



Determination of the distribution of bioactive compounds, antioxidant activities, polyphenols and macro and microelement contents in different parts of wild and cultivated purslane (*Portulaca oleracea* L.) plants

Isam Ali Mohamed Ahmed¹ · Fahad AlJuhaime¹ · Mehmet Musa Özcan² · Nurhan Uslu² · Emad Karrar³

Received: 27 April 2024 / Accepted: 20 March 2025 / Published online: 3 April 2025
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Abstract

In this study, differences in total phenol, flavonoid, carotenoid content, antioxidant activity, polyphenols and minerals in different parts (flower, leaf, stem, root) of the purslane plant were investigated. Total amounts of carotenoids ranged from 1.69 ± 0.05 (stem) to 27.92 ± 0.00 $\mu\text{g/g}$ (leaf) and 2.22 ± 0.00 (root) to 48.03 ± 0.10 $\mu\text{g/g}$ (leaf) in the cultivated and wild purslane respectively. Total phenolic contents of cultivated and wild purslane plant were characterized between 29.40 ± 0.43 (stem) and 102.42 ± 4.63 (flower) to 37.17 ± 0.28 (stem) and 64.56 ± 0.68 mg gallic acid equivalent (GAE)/100 g (flower), respectively. Total flavonoid amounts of cultivated and wild purslane plants were established between 53.29 ± 0.84 (stem) and 402.71 ± 13.14 mg/100 g (flower) to 87.57 ± 1.93 (stem) and 153.95 ± 1.10 mg/100 g (flower), respectively. While antioxidant activities of cultivated purslane plant was determined between 1.45 ± 0.00 (root) and 1.53 ± 0.00 mmol/kg (leaf), antioxidant activities of wild purslane parts were monitored between 1.51 ± 0.02 (flower and root) and 1.58 ± 0.00 mmol/kg (leaf). While gallic acid contents of the parts of cultivated purslane were detected between 0.43 ± 0.14 (flower) and 3.67 ± 0.00 mg/100 g (stem), the gallic acid amounts of the parts of wild purslane plant were recorded between 2.46 ± 0.29 (stem) and 3.62 ± 0.36 mg/100 g (flower). 3,4-Dihydroxybenzoic acid amounts of the parts of both cultivated and wild purslane plants were identified between 0.98 ± 0.90 (flower) and 3.98 ± 0.29 (leaf) to 3.24 ± 0.34 (stem) and 6.77 ± 0.30 mg/100 g (flower), respectively. The amount of phosphorus (P) in parts of cultivated and wild purslane plants were determined between 1059.38 ± 74.08 (root) and 3039.08 ± 168.38 (flower) to 1177.46 ± 40.80 (root) and 3078.11 ± 96.05 mg/kg (flower), respectively. While amounts of K in cultivated purslane parts are recorded between $28,341.18 \pm 1598.47$ (flower) and $85,645.01 \pm 1033.52$ mg/kg (stem), K contents of wild purslane plant were found between $27,213.16 \pm 636.85$ (root) and $59,281.55 \pm 1412.66$ mg/kg (stem). The lowest bioactive components were determined in the stem part of both plants (cultivated and wild). Interestingly, the roots of the cultivated and wild purslane plant had a higher total flavonoid content. The highest ferulic acid and quercetin were found in the flower and leaf parts of both plants, respectively.

Keywords Purslane · Wild · Cultivated · Plant parts · Protein · Bioactive properties · Polyphenols · Minerals

Introduction

Purslane (*Portulaca oleracea* L.), which has a worldwide distribution and grows widely in the subtropical and tropical regions of the Mediterranean basin, is an annual succulent plant and cosmopolitan herb with thick, green leaves and medicinal properties [1–5]. Purslane is called “Reglah” in Egypt [6]. The World Health Organization reported that purslane is among the most used medicinal plants [7]. Purslane has been reported to thrive in many biogeographical regions around the world and has been reported to be highly

✉ Mehmet Musa Özcan
mozcan@selcuk.edu.tr

¹ Department of Food Science & Nutrition, College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia

² Faculty of Agriculture, Department of Food Engineering, Selcuk University, 42031 Konya, Turkey

³ Department of Plant Sciences, North Dakota State University, Fargo 58108 ND, USA

