 5%, 10%, and 15% FP to ice cream on its fatty acid composition, mineral content, antioxidant activity, aroma, viscosity, melting properties, and sensory quality.

MATERIAL AND METHODS

Material. Ultra-high temperature processing (UHT) milk (Pınar A.Ş. İzmir, Türkiye), UHT cow's milk cream (Ak Gıda A.Ş. İstanbul, Türkiye), and milk powder (Pınar A.Ş. İzmir, Türkiye), FP was obtained from Şeker Greengrocer, granulated sugar (Konya Sugar Industry and Trade Inc., Türkiye), emulsifier (sahlep), and stabilizer (monoglyceride) were obtained from Gülüm Herbalist Shop in the Gümüşhane Province, which is located in the northern part of Türkiye.

Chemicals and n-alkanes series (C7–C30) were obtained from Supelco (Merck, Germany). Mineral standard solutions for the determination of mineral content were purchased from Merck (Germany). Chemicals for the total antioxidant capacity (TAC), total phenolic content (TPC), and 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical scavenging activity analysis were obtained from Sigma-Aldrich (Saint Louis, USA).

Preparation of fresh purslane and ice cream production. FP was cleaned, sorted, washed with tap water, drained, and blended with a hand blender until smooth. It was then weighed to prepare different concentrations. Four types of ice cream, including a control (0% FP) and three types with varying amounts of FP [5%, 10%, and 15% (w/w)] were produced. Ice cream mixes were prepared with milk adjusted to 5% fat, containing 11% skimmed milk solids, 15% sugar, 0.7% stabiliser, and 0.2% emulsifier. Each mix was heated to 85 °C, then FP was added and pasteurised for 5 min, cooled rapidly with ice water, and ripened at 4 ± 1 °C for 24 h. The mix without purslane served as the control (C), while samples with purslane were labelled P5, P10, and P15, respectively. After ripening, ice creams were made in an ice cream machine (Uğur Refrigeration Machines Inc., Türkiye), hardened at –22 °C overnight, and analysed the next day (Figure 1). All ice creams were produced in duplicate.

Physicochemical analysis. Dry matter and ash content of ice cream samples were determined using the gravimetric method. Fat content was measured by the Gerber method, pH values with a pH meter (HANNA HI2202-02, USA), and titration acidity (lactic acid %) using 0.1 M NaOH and phenolphthalein. Protein content was determined by the Kjeldahl method (Kurt et al. 2015). Colour was measured with a Konica Minolta colorimeter (Chroma Meter, CR-400, Japan), and L^*, a^*, b^* (L^* – lightness, a^* – yellowness, b^* – redness) values were averaged from different points on each sample (Çelik et al. 2009).

Overrun, first dripping time, and complete melting times. By the analysis of overrun, the change in the volume of the mix during the ice cream production is measured. It is calculated by using the ice cream weight in a certain volume and the mix weight in the same volume, using the equation below (Daw and Hartel 2015):

$$\text{Overrun}(\%) = [weight\ of\ mix(g) - weight\ of\ icecream(g)] / [weight\ of\ icecream(g)] \times 100 \quad (1)$$

For the first dripping and complete melting times, 50 g ice cream samples were placed on a wire mesh (0.9 mm) and 250 mL beakers were placed beneath, and the samples were left to melt for 60 min at room temperature. The first dripping and complete melting times of the ice cream samples were recorded in seconds (Güven and Karaca 2002).

Figure 1. Ice cream samples

C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane

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Viscosity of ice creams. Viscosity of ice cream samples was measured with J.P. Selecta, a.s, Spain device at 20 revolutions per minute (rpm).

Fatty acid composition. Fatty acid composition was determined according to the TS EN ISO 12966-4 method (2015). Fatty acid methyl esters (FAMEs) were obtained by the addition of 5 mL n-hexane and 100 µL 2 N KOH (in methanol) to the sample. FAMEs were injected into a GC-MS/FID detector (Agilent 5975, Agilent Technologies Inc., USA) and a column (30 m, 0.25 mm ID, and 0.2 µm HP-5MS). GS-MS/FID adjustment was: detector column was 30 m × 0.25 mm ID, 0.2 µm HP-5MS. Oven: 50 °C, 25 °C·min^{-1}, 200 °C per 1 min; 3 °C·min^{-1}, 230 per 27 min. Carrier gas: helium (He), constant flow 25 mL·min^{-1}. Injection: 250 °C. Detector: MS, 230 °C. Split: 1.20. Injection volume: 1 µL. Hydrogen (H2): 40 mL·min^{-1}. Dry air: 450 mL·min^{-1}. The fatty acid was given in percentage relative to the total fatty acid contents.

