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Comparative analysis of antioxidant activities and phenolic contents in selected wild edible plants

Ertan Yildirim[1], Melek Ekinci[1], Metin Turan[2], Elif Maskan[1], Halil Ibrahim Binici[3]*

[1]Department of Horticulture, Faculty of Agriculture, Atatürk University, Erzurum, Turkey; [2]Department of Agricultural Trade and Management, School of Applied Sciences, Yeditepe University, Istanbul, Turkey; [3]Department of Food Technology, Vocational School, İstanbul Esenyurt University, İstanbul, Turkey

***Corresponding Author:** Halil Ibrahim Binici, Department of Food Technology, Vocational School, İstanbul Esenyurt University, İstanbul, Turkey. Email: halilibrahimbinici@esenyurt.edu.tr

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Abstract

This study presents a comparative evaluation of the antioxidant activities and phenolic contents of widely consumed wild edible plants in Türkiye. Various biochemical parameters, including moisture content, ash content, pH, titratable acidity, total phenolic content (TPC), total flavonol (Tflavonol), and total flavonoid (Tflavonoid) content, were determined alongside antioxidant activities assessed by FRAP, DPPH, ABTS, and CUPRAC assays. Significant variations were observed among the plant species. *Polygonum alpinum* exhibited the highest TPC (66.27 mg GAE/100 g) and CUPRAC antioxidant capacity (38.08 mg TEAC/100 g), whereas *Hylotelephium telephium* showed the lowest antioxidant activity (TPC: 7.99 mg GAE/100 g; ABTS: 7.11 mg TEAC/100 g). *Urtica dioica* demonstrated notable antioxidant activity, particularly in the FRAP (10.74 mg TEAC/100 g) and DPPH (7.89 mg TEAC/100 g) assays. Principal component analysis (PCA) effectively distinguished *Heracleum spondylium*, *Rumex tuberosus*, and *Polygonum alpinum* from the other species, clustering them based on their elevated antioxidant and phenolic content. The findings emphasize the nutritional significance and functional food potential of these wild plants, offering valuable insights for future applications in the food and health industries.

Keywords: Wild edible plants, antioxidant capacity, phenolic compounds, functional foods

Introduction

Plants are indispensable natural resources for human health because of their rich biochemical components and potential pharmacological effects. Because of the increasing population and limited resources, food security has become a major global challenge. To meet the ever-increasing demand for food to feed the growing population, we need to continuously upgrade and enrich our food basket by discovering and utilizing new and nutritious food options. In particular, phenolic compounds, flavonoids, and their antioxidant activities play a crucial role in preventing free radical damage and reducing oxidative stress (Rice-Evans *et al.*, 1997). The Anatolian region hosts numerous native plant species that are widely used in traditional medicine and stand out because of their high biochemical content. There is increasing scientific awareness that traditionally used wild vegetables play an important role in human nutrition and health and are natural sources of antioxidants. This feature of plants is the result of their high phytochemical content, including phenolic acids, ascorbic acid, flavonoids, carotenoids, and tocopherols. Studies on traditionally used wild vegetables in different parts of the world, such as India, Turkey, Tanzania, and Nigeria, have shown that many of these species have higher protein, mineral, and vitamin

content than cultivated vegetables such as spinach and cabbage. Consumption of wild vegetables and plants is one of the strategies adopted by the local people for nutrition and is linked to their strong traditional and cultural values. These locally available edible plants and plant parts are known to be rich sources of protein, iron (Fe), and calories. They are also noted for their characteristic color, taste, and therapeutic values, and they are used in diets to prevent nutritional deficiencies and degenerative diseases (Khan and Kakde, 2014). Among the secondary metabolites produced by plants, phenolics are the ones that contribute most to bitter, sour, or astringent tastes (these substances not only accumulate mostly in leaves and shoots but also in flowers and roots). They also provide a defense against insects and contribute to personal health and diet. Flavonoids, flavonols, tannins, and other polyphenolic compounds are also valuable antioxidant components of these wild edible vegetables (Samancioğlu *et al.*, 2016). Previous studies have also shown that wild edible plants are rich in phenolic content (Mwamatope *et al.*, 2023; Öztürk *et al.*, 2022; Pinela *et al.*, 2017).