adaptable to drought and salinity [8]. Purslane is an invasive weed, although the above-ground parts of the plant are consumed as a vegetable in Mediterranean regions [9]. It has been reported that the stem and leaves of purslane resemble spinach due to their salty and slightly acidic taste and are consumed as a vegetable. In addition to being consumed fresh, it has been reported to be used as a tea or soup after drying [10, 11]. The protein, crude fibers, ash, Ca and Fe contents of Purslane change between 17.50–29.04%, 5.00–12.00%, 17.80–23.01%, 380–2625 mg/100 g and 46–550 mg/100 g (dw), respectively [12, 13]. Because purslane contains high amounts of phenolic constituents, it has antioxidant properties that act as free radical scavenger and lipid peroxidation inhibitor [14–16]. As a result of various studies, the presence of flavonoids as the main components of purslane has been reported [17, 18]. Purslane, whose leaves and stems are added to salads as raw or cooked, has been defined as a “functional food” in recent years due to its high nutritional properties [1, 19]. Purslane has been reported as the “Powerful Foods of the Future” due to its high nutritional and high antioxidant values [6]. Total phenol content with antioxidant properties of six purslane cultivars varies between 127 and 478 mg/100 g (fw) [10]. Although purslane is a very invasive weed, it has been reported to be rich in high omega-3 fatty acids and especially α -linolenic acid [20]. Purslane is the richest vegetable in terms of Omega-3 fatty acids and contains 400 mg/100 g Omega-3 fatty acids, especially as its high α -linolenic acid content and α -linolenic acid/linoleic acid ratio reveal that purslane is an important plant for balanced nutrition. It is stated that the total unsaturated fatty acid content in purslane is approximately 7–8 times higher than in spinach [21]. The amount of α -linolenic acid (18.3), α -tocopherol, ascorbic acid and glutathione in both wild and cultivated forms of purslane is higher than the amount contained in spinach. A fresh purslane leaf contains approximately 300–400 mg/100 g α -linolenic acid; 12.2 mg/100 g α -tocopherol, 26.6 mg/100 g ascorbic acid, 1.9 mg/100 g beta-carotene and 14.8 mg/100 g glutathione [22]. Nowadays, awareness of the consumption of functional foods, which provide versatile benefits on health beyond human nutrition, and the importance given to a plant-based diet is increasing day by day. In particular, green plants are preferred because of their low energy content, as well as being an important source of minerals, vitamins and fiber [23]. Edible parts of purslane have been reported to be rich in calcium, potassium, phosphorus, protein, carbohydrates, tocopherols, carotenoids and ascorbic acid [24–26]. Purslane is a wild herb with important medicinal uses due to its high level of nutraceutical compounds and worldwide prevalence [27]. It has also been reported that purslane has pharmacological antifungal, antimicrobial, antidiabetic, diuretic, hepatoprotective, neuroprotective, febrifuge, antiseptic, antispasmodic, vermifuge, anticancer,

anti-hyperlipidemic, anti-arthritic, antiinflammatory, antioxidant, anticholinesterase activities and germicidal properties [28, 29]. Although there are different studies around the world regarding the chemical and bioactive compounds of *Portulaca oleracea*, limited studies have been conducted on the identification of bioactive properties, phenolic components and mineral amounts of different parts of *Portulaca oleracea* grown in Turkey. Today, due to the increasing awareness of the consumption of functional foods that provide multi-faceted benefits on health and human nutrition, the interest in plant-based nutrition is increasing day by day. The goal of current work was to determine differences in total phenol, flavonoid, carotenoid contents, antioxidant activity, polyphenols and minerals in different parts (flower, leaf, stem, root) of purslane plants.

Material and methods

Material

Wild and cultivated purslane plants (flower, leaf, stem and root) were collected from the Çaltı neighborhood of the Selçuklu district of Konya in July 2023. The collected purslane plants were immediately brought to the laboratory in a cold bag (about 15 °C) and washed with distilled water. After the washing process, the water droplets on the plant were removed with tissue paper, and it was made ready for analysis.

Methods

Moisture content

The moisture amounts of the parts of cultivated and wild purslane plants were measured using the KERN & SOHN GmbH infrared moisture analyser.

Carotenoid content

The carotenoid amounts of the parts of cultivated and wild purslane plants were recorded according to the report described by Silva da Rocha et al. [30] with some modifications. After pretreatments, the acetone in the sample was removed by washing twice with 100 mL of distilled water. Then, the sample was completed with 25 ml of petroleum ether. After these processes, the absorbance values of the extract were recorded at 450 nm at spectrophotometer (Shimadzu UV mini 1240 Japan). The parts of purslane tested for carotenoid content were prepared in three replicates.

Extraction procedure

The parts of cultivated and wild purslane plants were obtained using the method reported by Alam et al. [31]. After each crushed purslane sample (5 g) was mixed to 20 mL of methanol, the solution was shaken in rinsing water-bath for 2 h at 25 °C. Mixture was then centrifuged at 6000 rpm for 20 min. The extract acquisition process was repeated twice and the extracts were collected in a balloon. 10 mL of methanol was added to the extract, concentrated in a vacuum rotary evaporator at 40 °C and then filtered.

Total phenolic content (TPC)

Total phenolic values of cultivated and wild purslane parts were investigated using the method described by Yoo et al. [32]. After the extract of each purslane part was mixed with 1 mL Folin-Ciocalteu and 10 mL Na₂CO₃, the solution was vigorously vortexed for 5 min. 25 mL of deionized water was added to the extract, filling it up to the balloon volume, and the mixture was left for 1 h. Then, total phenolic amount of purslane sample was monitored at 750 nm using a spectrophotometer (Shimadzu UV mini 1240, Japan). A calibration curve was prepared with gallic acid (0–200 mg/ml) as the standard (Fig. 1). TPC of samples was calculated as mg gallic acid equivalent (GAE) /100 g (fw). All treatments were performed in three replicates.

Total flavonoid content

Total flavonoid amounts of purslane extracts were recorded using colorimetric method as described by Hogan et al. [33]. After preprocessing, the absorbance values were read at 510 nm. The results obtained are stated as mg catechin equivalent (CE)/100 g (fw). All treatments were performed in three replicates.

Antioxidant activity (DPPH assay)

The antioxidant activity values of purslane extracts were measured using 1,1-diphenyl-2-picrylhydrazil (DPPH) as described by Lee et al. [34]. After mixing the extract with 2 ml of DPPH methanolic solution, the solution was vigorously stirred by vortexing and stored for 30 min for reaction in a dark room. The absorbance values (ΔA) were recorded at 517 nm. The percentage inhibition of free radical or antioxidant activity of extracts was calculated using following equation:

$$\text{Antioxidant activity(\%)} = \frac{\Delta A_{\text{Control}} - \Delta A_{\text{Extract}}}{\Delta A_{\text{Control}}} \times 100$$

Determination of phenolic compounds

The phenolic compound analyses of purslane extracts were carried out by using a Shimadzu-High-Performance Liquid Chromatography (HPLC-SCL-10A VP-Shimadzu, Japan) equipped with a photo diode array (PDA) detector and an Inertsil ODS-3 (5 μ m; 4.6 $\times$ 250 mm) column. The flow rate of the mobile phase and the injection volume were 1 ml/min at 30 °C and 20 μ l, respectively. The peaks were recorded at 280 nm using a PDA detector. The time (60 min) was calibrated as the total running time for per sample.

