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Research Article

Quality Characteristics of Purslane (*Portulaca oleracea L.*) Leaf and Stem Powder-Supplemented Cupcakes

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The current research focused on improving the nutritional quality of cupcakes by using micronutrient-rich vegetables, specifically purslane's leaves and stems. The purslane leaves and stems were sun-dried and analyzed for their proximate, mineral, and antioxidant potential. After conducting preliminary trials, flour blends supplemented with purslane powders ranging from 2 to 4% were evaluated for their rheological behavior and suitability in bakery cupcakes. The results indicated that purslane leaves and stems are a rich source of crude proteins (18.04 ± 0.61 and $15.62 \pm 1.63\%$, respectively) and mineral contents, especially iron contents (214.28 ± 123.13 and 243.37 ± 5.25 mg/100 g, respectively). The powder retained a significant quantity of phenolic compounds and antioxidant potential after sun-drying. The rheological evaluation indicated the dose-dependent incremental response on dough development and dough stability time. Although cupcakes prepared with purslane leaves and stem powder received lower ratings than the control, statistically, the cupcakes supplemented with 2 to 4% purslane powder were on par with each other. In conclusion, purslane leaves and stems are a rich source of micronutrients and their incorporation in bakery products can improve the consumer's micronutrient intake.

1. Introduction

Starting from the last decade, the living standard of the consumer has changed toward an unhealthy lifestyle, demanding nutritious and appetizing foods with easy access. This shift has led consumers to rely on processed foods, which are characterized by increased calories, high sugar content, and an abundance of animal proteins and saturated fats (e.g., snacks). [1, 2]. In developing countries, a significant number of people are facing major nutritional problems including vitamin A deficiency (VAD), iodine deficiency (ID), iron deficiency anemia (IDA), and protein energy malnutrition (PEM) due to inadequate intake of the daily recommended nutritional requirements that can be fulfilled by consuming traditional foods such as fruits and vegetables [3–7]. Numerous studies have explored the potential of green leafy vegetables to address these nutritional problems as they are rich in nutrients and can be consumed daily. However, their high moisture content makes them highly delicate and perishable, limiting their consumption to the season of production and contributing to post-harvest losses as well [8, 9].

The most common method for the preservation of these vegetables is sun-drying, which ensures their availability during the off-season and in remote locations while also preventing post-harvest losses and maintaining their nutritional quality for longer periods [10]. Drying green leafy vegetables is beneficial in addressing microbial growth and preventing rotting, hence improving their shelf life. Moreover, it is important to note that drying can have an impact on the

organoleptic properties, including the visual characteristics (color and appearance) as well as sensory properties (taste, mouth feel, and aroma) of green leafy vegetables [11–15].

Each year, thousands of tons of nutritious wild green leafy vegetables including *Brassica campestris, Brassica rapa*, *Portulaca oleracea*, *Chenopodium album,* and *Brassica oleracea*, grow in forest and riverine areas of warm climate regions such as Asian countries. Unfortunately, these vegetables go waste without their benefits being utilized. *P. oleracea* (purslane) is one of the wild green leafy vegetables found globally, rich in macronutrients and micronutrients as well as biologically active compounds such as antioxidants, phenolic contents, sterols, flavonoids, amino acids, vitamins, and plant acids [16–18]. Purslane leaves and stems are succulent, salty in taste, slightly acidic, and can be consumed just like spinach plants. For centuries, this plant has been used medicinally in various parts of the world [19, 20]. World Health Organization (WHO) has referred to this plant as the "Global Panacea" due to its pharmacological activities, including antioxidant, antidiabetic, anti-inflammatory, anticancerous, antimicrobial, and hepatoprotective [21]. With the objective of promoting positive health outcomes, this study was conducted, incorporating the purslane plant into an ordinary cupcake recipe to make it a part of daily consumption. Specifically, the study was designed to utilize purslane flowers and stems by incorporating them into certain food items, thereby enjoying their fully loaded nutritional benefits.