Aroma compounds. To determine aroma compounds, the method of Baltaci et al. (2022) was used with small modification. A modified double skin cooled Clevenger apparatus was used for the steam and liquid phase extraction of aroma compounds. A 50-mg sample was weighed to a 2000-mL flask diluted with a saturated NaCl solution (1/3). Later it was placed in a modified glass collection device containing 2 mL hexane for keeping aroma compounds while evaporating. After that, the water in hexane was dried with anhydrous Na_2SO_4. The 1.8 mL vials containing dried samples were placed in the GC-MS/FID detector (Agilent 5975, Agilent Technologies Inc., USA) device for analyses. Detector column was 30 m × 0.25 mm ID, 0.2 µm HP-5MS. Oven: 50 °C, 4 °C·min^{-1}, 260 °C per 15 min. Carrier gas: He, constant flow 1.2 mL·min^{-1}. Injection: 250 °C. Detector: MS, 230 °C. Split: 1.25. Injection volume: 1 µL. H_2: 40 mL·min^{-1}. Dry air: 400 mL·min^{-1}. Aroma compounds were expressed as area % by dividing the area of aroma compounds by the total area of aroma compounds.

Mineral content. A coupled plasma mass spectrometer was used for determining minerals. Fe, manganese (Mn), Cu, Ca, magnesium (Mg), Na, and potassium (K) were determined. For this aim, about 0.5 g of the sample was weighed and acidified with 6 mL of 65% nitric acid (HNO_3) and 2 mL of hydrogen peroxide (H_20_2). It was burned in a microwave (Milestone s.r.l, Start D, Sorisole BG, Italy) adjusted to 200 °C, 45 bar and for 15 min. At the end of the burning, the sample was transferred to a 25 mL balloon and completed with ultrapure water. Five different concentrations of all the analytes were used for calibration curves. Samples were passed through a 0.45-micron filter, then placed in the ICP/AES (NMKL 161 and 170).

Extraction of bioactive compounds of fresh purslane. An amount of 2.5 grams of FP was weighed. 10 mL of distilled water and 5 mL of ethanol were added. It was placed into an ultrasonic water bath (Bandelin Sonorex Super RK 103 H, Germany) for 20 min to achieve extraction. Afterwards, it was filtered through Whatman filter paper No. 1 (Sigma-Aldrich, Germany) and passed through a 0.45 µm filter and then taken into vials. The prepared extract was used for the determination of TAC, TPC and DPPH radical scavenging activity. The same extraction procedure was also applied to ice cream samples.

Total antioxidant activity. An amount of 500 µL of the prepared extract was taken and 2 500 µL of deionized water was added. 1 000 µL of molybdate reagent was added to the mixture. The mixture was vortexed and incubated for 90 min in a 95 °C water bath with the lid closed. After that it waited for 20–30 min to cool down to room temperature. The absorbance of an aliquot solution was measured at 695 nm against blank which contained 500 µL of distilled water instead of the sample. TAC of FP was expressed as mg of ascorbic acid equivalent (AAE) per 100 g FP by using the correct equation of the calibration graph obtained with different solution of AA (Kasangana et al. 2015).

Total phenolic content. After 300 µL of the extract and 3.4 mL of deionized water were mixed, 0.5 mL of methanol and 200 µL of Folin-Ciocalteu reagent were added and vortexed. The mixture was incubated for 10 min at room temperature, then 600 µL of 10% Na_2CO_3 solution was added. The final mixture was vortexed again and incubated in the dark at room temperature for 120 min. At the end of the incubation period, the absorbance of the mixture was recorded at 760 nm against blank containing 3.7 mL distilled water, 500 µL methanol + 100 µL Folin-Ciocalteu reagent + 600 µL Na_2CO_3. The TPC of the samples was expressed as mg of gallic acid equivalent (GAE) per 100 g FP with the correct equation of the calibration graph obtained with different solutions (20, 40, 60, 80, 120 and 160 µg·mL^{-1}) of GA (Kasangana et al. 2015).

2,2-diphenyl-1-picryl-hydrazyl radical scavenging activity analysis. An amount of 100 µL of the extract was added to 3 000 µL of DPPH working solution. After the mixture was vortexed, it was waited for 30 min. The absorbance of the aliquot solution was read in a spectrophotometer (Shimadzu UV-1800, Japan) at a 517 nm. An amount of 100 µL of methanol was used as blank.