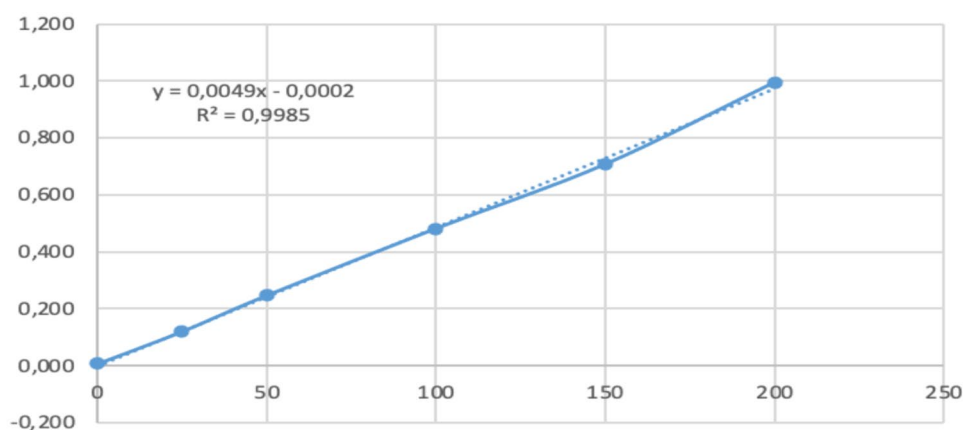
Determination of protein

Protein amounts of purslane seeds were established using the AOAC method [35].

Determination of mineral

After the crushed cultivated and wild purslane parts were dried in an oven at 70 °C for 48 h, 0.5 g of ground purslane powders was incinerated in a closed microwave system

Fig. 1 A calibration curve for total phenol



(Cem-MARS Xpress) using 5 ml of 65% HNO₃ and 2 ml of 35% H₂O₂. The volume of the sample was then completed up with 20 ml of distilled water. The mineral values of the purslane parts were determined by Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES) [36].

Statistical analyses

Mineral analyses of purslane parts were performed in triplicate, and variance analysis was performed on the results by averaging them. Analysis of variance (ANOVA) was performed by using JMP version 9.0 (SAS Inst. Inc., Cary, N.C.U.S.A). Duncan's Multiple Range test was used to establish the significant changes between the results of purslane samples ($p < 0.05$).

Results and discussion

Bioactive properties of the parts of cultivated and wild purslane

The moisture contents, total phenol, flavonoid, carotenoid and antioxidant capacities of the parts (flower, leaf, stem and root) of cultivated and wild Purslane are reported in Table 1. The moisture content of the parts of cultivated and wild purslane plants were established to be between 84.73 ± 0.07 (flower) and 92.19 ± 0.45 (leaf) to 79.77 ± 0.78 (root) and $89.79 \pm 0.49\%$ (stem), respectively. The highest total carotenoid contents were detected in the leaves of both cultivated and wild purslane parts. In addition, the highest total phenolic amounts were obtained in the flowers of both cultivated and wild purslane parts. Also, the lowest and highest total flavonoid contents of purslane parts were detected in the stem and flower parts, respectively. While antioxidant activities of cultivated purslane plants are determined between 1.45 ± 0.00 (root) and 1.53 ± 0.00 mmol/kg

(leaf), antioxidant activities of wild purslane parts were observed to be between 1.51 ± 0.02 (flower and root) and 1.58 ± 0.00 mmol/kg (leaf). Statistically significant differences were observed among moisture, total phenol, carotenoid and flavonoid contents of the purslane fractions ($p < 0.05$). Moisture amounts of both plants were determined mostly in the leaves and stem. The highest amounts of bioactive compounds (total phenol, flavonoid, and carotenoids) were obtained in the flowers and leaves of the cultivated and wild purslane plant. The total phenol values of the flowers and leaves of the cultivated purslane was higher than that of the flower and leaf of the wild purslane. However, the total carotenoid values and antioxidant activities of wild purslane flower and leaf were higher than those (flowers and leaves) obtained from the cultivated. The lowest bioactive components were determined in the stem of both plants (cultivated and wild). It has been observed that the roots of the cultivated and wild purslane plant contain higher total flavonoids than the stem parts. The leaves and stems of purslane plant contained 86.37–89.93% moisture, respectively [27]. The flowers and leaves of wild purslane plant samples had between 84.73 and 89.93% moisture content, respectively (Table 1), which are similar to results from the works of Dabbou et al. [27]. The total phenolic amounts of purslane plant parts were found to be between 78.3 and 633.9 mg/kg dry weight [20]. Methanol extract of Purslane plant contained 142.2 mgGAE/g total phenol and 81.2 mgQE/g total flavonoid [37]. In a previous study, Lim and Quah [10] reported that the total phenolic content of methanol extracts of 6 different cultures of *P. oleracea* changed between 127 and 478 mg GAE/100 g. Total phenolic and flavonoid contents of methanol extracts of purslane leaves were 326.80 mg/g and 44.33 mg GAE/100 g, respectively [9]. Total phenol and flavonoid in the leaves and stems of *P. oleracea* were found as 13.92 and 11.80 mg/100 g to 16.26 and 13.58 mg/100g, respectively [27]. Petropoulos et al. [38] pointed out that total phenol and total flavonoids of