2. Materials and Methods

2.1. Sample Collection. The study was performed in March 2022 in the Faculty of Food Science and Nutrition, Bahauddin Zakariya University (BZU), Multan, Pakistan. The researchers collected fresh purslane (*P. oleracea*) samples from local markets of Multan, Pakistan (Figure 1(a)). The leaves and stems of purslane were separated (Figures 1(b) and 1(c)), washed with tap water, and sun-dried on clean trays placed in a ventilated area directly under sunlight approximately at ±30°C (Figures 1(d) and 1(e)). The dried purslane was ground to a powder (Figures 1(f) and 1(g)) and sieved to remove coarse particles and stored in air-tight jars at room temperature for further use within one week.

2.2. Proximate Analysis of Dried Purslane Leaves and Stem Powder. Purslane samples were analyzed for moisture, crude protein, crude fat, crude fiber, ash, and nitrogen-free extract (NFE) according to their respective methods as described by the American Association for Cereal Chemistry and Association of Official Analytical Chemists [20, 22].

2.3. Mineral Determination. Mineral analysis of purslane leaves and stem powder samples was conducted using a Flame Photometer-410 (Sherwood Scientific Ltd., Cambridge, UK) (calcium, potassium, and sodium) and Atomic Absorption Spectrophotometer (Varian AA240, Australia) (iron, zinc, copper, manganese, cobalt, cadmium, and lead) following the AOAC [23] method no. 984.27. Acid digestion of 0.5 g of purslane powder sample was carried out in 10 mL of nitric acid (HNO_3) and 5 mL of perchloric acid ($HClO_4$) solutions using a hot plate until 1-2 mL of the colorless solution remained. The digested sample was diluted up to 25 mL and filtered for further analysis.

2.4. Rheological Characteristics. The rheological characteristics of dough prepared with white flour and supplemented with purslane leaves and stem powders were analyzed by following AACC [22], standard method no. 54-21.02. The purslane leaves and stems were ground finely in a regular kitchen blender and were sieved through 40 mesh regular sieve size to attain uniformity and were then mixed with white flour in 2, 3, and 4% lower grade fortification levels based on its sourness. The parameters including water absorption capacity of flour, dough development time (DDT), dough stability and weakening, and dough consistency were analyzed over *Mixolab (Rehmat flour mills, Lahore, Pakistan)*. For this purpose a 300 g sample of each mix was placed in the farinograph mixing bowl; water was carefully added to farinograph demand to achieve the dough's actual consistency. After 20 min, the computer generated a farinograph curve to calculate farinograph characteristics such as water absorption, dough development time, stability time, weakening, and C-max [24, 25].

2.5. Extraction of Phenolic Compounds. 20 g of purslane leaves and stems powder sample was weighed and placed in a 250 mL conical flask and 200 mL of selected solvents i.e., hexane, acetone, ethanol, and distilled water were added with the ratio of 1 : 10 (w/v) and kept over an orbital shaker for 6 hours with 280 rpm at room temperature [26]. Then, the filtrate was separated from the residue by filtering through a filter paper (Whatman number 1). The excess solvents were then evaporated under reduced pressure through a rotatory evaporator (Buchi Rotavapor R-210, City, Switzerland). Then, the concentrated extract was stored at 4°C for further analysis. The methods by Crozier et al. [27] were followed with slight modifications for the preparation of extracts.

2.6. Antioxidant Determination. TPC in purslane powder extracts was analyzed by using the Folin–Ciocalteu reagent following the method reported by Singleton et al. [28]. 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was used to determine the free radical scavenging activity of purslane powder extracts following the method of Alam et al. [27] with some modifications [29, 30]. The FRAP assay was conducted based on the method described by Benzie et al. [31] with minor modifications.

2.7. Cupcake's Development. The cupcake preparation followed the AACC [20, 32] standard treatment plan for product development. A regular, traditional cupcake recipe was chosen for the preparation of control sample cupcakes. Purslane leaves and stem powders were then supplemented at a constant ratio with the flour on a weight basis with the concentration of up to 2, 3, and 4%. First, the dry and wet

(a) (b) (c) (d) (e) (f) (g)

Figure 1: (a). Fresh purslane leaves with the stem. (b) Separation of leaves and stem. (c) Separated leaves and stem of purslane. (d) Sundried leaves of purslane. (e) Sundried stem of purslane. (f) Dried leaves powder. (g) Dried stem powder.

ingredients were mixed separately, and then, wet mixtures were added to the dry ingredients mixtures, and mixed to prepare the batter. The batter (50 g) was placed into previously oiled aluminum pans sprinkled with wheat flour. The cupcakes were baked in a conventional oven preheated to 190°C for 25 min. After cooling, the cupcakes were wrapped in plastic bags and kept at room temperature for further analysis.