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Table 1. Some physicochemical properties of raw materials used in the ice cream production

Parameters	Milk	Cream	FP
pH	–	–	5.05 ± 0.01
Dry matter (%)	11.00	39.50	3.77 ± 0.02
Ash (%)	–	–	0.69 ± 0.02
Protein (%)	3.00	1.50	3.60 ± 0.04
Fat (%)	3.30	35.00	–
Vitamin C (%)	–	–	131.79 ± 0.00
TAC (mg AAE·100 g^{-1})	–	–	355.58 ± 17.21
TPC (mg GAE·100 g^{-1})	–	–	90.76 ± 9.59
DPPH (inhibition %)	–	–	58.06 ± 0.70

TAC – total antioxidant capacity; AAE – ascorbic acid equivalent; TPC – total phenolic content; GAE – gallic acid equivalent; DPPH – 2,2-diphenyl-1-picryl-hydrazyl radical scavenging activity; FP – fresh purslane

The same procedures were applied to the standard (AA). DPPH radical scavenging activity in FP samples was expressed as inhibition % (Ahmed et al. 2015).

Sensory analyses. Sensory analysis of ice cream samples was carried out at 25 °C by a group of 34 panellists who were students at the Food Engineering Department of Gümüşhane University and who were familiar with ice cream. Colour and appearance, texture, gummy structure, flavour, degree of sweetness, resistance to melting in the mouth and general acceptability parameters, which are important criteria of ice cream, were measured by a hedonic type of scale using the scores between 1 (very good) and 9 (very poor).

Statistical analysis. In this study, 4 types of ice cream were produced with the addition of purslane at 3 different ratios [5%, 10%, 15% (w/w)] and a control, and the study was carried out with 2 replications. The results obtained were subjected to analysis of variance in the SPSS 22 (2013) program. The Duncan Multiple Comparison Test was applied to the means that were significant as a result of the test.

RESULTS AND DISCUSSION

Some physicochemical properties, antioxidant activity, TPC and vitamin C content of raw materials used in the ice cream production are given in Table 1. While dry matter, protein, and fat content of UHT milk and cream were obtained from label information, the content of FP was analysed in the laboratory. As seen in Table 1, FP has high TAC, TPC, DPPH radical scavenging activity, and vitamin C. The AA content and DPPH radical scavenging activity of purslane were 32.29 ± 3.93% and 12.55 ± 0.07%, respectively (Desta et al. 2020). Sicari et al. (2018) reported that total phenols were higher in FP (565.07 ± 3.23 mg GAE·100 g^{-1}) than in dried purslane (244.17 ± 4.04 mg GAE·100 g^{-1}).

Physicochemical properties of ice cream samples. Table 2 presents the physicochemical properties of ice cream samples. The addition of FP up to 10% had no significant effect on pH or dry matter content ($P > 0.05$), but 15% reduced these properties compared to the control ($P < 0.01$). These findings are consistent with Salem et al. (2017), who observed no significant pH change in ice cream with 5–10% date paste. However, they differ from Naeem et al. (2019), who found that golden berry juice reduced pH depending on concentration, and from Salehi et al. (2021), who reported a pH decrease in yogurt with increasing purslane extract. FP addition decreased ash and protein content regardless of the concentration and progressively reduced fat content ($P < 0.01$), likely due to the low protein (3.60%) and dry matter (3.77%) content of the vegetable. The high water content likely diluted the ice cream dry matter and fat content. Similar trends were reported by Durak (2006)

Table 2. Some physicochemical properties of ice cream samples

Samples	pH	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)
C	6.46 ± 0.01^{a}	33.77 ± 0.17^{a}	0.92 ± 0.03^{a}	4.06 ± 0.04^{a}	5.00 ± 0.00^{a}
P5	6.45 ± 0.03^{a}	33.30 ± 0.43^{a}	0.85 ± 0.09^{a}	3.83 ± 0.02^{b}	4.90 ± 0.06^{b}
P10	6.46 ± 0.02^{a}	33.57 ± 0.47^{a}	0.88 ± 0.04^{a}	3.89 ± 0.06^{b}	4.80 ± 0.06^{c}
P15	6.41 ± 0.01^{b}	31.45 ± 0.11^{b}	0.85 ± 0.06^{a}	3.83 ± 0.06^{b}	4.70 ± 0.06^{d}
ANOVA					
DF (3 samples)	5.14*	40.20**	1.24	18.33**	35.67**