Table 1 Moisture content and bioactive properties of cultivated and wild purslane plant parts(fw)

Sample	Parts of purslane	Moisture content (%)		Carotenoid content (µg/g)		Total phenolic content (mg/100 g)		Total flavonoid content (mg/100 g)		Antioxidant activity (mmol/kg)	
Cultivated	Flower	84.73	± 0.07d*	13.38	± 0.02b	102.42	± 4.63a	402.71	± 13.14a	1.50	± 0.00ab
	Leaf	92.19	± 0.45a	27.92	± 0.00a	63.29	± 0.49c	179.10	± 4.55c	1.53	± 0.00a
	Stem	91.48	± 0.68b	1.69	± 0.05 cd	29.40	± 0.43d	53.29	± 0.84d	1.48	± 0.02c
	Root	85.74	± 0.06c	1.90	± 0.02c	75.83	± 0.85b	281.86	± 9.83b	1.45	± 0.00 cd
Wild	Flower	85.55	± 0.39c	14.81	± 0.05b	64.56	± 0.68a	153.95	± 1.10a	1.51	± 0.02c
	Leaf	88.47	± 0.35b	48.03	± 0.10a	60.12	± 0.85b	141.10	± 3.94b	1.58	± 0.01ab
	Stem	89.78	± 0.49a	3.76	± 0.05c	37.17	± 0.28d	87.57	± 1.93d	1.59	± 0.00a
	Root	79.77	± 0.78d	2.22	± 0.00d	42.42	± 1.76c	126.52	± 2.75c	1.51	± 0.00c

*Values are mean ± standard deviation and those with different letters in each column are significantly different ($p < 0.05$)

6 different genotypes of *P. oleracea* were established to be between 7.65 and 20.1 mg GAE/g to 0.12 and 5.30 mg CE/g, respectively. Ercisli et al. [39] determined 17.88 µg GAE/mg total phenolic in purslane extract. Antioxidant activity values for DPPH and ABTS '2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) of fresh purslane leaves were 53.23% and 147.78 µmol trolox /100 g (dw), respectively [40]. DPPH radicals scavenging activities, total flavonoid and total phenolic values of the methanol extracts from the aerial parts of *P. oleracea* were 47.13%, 1317.41 µg/gCE/g, 75.96 mgGAE/g, respectively [41]. Purslane can be an easily accessible and natural source of phytochemicals and antioxidants [42] as reports have shown that an aqueous extract from Purslane may show high phenolic, flavonoid, anthocyanin, antioxidant effects [39, 42, 43]. Therefore, the antioxidant activities and free radical scavenging properties of phenolic compounds commonly found in plants are quite high [44]. It has been reported in another study that purslane leaves have the effect of increasing the antioxidant capacity, total phenolic and flavonoids and act as scavengers of free radicals produced during oxidation reactions [40]. However, the bioactive compound contents and antioxidant activities of the plants have significant differences according to the parts of the plant [44]. In general, it has been reported that the flavonoid contents of plants vary depending on the plant parts and solvents used for their extraction, genetic variability and edaphoclimatic conditions [45].

Phenolic compounds of the parts of cultivated and wild purslane

The phenolic profiles of the flower, leaf, stem and root of cultivated and wild purslane plants are displayed in Table 2. Results showed some differences among the purslane parts. Gallic acid, 3,4-dihydroxybenzoic acid, catechin, rutin and kaempferol were the dominant phenolic compounds in the various parts of cultivated and wild purslane investigated (Fig. 2). While the lowest and highest 3,4-Dihydroxybenzoic acid contents of the parts of cultivated purslane plants are identified in flowers and leaves, the lowest and highest 3,4-Dihydroxybenzoic acid contents of the parts of wild purslane plants were characterized in stems and flowers, respectively. While catechin amounts of the parts (flower, leaf, stem and root) of cultivated purslane plant varied between 2.57 ± 0.92 (root) and 9.36 ± 1.48 (leaf), catechin contents of the wild purslane parts were determined between 4.83 ± 0.87 (leaf) and 10.30 ± 2.08 mg/100 g (stem). While rutin values of cultivated purslane plant parts change between 0.51 ± 0.32 (root) and 4.08 ± 0.23 (leaf), rutin amounts of wild purslane parts were defined to be between 0.67 ± 0.35 (stem) to 5.45 ± 0.59 mg/100 g (flower) (Table 2). Kaempferol values of cultivated purslane parts were determined between 7.88 ± 0.76 (leaf) and

Table 2 Phenolic compounds of cultivated and wild purslane plant parts (mg/100 g)(fw)