2.8. Color Tonalities of Cupcakes. The color tonality of the cupcakes, supplemented with different percentages of purslane leaves and stem powders was analyzed by using a spectrophotometer (YS3010, 3nh Technology Co., Ltd. Shenzhen, China). The cupcakes were evaluated for $+L^*$ (lightness), $-L^*$ (darkness), $+a^*$ (redness), $-a$ (greenness), $+b^*$ (yellowness), and $-b$ (blueness). The data obtained were further used to calculate c^* (chroma: color intensity) and h^* (hue: the saturation of chroma) [33, 34].

2.9. Statistical Analysis. For the statistical analysis of current research results, Statistix 8.1 software used a completely randomized design. All determinations were performed at least in triplicates present as averaged. The confidence limits used in this study were based on 95% ($p \leq 0.05$). Moreover, means for all treatments were compared using Latin square design (LSD).

3. Results and Discussion

3.1. Proximate Analysis. Purslane is one of the wild, green, leafy vegetables that grow in the riverine areas of Southern Punjab in Pakistan, providing ample nutrition to fulfil consumer needs. Dehydrating purslane leaves and stems reduces the moisture contents by approximately 6.90 ± 0.56 and $4.14 \pm 0.64\%$, respectively (Table 1). Purslane's leaves and stems are rich sources of good quality protein, with contents of approximately 18.04 ± 0.61 and $15.62 \pm 1.63\%$, respectively. The higher protein content strengthens the purslane powder and enhances the water absorption for dough development. The ash contents, which represent the mineral elements, are also higher in purslane, with quantities of 19.70 ± 0.15 in leaves and $14.74 \pm 0.33\%$ in stem powders. The elevated ash content indicates that purslane is also a valuable source of minerals, addressing consumer mineral deficiencies. Nutritional analysis reveals that purslane contains approximately 3.97 ± 0.23 and $3.06 \pm 0.34\%$ fat in leaves and stem powders, respectively. Some results indicate the presence of health-promoting omega-3 fatty acids in purslane. Crude fiber, which can improve digestibility, is present in purslane leaves and stem powder samples at levels of 6.90 ± 0.07 and $5.04 \pm 1.13\%$, respectively. The NFE contents, calculated in purslane leaves and stem powder samples were 47.25 ± 0.34 and $54.63 \pm 1.70\%$, respectively. Salman et al. [35] obtained results for ash (22.51%) and moisture (3.40%) contents in purslane that almost aligned with the current research study. However, they also found higher protein content (34.21%) and lower fat content (2.01%), which contradicted the current study. Mastud et al. [36] conducted a study on the proximate composition of purslane, which mostly agreed with the current research study for moisture (4.20%), ash (18.20%), protein (16.38%), and fiber (4.5%) contents. However, their findings contradicted with the current study regarding fat (2.33%) and NFE (58.89%) contents. Similarly, Badawy et al. [37] discovered lower protein content but higher fat, fiber, and ash contents than the current study's results.