$^{a–d}$Different letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane; ANOVA – analysis of variance; DF – degrees of freedom

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Table 3. Overrun, viscosity, first dripping and complete melting times of ice creams

Samples	Overrun (%)	Viscosity (20 cp)	First dropping (s)	Full melting time (s)
C	38.64 ± 1.26[a]	9363.30 ± 399.66[a]	600.00 ± 0.00[d]	2640.00 ± 69.28[d]
P5	34.47 ± 3.40[b]	8916.54 ± 53.61[b]	1080.00 ± 229.78[c]	3690.00 ± 151.00[c]
P10	34.93 ± 2.74[ab]	8146.73 ± 88.63[c]	1350.00 ± 66.33[b]	4560.00 ± 69.28[a]
P15	30.98 ± 1.81[b]	7402.00 ± 87.96[d]	1950.00 ± 151.00[a]	3870.00 ± 103.92[b]
ANOVA				
DF (3 samples)	6.54**	67.097**	63.420**	49.102**

[a–d]Different letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane; ANOVA – analysis of variance; DF – degrees of freedom

for blueberry, Bharatbhai (2014) for basil extract, and Öztürk et al. (2018) for fruit pulp. In contrast, Mastud et al. (2018) found that the purslane powder had no significant effect on moisture, fat, or protein content but it slightly increased ash content.

Overrun, viscosity, first dripping and total melting times. Table 3 shows the overrun, viscosity, first dripping, and complete melting times of ice cream samples. Adding FP reduced overrun and viscosity but it increased first dripping and complete melting times compared to the control ($P < 0.01$). The fatty acids in purslane may form complexes with ice cream ingredients, reducing air incorporation and overrun. Similar findings were reported by Hwang et al. (2009) and Patil et al. (2017) with plant-based additives, which reduced overrun by suppressing the whipping ability of milk proteins. While the FP ratio had no significant effect on overrun ($P > 0.05$), it significantly influenced other properties ($P < 0.01$).

Viscosity decreased with FP addition (C > P5 > P10 > P15, $P < 0.01$), likely due to the fatty acid content in purslane, which was consistent with studies by Gonzalez et al. (2003) and Patil et al. (2017). However, this contradicts Naeem et al. (2019), who observed increased viscosity with golden berry juice powder. Delvarianzadeh et al. (2020) similarly noted reduced viscosity with purslane powder in bread.

First dripping and complete melting times increased with FP addition and ratio ($P < 0.01$), possibly due to FP clogging pores or forming complexes with the ice cream matrix. Mastud et al. (2018) also reported slower melting rates with purslane powder in ice cream due to reduced heat transfer.

Antioxidant activity of ice cream samples. TPC, DPPH radical scavenging activity, and TAC of ice cream samples produced with FP are hown in Table 4. TPC and DPPH radical scavenging activity for all treatments of FP were higher than in the control sample ($P < 0.01$). It was because of high TPC (90.7.6 ± 9.59 mg GAE·100 g^{-1}) and DPPH radical scavenging activity (58.06 ± 0.70%) of FP. The use of FP in this study showed higher TPC than in the study by Mastud et al. (2018), who found the TPC of ice

Table 4. Antioxidant activity of ice creams

Samples		TPC (mg GAE·100 g^{-1})	DPPH (Inhition %)	TAC (mg AAE·100 g^{-1})
C		34.66 ± 19.57[d]	13.66 ± 0.05[d]	444.67 ± 81.51[a]
P5		73.48 ± 9.69[a]	19.43 ± 0.06[a]	456.10 ± 79.21[a]
P10		63.65 ± 9.79[c]	17.10 ± 1.34[b]	447.35 ± 17.79[a]
P15		68.90 ± 15.66[b]	15.76 ± 0.05[c]	440.45 ± 56.21[a]
ANOVA				
DF Samples	3	597.460**	52.198**	0.225

[a–d]Different letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane; TAC – total antioxidant capacity; AAE – ascorbic acid equivalent; TPC – total phenolic content; GAE – gallic acid equivalent; DPPH – 2,2-diphenyl-1-picryl-hydrazyl radical scavenging activity; ANOVA – analysis of variance; DF – degrees of freedom

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creams was 179.89 ± 0.03 mg GAE·100 g^{-1}. TPC and DPPH radical scavenging activity values of ice creams decreased as the FP ratio increased ($P < 0.01$). This was because of low dry matter content (3.77 ± 0.02%) of FP. Our result is not in agreement of the results by Hwang et al. (2009), who concluded that the DPPH radical scavenging activity increased depending on the ratio in the ice cream samples with grape wine residues. El Gindy (2017) showed that the addition of purslane to the pan bread resulted in an increase in the TPC and radical scavenging activity.