Phenolic compounds	Cultivated				Wild			
	Flower	Leaf	Stem	Root	Flower	Leaf	Stem	Root
Gallic acid	0.43 ± 0.04d*	2.73 ± 0.61b	3.67 ± 0.29a	0.89 ± 0.00a	3.62 ± 0.08c	2.51 ± 0.36a	2.46 ± 0.72c	3.45 ± 0.29cd
3,4-Dihydroxybenzoic acid	0.98 ± 0.09c	3.98 ± 0.29a	3.05 ± 0.49a	1.55 ± 0.49a	6.77 ± 0.94b	3.27 ± 0.30a	3.24 ± 0.98c	5.39 ± 0.34cd
Catechin	4.12 ± 0.83c	9.36 ± 1.48a	7.06 ± 0.54b	2.57 ± 0.17b	6.28 ± 0.92d	4.83 ± 0.26c	10.30 ± 0.87d	7.61 ± 2.08a
Caffeic acid	0.28 ± 0.08d	1.74 ± 0.53a	0.94 ± 0.53a	0.36 ± 0.17b	0.84 ± 0.01c	1.08 ± 0.05c	0.64 ± 0.37b	1.80 ± 0.03d
Syringic acid	0.41 ± 0.07c	1.54 ± 0.99a	0.68 ± 0.23a	0.29 ± 0.06b	1.83 ± 0.03d	0.88 ± 0.61a	0.33 ± 0.40c	1.35 ± 0.06d
Rutin	2.01 ± 0.36b	4.08 ± 0.23a	1.11 ± 0.34c	0.51 ± 0.34c	5.45 ± 0.02d	2.19 ± 0.59a	0.67 ± 0.08b	1.06 ± 0.35d
p-Coumaric acid	0.30 ± 0.05b	0.64 ± 0.05a	0.03 ± 0.05a	0.01 ± 0.01c	0.37 ± 0.00cd	0.13 ± 0.18b	0.03 ± 0.02c	0.51 ± 0.01d
Ferulic acid	3.24 ± 0.98a	0.71 ± 0.02b	0.03 ± 0.02b	0.04 ± 0.01c	0.30 ± 0.01c	0.22 ± 0.08a	0.05 ± 0.04c	0.27 ± 0.01d
Resveratrol	0.89 ± 0.06b	1.18 ± 0.51a	0.03 ± 0.03a	0.03 ± 0.01c	0.09 ± 0.01c	0.09 ± 0.05a	0.08 ± 0.04a	0.04 ± 0.01b
Quercetin	0.95 ± 0.25b	3.81 ± 0.62a	0.21 ± 0.62a	0.38 ± 0.04d	0.34 ± 0.25c	0.35 ± 0.11b	0.11 ± 0.06a	0.21 ± 0.02d
Cinnamic acid	0.35 ± 0.02b	1.08 ± 0.64a	0.15 ± 0.64a	0.17 ± 0.03d	0.13 ± 0.09c	0.02 ± 0.04b	0.06 ± 0.01d	0.16 ± 0.01c
Kaempferol	12.89 ± 1.31a	7.88 ± 0.76d	10.11 ± 0.76d	8.38 ± 1.07b	6.57 ± 1.64c	5.19 ± 0.92c	7.68 ± 1.33d	7.16 ± 1.67a

*Values are mean ± standard deviation and those with different letters in each row are significantly different ($p < 0.05$)