3.2. Minerals Analysis. In Table 1, the current research study clearly indicates that purslane leaves and stems contain higher levels of calcium (1005.2 and 1.094.17 mg/100 g), potassium (2652 and 2665.8 mg/100 g), and sodium (228.2 and 201.3 mg/100 g), respectively. The findings of Badawy et al. [37] are consistent with the current study, Na (242 mg/100 g and Ca 1238 mg/100 g), but their K level (4694 mg/100 g) was higher. However, the results of the current study contradict with those of Salman et al. [35] for Na and K, as they found higher amounts (941.84 mg/100 g and 2570.47 mg/100 g, respectively) of these elements. The calcium measurement (1053.42 mg/100 g) was similar to the current study. Microminerals including iron (214.28, 243.37 mg/100 g), manganese (57.92, 52.42 mg/100 g), zinc (8.67, 8.44 mg/100 g), and copper (5.39 ± 0.24, 4.69 ± 0.30 mg/100 g) were found both in leaves and stem parts, respectively. Cadmium (11.42, 6.92 mg/100 g), lead (4.42, 5.08 mg/100 g), and cobalt (12.58, 7.17 mg/100 g) were also present in the leaves and stem parts, respectively. However, these heavy metals were found in limited quantities, as their higher amounts in purslane vegetables may cause health problems. In comparison to the current study, Aberoumand [38] reported lower amounts of iron (0.48 mg/100 g) and zinc (3.02 mg/100 g) in purslane. The results for the microminerals in purslane from the current study contradict with those reported by Almasoud and Salem [39] for Zn, Fe, and Mn, as they had lower amounts of these minerals. The variation in results for mineral elements of purslane could be attributed to its production areas, harvesting time, and stages of harvesting. In the current study, the purslane sample was taken from the riverine areas of Southern Punjab of Pakistan where it grows wildly in abundant quantity and meets different types of mineral elements and heavy metals.

3.3. Antioxidant Activity of Purslane Powder Extracts. Purslane leaves and stem powder extracts of different solvents showed different results over the spectrophotometer depending upon the type of solvent used i.e., acetone, ethanol, hexane, and distilled water (Table 2). The ethanolic extracts of both leaves and stem powders exhibited promising results for phenolic compounds, with the values of 242.83 ± 1.86 and 231.35 ± 0.85 mgGAE/100 g, respectively, surpassing the other solvent extracts. The water extracts reduced the TPC values, indicating that inorganic compounds were unable to extract higher polyphenols effectively. Sicari et al. [40] reported TPC results that were similar to our study, while Uddin et al. [15] also obtained comparable TPC results in purslane extracts using different solvents [41], highlighting the variations in results and stating that purslane extracts contain a high amount of TPC.

Table 1: Proximate analysis and mineral composition of purslane.

Parameters		Leaves	Stem
Proximate analysis (g/100 g)	Moisture	4.14 ± 0.64	6.90 ± 0.56
	Crude protein	18.04 ± 0.61	15.62 ± 1.63
	Total ash	19.70 ± 0.15	14.74 ± 0.33
	Crude fat	3.97 ± 0.23	3.06 ± 0.34
	Crude fiber	6.90 ± 0.07	5.04 ± 1.13
	NFE	47.25 ± 0.34	54.63 ± 1.70
Macronutrients (mg/100 g)	Na	228.20 ± 33.06	201.30 ± 32.56
	K	2652.00 ± 432.1	2665.80 ± 864.7
	Ca	1005.20 ± 366.52	1094.17 ± 425.83
Micronutrients (ppm or mg/100 g)	Cu	5.39 ± 0.24	4.69 ± 0.30
	Fe	214.28 ± 123.13	243.37 ± 5.25
	Mn	57.92 ± 3.25	52.42 ± 1.76
	Pb	4.42 ± 1.53	5.08 ± 1.53
	Cd	11.42 ± 2.84	6.92 ± 4.01
	Zn	8.67 ± 2.47	8.44 ± 0.20
	Co	12.58 ± 1.76	7.17 ± 1.51

Table 2: Total phenolic contents and antioxidant activity of solvent extracts of purslane.

Parameters		Acetone	Ethanol	Hexane	D. water
TPC (mg GAE/100 g)	Leaves	164.95 ± 0.93	242.83 ± 1.86	142.76 ± 0.45	125.94 ± 1.78
	Stem	162.79 ± 1.77	231.35 ± 0.85	139.14 ± 0.33	119.17 ± 0.23
DPPH (%)	Leaves	60.50 ± 1.36	47.62 ± 1.46	45.47 ± 0.29	11.05 ± 1.54
	Stem	57.21 ± 1.04	45.14 ± 1.74	42.01 ± 1.31	9.91 ± 1.26
FRAP (mg Trolox E/g)	Leaves	237.66 ± 1.57	182.02 ± 0.31	118.74 ± 0.78	101.50 ± 0.52
	Stem	231.39 ± 0.52	178.95 ± 0.65	111.94 ± 1.36	95.25 ± 0.92