On the other hand, the results for TAC were not similar to those of TPC and DPPH radical scavenging activity. The 5% and 10% (w/w) addition of FP increased the TAC but it was decreased by 15% (w/w) addition compared to the control. However, this decrease was not statistically significant between the control and other samples ($P > 0.05$). It can be due to other factors affecting TAC such as vitamin C content of FP. Our results were correlated with the results of the study by Sun-Waterhouse et al. (2013), who found that ice cream fortified with green kiwifruit showed high TPC but low antioxidant capacity. Different results were obtained by Salehi et al. (2021), who stated that the antioxidant capacity of yoghurts produced with the purslane extract increased depending on the ratio.

Mineral composition of ice creams. Table 5 shows minor (Fe, Mn, and Cu) and major mineral elements (Ca, Mg, Na, and K) of purslane and ice cream samples. In the FP, the highest mineral content was measured in K (359.40 ± 9.26 mg·100 g^{-1}) and the lowest mineral content in Cu (0.13 ± 0.02 mg·100 g^{-1}). While Alam et al. (2014) found that Fe, Mn, Ca, Mg, Na and K contents of 13 purslane kinds varied from 0.19–1.11; 0.14–0.16; 3.5–10.42; 4.08–10.14; 5.24–15.44 and 26.60–65.62 dry weight mg·100 g^{-1}, respectively. Our results are higher than the results of the above-mentioned study. But Oliveira et al. (2013) reported higher Ca (2 390 mg·100 g^{-1}), Mg (580 mg·100 g^{-1}), Mn (5.8 mg·100 g^{-1}), Fe (32.4 mg·100 g^{-1}) (de Souza et al. 2022). There was a significant difference in terms of all minerals between the control and FP ice cream samples ($P < 0.05$). While adding FP caused a decrease in Mn, Mg, and K levels when compared to the C sample, Fe, Ca, Cu and Na levels were higher in FP ice creams. On the other hand, Fe, Cu, Ca, and Na decreased depending on the ratio of FP, and the highest concentration was observed in the P5 sample. In contrast, Mn, Mg and K rose with the increase of FP ratio and the P15 sample had the highest levels of these minerals. Our study was different from the study by Arslaner and Salik (2022), who found a Ca decrease and a K increase with the addition of *Malus floribunda* fruit.

Fatty acid composition of ice cream samples. Fatty acid composition of purslane and ice creams are shown in Table 6. The most abundant fatty acids determined in purslane were palmitic acid (PA), OA, linoleic acid (LA), and α-linolenic acid (ALA). Petropoulos et al. (2015) reported significantly higher percentages for stearic acid (SA) (4.91–8.21%), OA (9.70–15.09%), and LA (25.09–32.90%) but lower percentages for ALA (17.91–28.40%) compared to our study (0.35%, 0.97%, 2.06% and 94.05%, respectively). Almashad et al. (2019) determined higher PA, SA, OA, LA but lower ALA than in our study, and also lauric and myristic acid, which were not found in our study. The same fatty acids were determined in the control and purslane ice cream samples, with significant differences between them ($P < 0.05$).

Table 5. Mineral composition of purslane and ice cream samples (mg·100 g^{-1})

Minerals	Samples				
	FP	C	P5	P10	P15
Fe	2.16 ± 0.28	0.62 ± 0.09^{d}	3.96 ± 0.46^{a}	1.26 ± 0.40^{b}	0.91 ± 0.02^{c}
Mn	0.45 ± 0.47	0.15 ± 0.02^{a}	0.05 ± 0.02^{d}	0.06 ± 0.01^{c}	0.07 ± 0.02^{b}
Cu	0.13 ± 0.02	0.15 ± 0.03^{c}	0.43 ± 0.15^{a}	0.29 ± 0.04^{b}	0.17 ± 0.02^{c}
Ca	87.40 ± 5.05	119.40 ± 1.52^{d}	185.11 ± 2.80^{a}	124.45 ± 3.38^{b}	121.48 ± 2.06^{c}
Mg	49.75 ± 1.95	24.43 ± 2.99^{a}	12.70 ± 0.71^{d}	18.42 ± 3.02^{c}	21.35 ± 1.98^{b}
Na	33.45 ± 3.42	53.82 ± 1.38^{d}	64.52 ± 3.02^{a}	55.70 ± 2.97^{b}	54.651 ± 3.32^{c}
K	359.40 ± 9.26	227.60 ± 4.37^{a}	163.41 ± 2.71^{d}	201.54± 3.78^{c}	124.48 ± 4.01^{b}