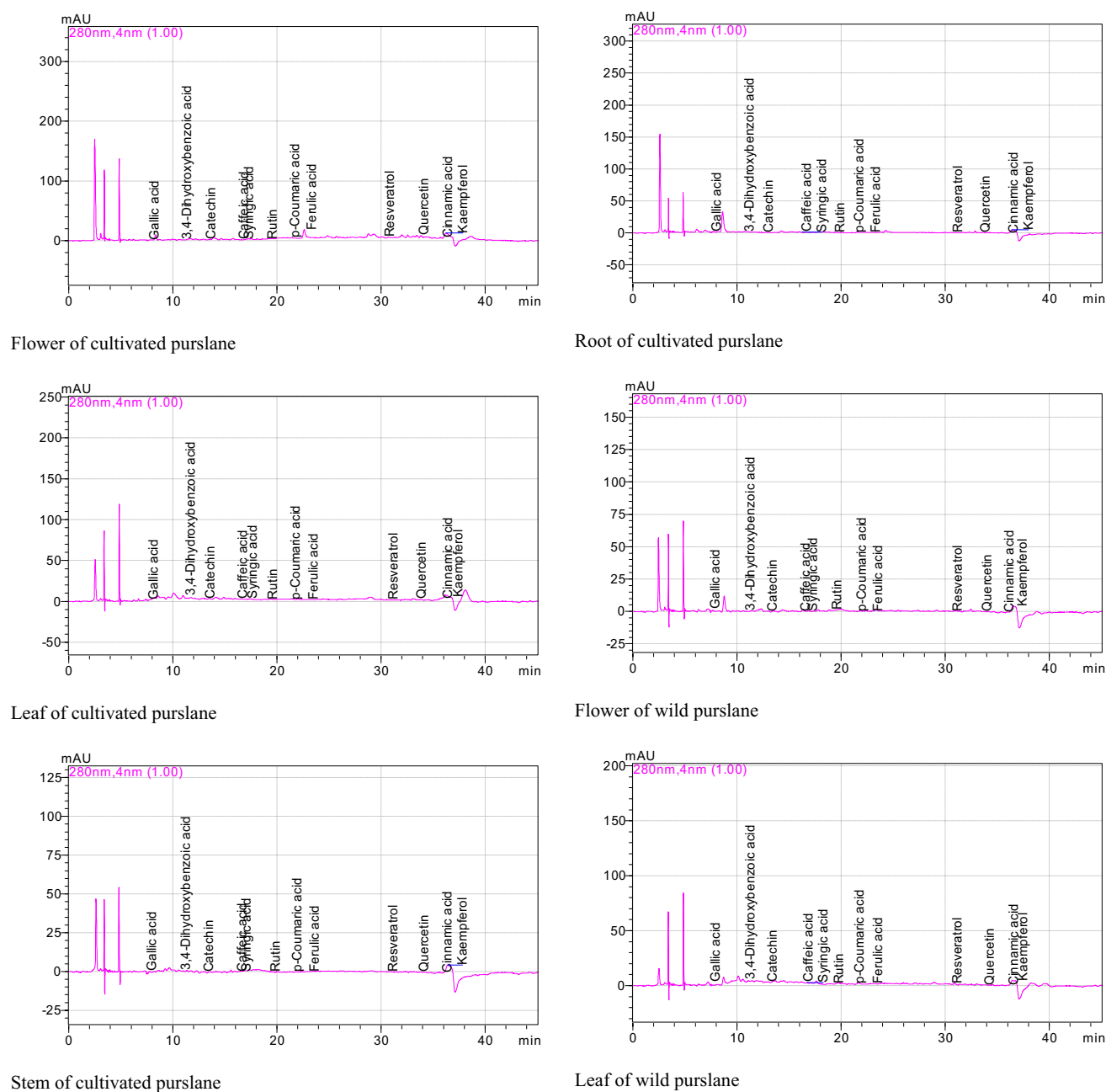


Fig. 2 Phenolic chromatograms of the parts of purslane plant. Flower of cultivated purslane. Leaf of cultivated purslane. Stem of cultivated purslane. Root of cultivated purslane. Flower of wild purslane. Leaf of wild purslane. Stem of wild purslane. Root of wild purslane

12.89 ± 1.31 (flower), while kaempferol contents of wild purslane parts are found between 5.19 ± 1.33 (leaf) and 7.68 ± 1.67 mg/100 g (stem). Statistically significant differences were observed among phenolic compounds of the parts of cultivated and wild purslane plants ($p < 0.05$). The highest ferulic acid and quercetin were found in the flowers and leaves of both plants, respectively. 3,4-dihydroxybenzoic acid, catechin and rutin were found in the leaves in cultivated purslane plant. The highest gallic acid and 3,4-dihydroxybenzoic acid were detected in the flowers of

the wild purslane plant. In general, phenolic component amounts (except kaempferol) of wild purslane parts were slightly higher than cultivated purslane plant parts. In addition, the content of phenolic compounds in the purslane plant showed changes according to plant part as well as plant types as well as plant type. Leaf, stem, and flower fractions of Thai purslane contained 2.78, 4.15 and 3.11 mg/g gallic acid, 1.93, 2.40 and 3.78 mg/g protocatechuic acid, 2.45, 2.08 and 2.84 mg/g *p*-hydroxybenzoic acid, 15.30, 14.95 and 18.20 mg/g chlorogenic acid, 1.28, 0.84 and 1.20 g/mg

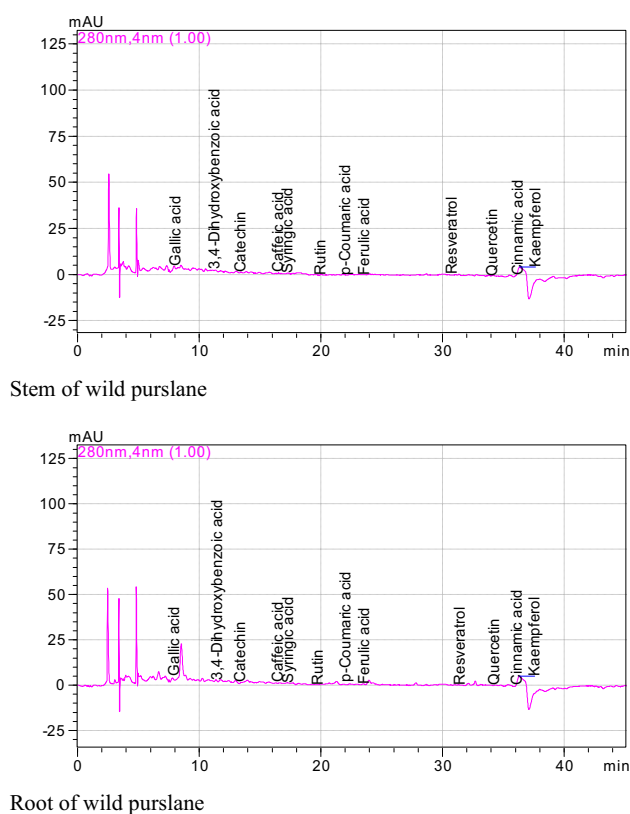


Fig. 2 (continued)

vanillic acid, 2.47, 2.97 and 3.68 mg/g caffeic acid, 2.38, 2.09 and 2.49 mg/g syringic acid, 1.82, 1.91 and 2.23 mg/g *p*-coumaric acid [14]. Leaves have a lower total phenolic content and antioxidant activity values than stems [46]. Flavonoids such as kaempferol, apigenin, myricetin, quercetin, and luteolin have been reported to be the main phenolic constituents found in purslane [11, 17]. *P. oleracea* L from different locations contain (in $\mu\text{g/g}$) 0.062–27.20 caffeic acid, 4.450–572.9 *p*-coumaric acid, 3.921–146.5 ferulic acid, 5.428–32.71 quercetin and 0.476–164.7 $\mu\text{g/g}$ apigenin [47]. *Portulaca oleracea* aerial parts contain (in $\mu\text{g/g}$) 0.10 rutin, 0.05 quercetin, 0.05 kaempferol, 5.10 catechin, 0.05 naringenin, 0.10 resveratrol, 5.75 vanillic acid, 25.05 gallic acid, 0.95 hydroxycinnamic acid, 11.10 caffeic acid, 2.35 ferulic acid, 4.70 rosmarinic acid [41]. The leaves, stems and flowers of *Portulaca oleracea* contain (in $\mu\text{g/g}$) 5.7, 13.58 and 7.8 coumaric acid, 71.3, 30.57 and 8.0 sinapic acid, 1.2, 0.0 and 0.8 caffeic acid, 4.2, 0.0 and 5.0 catechin, 6.8, 0.0 and 1.0 epicatechin, 7.3, 7.87 and 0.8 kaempferol, respectively [46]. Although phenolic compounds and oleracein derivatives have been detected in plant parts, the main compounds detected in the leaves of purslane have always been oleracein A and C [48]. Other phenolic compounds identified in purslane include apigenin, kaempferol, luteolin, quercetin, myricetin, genistein, genistin, portulacanonones A to D, caffeic,