DPPH is often used to evaluate free radical scavengers or hydrogen donors and to quantify antioxidants in complex systems. The highest DPPH scavenging activity (%) was observed in acetone extracts of purslane leaves and stem powder samples (60.50 ± 1.36 and 57.21 ± 1.04%) and lowest in water extracts (11.05 ± 1.54, 9.91 ± 1.26%), respectively. Almasoud and Salem [39] reported the highest radical scavenging activity (RSA) of purslane at 89.23% but Uddin et al. [15] also reported the high DPPH scavenging activity of purslane, while Sallam and Anwar's [41] obtained results for DPPH activity in purslane extract were in line with the current study. Generally, promising results were observed for the ferric-reducing antioxidant power (FRAP) of purslane extracts. The acetone extracts of purslane leaves and stems showed the highest FRAP values of 237.66 ± 1.57 and 231.39 ± 0.52 μg GAE/g, respectively, whereas the lowest values were reported in water extracts i.e., 101.50 ± 0.52 and 95.25 ± 0.92 mg Trolox E/g. FRAP scavenging power of dried purslane extracts calculated in the current research showed higher values than the results calculated by Sicari et al. [40]. Current research showed results in agreement with the results reported by Uddin et al. [15] for the FRAP scavenging power of dried purslane extracts. Note that, the antioxidant activities of compounds depended on the solvent used, with organic solvents yielding better results for the antioxidant activities of purslane extracts as compared to the distilled water extracts.

3.4. Rheological Characteristics of Purslane Powder. Rheological parameters including flour's water absorption capacity, dough development time, dough stability, dough weakening, and desired consistency dough are important parameters for the product formulation. Dough prepared with 100% white flour (control sample) showed better rheological characteristics and was considered as standard for comparing the purslane leaves and stem powders formulated doughs (Table 3). The addition of purslane leaves and stem powder at different levels to white flour did not significantly affect the water absorption capacity of the flour. However, purslane leaves and stems are a good source of fiber and showed slight variations in the water absorption capacity of flour blends. The water absorption capacity in flour blends supplemented with purslane leaves and stems ranged from 59.02 ± 0.35% to 59.31 ± 0.18%. The water absorption capacity of leaves and stem powder-supplemented flour blends were in line with each other. The dough development time of purslane leaves and stem powder-supplemented blends was significantly affected in a dose-dependent manner. Treatment T3, which involved a 4% supplementation of purslane powder, required a longer time for dough development in both leaves (3.03 ± 0.12 min) and stem (3.01 ± 0.07 min) powder blends. The presence of higher fiber content in the blends increased the water absorption capacity of the flour, resulting in longer mixing times for dough preparation. The hydroxy groups present in fiber interact with water molecules, leading to

Table 3: Rheological characteristics of purslane powder.

Treatments		Water absorption (%)	Development time (min)	Stability (min)	Weakening (UF)	C-max (UF)
	T_0	59.00 ± 0.56	2.85 ± 0.09	11.48 ± 0.17	37.43 ± 1.38	493.09 ± 10.18
Leaves	T_1	59.31 ± 0.18	2.50 ± 0.07	9.50 ± 0.22	52.99 ± 1.76	474.84 ± 12.19
	T_2	59.02 ± 0.35	3.00 ± 0.10	10.50 ± 0.14	40.82 ± 1.87	465.97 ± 13.91
	T_3	59.12 ± 0.22	3.03 ± 0.12	10.50 ± 0.18	37.40 ± 2.16	466.75 ± 10.77
Stem	T_1	59.30 ± 0.09	2.03 ± 0.11	9.50 ± 0.25	57.41 ± 3.17	495.94 ± 7.64
	T_2	59.21 ± 0.12	2.50 ± 0.10	9.50 ± 0.24	50.85 ± 1.07	493.14 ± 14.68
	T_3	59.13 ± 0.19	3.01 ± 0.07	12.50 ± 0.13	40.11 ± 2.71	465.10 ± 12.72