$^{a–d}$Different letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane

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Table 6. Fatty acid composition of ice cream samples (%)

Fatty acids	Samples					
	RT	FP	C	P5	P10	P15
Butyric acid	3.543	nd	0.10	0.11	0.13	0.12
Caproic acid	4.465	nd	1.92	1.71	1.78	1.73
Caprilic acid	6.237	nd	1.44	1.08	1.32	1.21
Capric acid	7.987	nd	3.17	2.55	3.45	2.55
4-Decenoic acid	8.391	nd	0.38	0.22	0.32	0.23
Lauric acid	9.687	nd	3.42	3.04	3.31	3.25
Tridecanoic acid	10.602	nd	0.20	0.12	0.11	0.16
Myristic acid	11.783	nd	11.40	11.22	11.29	11.26
Myristoleic acid (ω3)	12.207	nd	0.97	0.89	0.88	0.88
Pentadecanoic acid (ω5)	12.981	nd	1.50	1.21	1.25	1.19
Pentadecanoic acid. 14-methyl ester	13.756	nd	0.34	0.38	0.39	0.30
Palmitic acid	14.633	2.31	35.74^{a}	33.62^{c}	34.89^{b}	33.46^{d}
Palmitooleic acid ω7	15.037	nd	1.84^{a}	1.77^{b}	1.71^{c}	1.76^{b}
Margaric acid (Heptadecanoic acid)	15.407	0.27	0.11^{b}	0.53^{a}	0.50^{a}	0.50^{a}
Stearic acid	18.495	0.35	11.13^{d}	13.90^{b}	11.70^{c}	14.37^{a}
Oleic acid	19.127	0.97	22.24^{c}	23.05^{a}	22.80^{b}	22.80^{b}
Linoleic acid (ω6)	19.958	2.06	2.87^{a}	2.62^{b}	2.36^{d}	2.54^{c}
Linolenic acid (ω6)	21.514	nd	0.35^{a}	0.32^{a}	0.36^{a}	0.30^{a}
α-linolenic acid (ALA) (ω3)	22.155	94.05	0.48^{d}	0.61^{c}	0.86^{b}	1.19^{a}
Arachidic acid	23.502	nd	0.65^{a}	0.23^{b}	0.17^{c}	0.17^{c}

$^{a–d}$Different letters indicate statistically significant differences at $P = 0.05$; RT – retention time; FP – fresh purslane; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; nd – not determined

While control samples had higher LA than other samples, ice creams containing FP had higher oleic and ALA than the control sample. On the other hand, LA content did not change with the addition of purslane ($P < 0.05$). LA decreased depending on the ratio of purslane. This result was consistent with Melilli et al. (2020a), who reported a decrease in LA in breads fortified with the purslane powder. On the other hand, the ALA increase was correlated with the FP ratio and it was in the order P15 > P10 > P5 > C. This result was different from the study where bread with 5% substitution of purslane powder gave higher ALA than 10 and 15% (w/w) purslane bread (Melilli et al. 2020a), and the researchers thought that the reason could be a result of the cooking process.

Aroma compounds of ice cream samples. The results of volatile compounds of FP, ice cream samples and retention time (RT), retention index (RI) and literature retention index (LRI) are presented in Table 7. As seen from this table, thirty-one compounds were identified as constituents of ice cream, 21 of them were detected only in FP. The most abundant volatile compounds were: 2-hexenal (70.34%), hexanal (6.90%), eucalyptol (3.74), α-pinene (2.84%), α-sabinene (2.84%), octadecane (2.37%), dodecane (2.30%), β-pinene (1.48%), 3-hexen-2-one (1.43%), tetradecane (1.12%), nonanal (1.03%), oxirane-pentyl (1.14%) in FP. However, our findings contrast with those of Almashad et al. (2019), who identified linalool and 2-hexadecen-1-o1, 3, 7, 11, 15-tetramethyl as the main components in Chinese Portulaca oleracea oil. These discrepancies may arise from variances in cultivar, extraction method, climatic conditions, and plant parts analysed.