chlorogenic, *p*-coumaric, ferulic and rosmarinic acids, lignins, stilbenes, terpenoids, saponins, tannins, chlorophyll, melatonin, bergapten and robustin, and the majority of these compounds are found in the aerial parts of purslane [49–51]. In addition, it has been reported that the amounts of phenolic compounds in purslane greatly increase with the progression of plant maturity [52]. When our results were compared to results of previous studies [46, 47], these changes may have been due to differences in genetic makeup, environmental factors, maturation and analytical factors [2, 3].

Macro-, micro element and crude protein contents of the parts of cultivated and wild purslane

The macro-, micro element and crude protein contents of the flower, leaf, stem and roots of cultivated and wild purslane plants are presented in Table 3. Significant differences ($p < 0.05$) were observed in the mineral and protein contents of both plant parts. The macro element amounts of both plant parts were found at very high levels. The amounts of phosphorus in parts of the cultivated and wild purslane plant were found to be between 1059.38 ± 74.08 (root) and 3039.08 ± 168.38 (flower) to 1177.46 ± 40.80 (root) and 3078.11 ± 96.05 mg/kg (flower), respectively. While K amounts of cultivated purslane parts are recorded between $28,341.18 \pm 1598.47$ (flower) and $85,645.01 \pm 1033.52$ mg/kg (stem), K contents of wild purslane plant were found between $27,213.16 \pm 636.85$ (root) and $59,281.55 \pm 1412.66$ mg/kg (stem). Flowers and leaves from cultivated Purslane had the least amounts of Ca while those from the roots and leaves of the wild plant recorded the highest Ca content (Table 3). Also, the amounts of Mg in cultivated and wild purslane plants (flower, leaf, stem and root) were measured between 6164.21 ± 95.94 (flower) and $14,538.97 \pm 825.74$ (leaf) to 3745.56 ± 61.94 (root) and $15,752.47 \pm 1241.28$ mg/kg (leaf), respectively. Statistically significant differences were recorded in the Mg contents of the parts of cultivated and wild purslane plants ($p < 0.05$). The highest S in cultivated and wild purslane plants were determined in the leaves (2251.40 ± 84.46 mg/kg) and flowers (1840.44 ± 111.59 mg/kg), respectively. Among the microelements of both plants, Fe was the element with the highest amount, followed by Mn, Zn, B and Cu. Fe amount of the parts of cultivated and wild purslane plants ranged from 64.61 ± 1.63 (stem) to 608.39 ± 1.40 (root) and 134.68 ± 0.61 (stem) to 592.05 ± 1.90 mg/kg (leaf) respectively. However, the Fe content in the leaves and roots of wild purslane were partly similar ($p < 0.05$). While Mn amounts in parts of cultivated purslane plant varied between 17.52 ± 0.60 (stem) and 94.46 ± 1.08 (leaf), Mn amounts of wild purslane parts changed between 13.55 ± 0.94 (stem) and 73.9 ± 1.69 mg/kg (leaf). The lowest and highest Zn contents in different parts of cultivated and wild purslane

Table 3 Mineral (mg/kg) and protein (%) contents of cultivated and wild purslane plant parts (dw)