slower water flow and requiring more time to reach all flour particles for dough preparation. Kohajdová et al. [42] reported similar findings, observing an increasing trend in the water absorption percentage in carrot pomace powder-supplemented blends from 60.67% to 72.01%. Ashoush and Gadallah [43] calculated the results for the increased water capacity of blends and also agreed when they incorporated mango peel powder and carrot pomace powder in wheat flour separately. In T_3, the blends showed higher dough development time of 3.03 ± 0.12 min and 3.01 ± 0.07 min both in leaves and stem powder-supplemented blends, respectively. It was evident from the results that the dough development time of blends was increased in a dose-dependent manner. Strong flours have high dough development time due to higher protein contents and gluten network formation. Dough stability and weakening depend upon the dough development time. Doughs with higher development time were more stable and stronger than those which took less time for development. The leaves and stem powder-supplemented doughs in treatment T_3 were more stable (10.50 ± 0.18 and 12.50 ± 0.13 min) and stronger (37.40 ± 2.16 and 40.11 ± 2.71 UF), respectively, as compared to the doughs in other treatments. Dough development time directly affected the dough's stability and inversely affected the dough's weakening. It was noticed that an increase in dough stability and a decrease in dough weakness was in a dose-dependent manner for all treatments. The blends containing 4% purslane powders (leaves and stem) added more protein contents in flour blends and resulted in increased dough development time with more stable, stronger, and elastic doughs. The consistency of the dough was decreased due to the addition of purslane leaves and stem powders in a dose-dependent manner. Leaves powder supplementation nonsignificantly affected the dough and showed consistency in the range of 465.97 ± 13.91–474.84 ± 12.19 UF, while stem powder supplementation affected the dough significantly and a slightly higher consistency of 495.94 ± 7.64 UF was measured in treatment T_1 and lower consistency of 465.10 ± 12.72 UF was measured in treatment T_3. Although, the rheological characteristics of purslane leaves and stem powders supplemented blends were determined for the first time; however, results measured for all rheological parameters were slightly in agreement with the rheological characteristics of other vegetables and fruit powder blends. Mironeasa and Codină [44] reported results for dough development time, dough stability, and dough strength that were consistent with the current study when tomato seed powder was added to wheat flour. However, Majzoobi et al. [45] gave contradictory results for the said parameters. They said that the addition of tomato pomace powder in white flour blends decreased the dough development time, dough stability, and dough weakness because the hydrophilic compounds present in tomato pomace powder absorb water quickly and increase the consistency of dough consequently, hence reducing the time required to prepare the dough of desired consistency. Rosell and Foegeding [46] said that as the dough is formulated it produces heat during the mixing process which causes protein denaturation and aggregation that result in decreased dough consistency.

3.5. Color Tonality of Purslane Powder Cupcakes. The color analysis of cupcakes supplemented with different concentrations of purslane leaves and stem powder was compared with the cupcakes supplemented with 100% white flour (control). The control sample made from white flour without sample supplementation was lighter as compared to the purslane powder-supplemented cupcakes. The color saturation and intensity were increased due to the highest values of redness and yellowness, while the purslane leaves and stem powder-supplemented cupcakes showed a decrease in color tonality as the percentage of powder increased (Table 4). Leaves powder-supplemented cupcakes gave the highest values for brightness (42.82 ± 1.27), yellowness (28.26 ± 0.42), and chroma (51.32 ± 0.98) in T_2, while T_1 showed the highest values for redness (11.23 ± 2.21). The brightness, yellowness, and saturation of colors in the T_2 confirmed that a specified amount of purslane leaf powder could be added for obtaining the desired color, with the increase in powder percentage fading the color of the cupcakes. The redness of cupcakes decreased with the increased percentage of purslane leaves powder, as the powder of purslane leaves was dark green in color. It was also noticed that percentage of purslane leaves powder was increased then its intensity was also increased as the highest hue angle (73.81 ± 2.03) was observed in T3. Purslane stems powder-supplemented cupcakes showed some variations from purslane leaves powder-supplemented cupcakes in case of redness and hue angle. In T_2, the lowest value (12.26 ± 0.25) for the redness of cupcakes was measured but the highest value (68.54 ± 0.90) was measured for color intensity. Similarly, the highest values for lightness (46.16 ± 1.81), yellowness (31.23 ± 0.97), and chroma (55.72 ± 1.91) were observed in T_2. The change in color tonality of cupcakes could be due to the color of the plant powder used. The results confirmed that to obtain the desired color of cupcakes a specified amount of purslane leaves and stem powder should be supplemented. The color changes of cupcakes could be due to the plant powder color,

Table 4: Color tonality of purslane powder cupcakes.