Colour properties. Colour measurements (L^*, a^* and b^*) of ice cream samples are illustrated in Figure 2. According to Figure 2, the addition of FP caused significant differences in the colour values of the ice cream samples compared to the control sample ($P < 0.01$). By increasing the ratio of FP, the L^* value decreased significantly ($P < 0.01$). On the other hand, a^* and b^* values of ice creams enriched with FP increased compared to the control sample, and this increase was sta-

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Table 7. Aroma compounds of purslane and ice cream samples

Aroma compound	Samples							
	RT	FP	C	P5	P10	P15	RI	LRI
Hexenal	6.449	6.90	3.68a	1.38^{d}	1.45^{b}	1.43^{c}	801	801
3-hexen-2-one	7.954	1.43	nd	nd	nd	0.43	842	843
2-hexenal	8.184	70.34	0.54^{d}	7.92^{c}	8.04^{b}	16.09^{a}	849	848
2-heptanone	9.647	nd	6.53^{a}	5.61^{b}	5.62^{b}	4.94^{c}	889	889
Heptanal	10.109	0.18	0.81^{a}	0.24^{b}	0.20^{b}	0.17^{b}	902	902
α-thujene	11.264	0.41	1.07^{a}	1.04^{b}	0.95^{c}	0.76^{d}	925	925
α-pinene	11.569	2.84	10.27^{a}	9.73^{b}	7.56^{c}	7.12^{d}	932	932
Camphene	12.261	nd	0.96^{a}	0.62^{b}	0.10^{c}	0.58^{b}	946	946
α-sabinene	13.503	2.84	5.39^{a}	5.33^{a}	4.79^{b}	4.70^{b}	972	972
β-pinene	13.644	1.48	5.76^{a}	5.30^{b}	4.40^{c}	3.93^{d}	975	975
Furan, 2-pentyl-	14.438	0.19	0.80^{a}	0.25^{b}	0.23^{b}	0.21^{b}	991	991
Oxirane, pentyl-	14.843	1.14	nd	0.34^{c}	0.38^{b}	0.53^{a}	999	1003
n-octanal	15.055	nd	1.38^{a}	0.35^{b}	0.27^{bc}	0.20^{c}	1003	1003
p-cymene	16.162	0.51	2.36^{a}	1.75^{b}	1.52^{c}	1.23^{d}	1024	1024
α-limonene	16.387	0.77	2.89^{a}	1.95^{b}	1.83^{c}	1.53^{d}	1028	1028
Eucalyptol	16.491	3.74	22.56^{a}	14.02^{b}	11.64^{c}	11.00^{d}	1030	1030
γ-terpinene	18.021	0.41	0.94^{a}	0.78^{b}	0.66^{c}	0.58^{d}	1058	1058
2-nonanone	19.896	nd	6.56^{a}	5.86^{b}	4.42^{c}	4.31^{d}	1093	1093
Nonanal	20.571	1.03	3.43^{a}	1.04^{b}	0.93^{c}	0.79^{d}	1105	1105
1-terpinenol	24.636	nd	0.78^{a}	0.12^{b}	0.12^{b}	0.03^{c}	1177	1167
Dodecane	25.894	2.30	nd	0.97^{c}	1.08^{b}	1.25^{a}	1199	1200
2-undecanone	31.031	nd	7.26^{a}	7.17^{b}	6.71^{c}	5.69^{d}	1293	1294
Trans-myrtanyl acetate	33.955	0.33	1.15^{a}	0.99^{b}	0.95^{b}	0.90^{b}	1349	1360
Tetradecane	36.548	1.12	3.99^{a}	2.07^{b}	1.38^{c}	1.35^{d}	1399	1400
2-tridecanone	41.318	nd	9.69^{a}	8.33^{b}	8.22^{c}	6.82^{d}	1495	1495
6-dodecenyl-γ-lactone	49.748	nd	2.11^{a}	1.66^{b}	1.61^{c}	1.51^{d}	1679	1676
2-pentadecanone	50.616	0.21	8.82^{a}	7.72^{b}	7.13^{c}	6.01^{d}	1698	1698
δ-dodecalactone	51.029	nd	2.37^{a}	1.70^{b}	1.42^{c}	1.40^{c}	1707	1707
Octadecane	55.029	2.37	0.52^{d}	0.91^{c}	0.99^{b}	1.24^{a}	1798	1800
γ-tetradecalactone	59.954	nd	4.02^{a}	3.16^{b}	2.97^{c}	2.41^{d}	1921	1920
Eicosane	61.428	0.61	nd	nd	0.48^{b}	0.52^{a}	1998	2000

$^{a–d}$Different letters indicate statistically significant differences at $P = 0.05$; RT – retention time; FP – fresh purslane; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; LRI – literature retention index; nd – not determined

tistically significant ($P < 0.01$). Increasing these values is related with the green colour of FP. But the addition of over 10% of FP had no statistical effect on the a^* and b^* values. Similar results were found by Apostol et al. (2020), who added FP leaves at different rates [1%, 2%, 5%, and 10% (w/w)] to the tomato sauce, and they found adding FP decreased the L^* values and increased the a^* and b^* values. Likewise Fan et al. (2019) reported that purslane extract significantly improved the colour properties of chilled pork meat in relation to the control, butylated hydroxyanisole (BHA) and tea phenols.