Sample	P	K	Ca	Mg	S	Fe	Cu	Mn	B	Zn	Protein (%)
Cultivated (C) Flower	3039.08 ± 168.38b	28,341.18 ± 1598.47 g	5104.37 ± 21.82 h	6164.21 ± 95.94 g	1873.90 ± 78.23b	142.70 ± 0.31f	13.80 ± 0.94c	43.39 ± 0.77d	12.57 ± 0.34 h	32.61 ± 0.82a	20.27 ± 0.73a
C-leaf	2841.07 ± 105.75d	71,312.17 ± 900.99b	19,600.81 ± 92.10a	14,538.97 ± 825.74b	2251.40 ± 84.46a	349.62 ± 2.30e	11.64 ± 0.94e	94.46 ± 1.08a	27.71 ± 0.80b	25.35 ± 0.69b	18.98 ± 0.54b
C-stem	1067.27 ± 59.70 g	85,645.01 ± 1033.52a	17,803.17 ± 1378.21c	7174.03 ± 96.40e	1437.09 ± 63.89e	64.61 ± 1.63 h	6.24 ± 0.26 h	17.52 ± 0.60 g	21.45 ± 0.45d	10.72 ± 0.77f	12.72 ± 0.38ef
C-root	1059.38 ± 74.08 h	46,798.00 ± 502.96d	13,494.74 ± 1339.54d	6364.04 ± 108.66f	1104.22 ± 137.44f	608.39 ± 1.40a	8.56 ± 0.81 g	24.42 ± 0.97e	17.59 ± 1.85f	13.32 ± 1.86e	12.89 ± 0.56e
Wild (W) flower	3078.11 ± 96.05a	36,808.90 ± 506.16f	11,755.17 ± 1537.06f	12,295.85 ± 121.81c	1840.44 ± 111.59c	396.30 ± 0.87d	16.81 ± 0.50a	50.56 ± 1.69c	20.68 ± 0.55e	24.27 ± 1.87c	16.05 ± 0.71d
W-leaf	2927.58 ± 51.31c	41,498.38 ± 141.10e	18,638.82 ± 501.08b	15,752.47 ± 1241.28a	1615.18 ± 50.56d	592.05 ± 1.90b	15.78 ± 1.56b	73.90 ± 1.69b	34.31 ± 2.28a	16.64 ± 1.02d	18.43 ± 1.18bc
W-stem	1207.68 ± 4.93e	59,281.55 ± 1412.66c	13,461.98 ± 1057.45e	8370.88 ± 146.16d	946.68 ± 3.39 g	134.68 ± 0.61 g	8.94 ± 0.13f	13.55 ± 0.94 h	23.56 ± 0.96c	7.56 ± 1.27 h	8.50 ± 0.36gh
W-root	1177.46 ± 40.80f	27,213.16 ± 636.85 h	7535.97 ± 90.85 g	3745.56 ± 61.94 h	814.60 ± 1.24 h	527.46 ± 2.43c	12.66 ± 1.29d	21.71 ± 0.55f	17.31 ± 1.39 g	9.36 ± 1.34 g	8.85 ± 0.11 g

*Values are mean ± standard deviation and those with different letters in each column are significantly different ($p < 0.05$)

plants were obtained in the stems and flowers of both plant types, respectively. Statistically significant differences were recorded in the mineral contents of the parts of cultivated and wild purslane plants ($p < 0.05$). It can be seen that the highest and lowest Mn and Zn contents in cultivated and wild purslane were recorded in the leaves and stems parts of the plants, respectively (Table 3). Also, the highest amount of B was measured in the leaves of cultivated and wild purslane plants. The element found at the highest amount among the macroelements of purslane plants was K, followed by Ca, Mg, P and S in decreasing order. In general, the K, Ca, S and Zn contents of the cultivated purslane plant were high when compared to the parts of wild purslane while the P, Mg, Fe, Cu, Mn and B values of the cultivated purslane plant were found to be low. In general, the lowest macro elements were detected in the roots of both plants. This shows that the parts where both macro and microelements accumulate the most are the above-ground parts. In this study, it was observed that the leaves and floral parts had the highest mineral content compared with the other parts above ground surface. The flower and leafy parts of the Purslane plant were found to be higher in protein. While crude protein contents of the parts of cultivated purslane plant are determined between 12.72 ± 0.38 (stem) and $20.27 \pm 0.73\%$ (flower), the amounts of crude protein in wild purslane parts were found between 8.50 ± 0.36 (stem) and $18.43 \pm 1.18\%$ (leaf). It was also established that protein contents in all parts of both the cultivated and wild purslane plants were significantly different ($p < 0.05$). As seen in Table 3, the lowest protein content was detected in the stems of both purslane plants. In general, the protein contents of cultivated purslane plant parts were higher than wild purslane parts. Purslane is very rich in Fe, Zn, K, B, N, Mn, Ca Cu, Mg. However, P, S and Na elements were present in relatively low amounts in purslane [38, 53, 54]. Purslane leaves contained 188.6 mg/g Fe, 126.3 mg/g Zn, 53.7 mg/g K, 41.0 mg/g B, 14.0 mg/g Ca, 14.0 mg/g Cu, 8.4 mg/g Mg, 5.3 mg/g P [54]. In a previous study, the leaves, stems and roots of purslane were reported to contain 76,846, 51,376 and 45,720 $\mu\text{g/g}$ P, 267.79, 110.18 and 138.23 $\mu\text{g/g}$ Ca, 581.80, 447.41 and 529.17 $\mu\text{g/g}$ K, 28.05, 11.58 and 64.65 $\mu\text{g/g}$ Fe, 19.85, 2.34 and 2.83 $\mu\text{g/g}$ Mn, and 9.21, 2.41 and 5.18 $\mu\text{g/g}$ Cu, respectively [24]. There are reports of lowered blood pressure when hypertension patients were fed diets high in potassium [55]. Therefore consuming Purslane as food could help reduce the blood pressure of hypertension patients as they benefit from its high potassium content, compared to most other vegetables [55]. It may be recommended that the soil of the Purslane cultivation for nutritional purposes be tested for the presence of heavy metals or that it be grown in soilless environments where the mineral content of the growth medium can be easily monitored and controlled. In addition, the crop's bio-accumulation potential could make it a good candidate for

highly represented followed by Ca, Mg, P and S (in decreasing order). Future studies will be on the determination of changes in bioactive properties and phenolic components of purslane, which has succulent properties, for processing into fermented products.

Acknowledgements The authors extend their appreciation to Researchers Supporting Project Number (RSPD2025R1074), King Saud University, Riyadh, Saudi Arabia.

Author contributions Isam A. Mohamed Ahmed: editing; Fahad AlJuhaimi: validation, software, editing; Mehmet Musa Özcan: Methodology, writing-reviewing; Nurhan Uslu: formal analysis; Emad Karrar: editing; investifation.

Funding Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). This study was funded (RSPD2025R1074) by King Saud University, Riyadh, Saudi Arabia.

Data availability The data have been reviewed depending on the literature.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable.

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