Treatments		L^*	a^*	b^*	c^*	h^*
	T_0	48.31 ± 1.67	15.42 ± 0.68	35.55 ± 1.39	59.98 ± 2.16	66.55 ± 0.49
Leaves	T_1	39.90 ± 4.79	11.23 ± 2.21	27.73 ± 3.34	48.60 ± 5.83	68.08 ± 2.28
	T_2	42.82 ± 1.27	9.30 ± 0.41	28.26 ± 0.42	51.32 ± 0.98	71.78 ± 0.52
	T_3	42.37 ± 1.81	7.60 ± 0.63	26.28 ± 1.33	49.86 ± 2.07	73.81 ± 2.03
Stem	T_1	42.89 ± 1.67	14.01 ± 1.78	30.26 ± 1.33	52.49 ± 2.02	65.21 ± 2.33
	T_2	46.16 ± 1.81	12.26 ± 0.25	31.23 ± 0.97	55.72 ± 1.91	68.54 ± 0.90
	T_3	35.96 ± 2.92	14.02 ± 0.61	27.95 ± 2.36	45.60 ± 2.62	63.27 ± 2.66

L^*, lightness; a^*, redness; b^*, yellowness; c^*, chroma; h^*, hue.

baking time, baking temperature, and the tray used for the baking purpose. The caramelization of sugars may also occur in supplemented cupcakes during baking, which also changes the color. Sello and Mostafa [47] supplemented 5–10% of pumpkin powder in cupcakes and evaluated that an increase in lightness and yellowness and a decrease in redness of cupcakes occurred in a dose-dependent manner. Ghaboos et al. [48] prepared the sponge cake with the addition of pumpkin powder up to 5–20%, which decreased the lightness and increased the redness and yellowness of the sponge cake in a dose-dependent manner. Adegunwa et al. [49] added watermelon flour up to 10 to 50% replacing plantain flour and prepared the cake. They observed that the replacement of plantain flour with watermelon flour in the cake gave dark, green, and blue shades to the cake.

4. Conclusions

The study focused on dehydrating purslane and analyzing its potential use in cupcakes by supplementing them with up to 4% purslane leaves and stem powders. The results indicated significant amounts of proteins and minerals in purslane leaves and powders. By incorporating purslane leaves and stem powder in cupcakes, it can fulfil to meet the dietary requirements and address the micronutrient deficiencies (calcium, potassium, and iron). Moreover, purslane leaves exhibited higher levels of TPC, %DPPH inhibition, and FRAP values as than stems. These improved rheological parameters, color indices, and sensorial appraisals were observed for the supplementation of purslane into traditional unsupplemented bakery items, in order to improve nutritional and phytochemical levels in baking innovations. Future bioethical studies are encouraged to explore the nutraceutical potential of purslane intake.

Data Availability

The data used to support the findings of the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Muhammad Younis performed the formal analysis and wrote the original draft. Khurram Afzal performed the formal analysis and wrote, reviewed, and edited the article. Muhammad Tauseef Sultan supervised, validated, reviewed, and edited the study. Roshina Rabail and Muhammad Asim Shabbir acquired the data and wrote, reviewed, and edited the study. Saeed Akhtar validated the study and wrote, reviewed, and edited the study. Tariq Ismail interpreted the data and utilized the resources and wrote, reviewed, and edited the study. Muhammad Usman Khalid interpreted the data and wrote, reviewed, and edited the study. Rana Muhammad Aadil supervised the study and wrote, reviewed, and edited the study. All the authors agreed to submit this article.

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