Sensory analysis of ice cream samples. Sensory analysis results of ice cream samples are shown in Figure 3. The effect of FP at different ratios on the colour, appearance, texture and general acceptability scores of the ice cream samples was statistically significant ($P < 0.05$), the effect on the scores of gummy structure,

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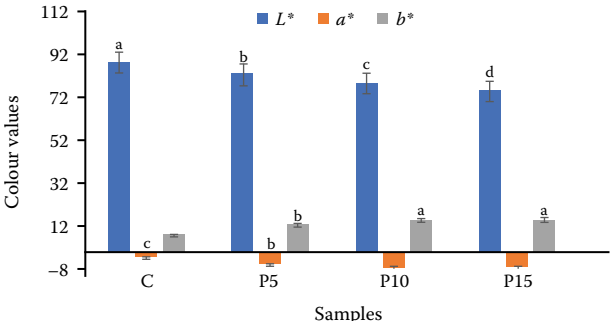

Figure 2. Colour values of ice cream

a–dDifferent letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane; L*– lightness; a* – yellowness; b* – redness

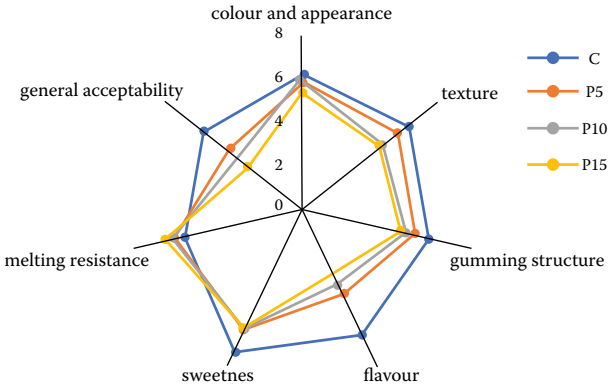

Figure 3. Sensory properties of ice creams

[a–d]Different letters indicate statistically significant differences at $P = 0.05$; C – control sample without FP; P5 – sample with 5% FP; P10 – sample with 10% FP; P15 – sample with 15% FP; FP – fresh purslane

flavour, sweetness degree and resistance to melting in the mouth was insignificant ($P > 0.05$).

Considering the colour and appearance, texture and general acceptability scores given to the ice cream samples, the control sample received the highest score and the P15 sample received the lowest score. It is obvious that as the FP ratio increased, the scores given to the samples decreased in parallel. The same findings were published by Delvarianzadeh et al. (2020), who reported that breads with 15% of purslane powder received minimum scores for sensory properties. The general acceptability score for ice cream samples ranked in the following order: C > 5% > 10% > 15% (w/w). The control sample was found to be similar to the sample containing 5% of FP, while it was statistically different from the other samples ($P < 0.05$). As the percentage of purslane extract increased, the sensory scores of the enriched yogurt samples decreased compared to the control; however, this decrease was not significant. The results of our study were different from the results obtained by Salehi et al. (2021), who recorded that Fan et al. (2019) found no difference between control and pork meat containing purslane extracts; even 1% purslane increased odour, taste, texture and general acceptability of meats.

CONCLUSION

This study was aimed at producing ice cream with FP (*Portulaca oleracea* L.), which has nutritional, medicinal, pharmacological, and phytoremediation properties. The results of the study showed that phenolic content, DPPH free radical scavenging activity of samples with FP provide a twofold increase when compared to the control sample. Ice creams containing purslane had higher OA, ALA, Fe, Ca, Cu and Na contents than control ice creams. Based on the sensory results, 5% of FP can be used for ice cream fortification. The P5 sample had the highest score after C in terms of sensory properties, but there was no difference in general acceptability scores between the samples ($P > 0.05$). As a result, the use of 5% (w/w) FP in ice cream making can be accepted for increasing TPC, mineral content, fatty acid composition but it needs to be further evaluated.

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