Several plant species from Anatolia's local flora, such as *Onopordum acanthium, Hylotelephium telephium, Achillea arabica, Arctium minus, Malva neglecta, Polygonum alpinum, Rumex crispus,* and *Glaucium grandiflorum*, are highly sought after for their antioxidant, anti-inflammatory, and antimicrobial properties. These bioactive properties make them valuable not only for herbal treatments but also for applications in the food industry (Avci *et al.*, 2014; Dalla Costa *et al.*, 2024; Garsiya *et al.*, 2019; Ozsoy *et al.*, 2018; Şekeroğlu & Gezici, 2020). The total phenolic content (TPC), flavonoid and flavonol levels, and antioxidant capacities of these plants are of great significance for both health and food applications (Binici *et al.*, 2024). Kordali *et al.* (2021) investigated the activities of the antioxidant enzyme and total antioxidant, phenolic substance, and plant nutrient content of *Malva sylvestris* L. (mallow) and *Alcea rosea* L. (marshmallow) plant species belonging to the Malvaceae family. According to the research results, the highest peroxidase, catalase, superoxide dismutase, and ascorbate peroxidase enzyme activities were determined in *Alcea rosea* L. Total carotenoid and total phenolic substance values were also found to be higher in Alcea rosea L. compared to *Malva sylvestris* L. When the nutrient contents of the plants were evaluated, the highest amounts of nitrogen (N), phosphorus (P), sodium (Na), Fe, and manganese (Mn) were determined in *Alcea rosea* L., while the highest amounts of potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and copper (Cu) were determined in *Malva sylvestris* L.

The available data on the composition of bioactive compounds of many wild edible plants that are not cultivated but consumed as vegetables by local populations are still insufficient. Comprehensive biochemical analyses of species such as *Urtica dioica, Falcaria falcarioides, Artemisia absinthium, Polygonum cognatum, Rumex tuberosus, Heracleum spondylium,* and *Tragopogon reticulatus* remain limited. Therefore, this study aims to determine the total phenolic, flavonoid, and flavonol contents, as well as the antioxidant capacities of 20 different plant species native to Anatolia using DPPH, ABTS, FRAP, and CUPRAC methods. This research represents a significant step in scientifically supporting the biochemical potential of these plants and contributing to the existing literature.

Materials and Methods

Materials

In this study, wild herbs consumed as vegetables by the local population in the Kars region were collected between May and August 2023. The plant taxa used as materials include *Onopordum acanthium* (boğa dikeni), *Hylotelephium telephium* (camış kulağı), *Achillea arabica* (civanperçemi), *Arctium minus* (deve tabanı), *Malva neglecta* (ebemgümeci), *Polygonum alpinum* (eşkiman-at kulağı), *Rumex crispus* (evelik), *Glaucium grandiflorum* (haşhaş), *Urtica dioica* (ısırgan), *Falcaria falcarioides* (kazayağı), *Artemisia absinthium* (kelemenkeşir), *Astrodaucus orientalis* (kımı), *Polygonum cognatum* (kuşekmeği), *Rumex tuberosus* (kuzukulağı), *Salvia aethiopis* (öküzpöçüğü), *Heracleum spondylium* (tavşan topuğu), *Atriplex tatarica* (unluca), *Capsella bursa-pastoris, Nasturtium officinale* (yabani tere-acıgıcı), *Mentha spicata* (yarpuz), and *Tragopogon reticulatus* (yemlik). The plant species were collected from mountains, cultivated fields, river edges, roadsides, and pastures. All species were recognized by a medicinal botany expert from the Ataturk University and the University of Erzincan. Each batch consisted of at least 500 g of the edible parts of the plants, that is, basal leaves, young leaves and stems, or mid-ribs of basal leaves, depending on the species. They were collected at the optimum time for harvesting, when the edible parts were large enough. After collection and preparation, each sample was packed in plastic bags and transported to the laboratory in a cooled environment within 1 day. A specific specimen of each species was deposited at the Yeditepe University. The edible portions of the plant specimens were collected and stored at –20°C for further analysis. The family, species, local name, and geographical coordinates (altitude) of the wild plants consumed as vegetables collected within the scope of the study are presented in Table 1.

Total dry matter

Twenty randomly selected plants from each species, with their fresh weights measured, were first air-dried for 48 hours. Then, they were dried in an oven set at

Table 1. Family, local name, and coordinates of wild plants.

Family	Species	Local name	Geographical coordinates (Altitude)
Asteraceae	*Onopordum acanthium*	Boğa dikeni	40.5754 043.0373
Crassulaceae	*Hylotelephium telephium*	Camış kulağı	40.9008 043.0410
Asteraceae	*Achillea arabica*	Civan perçemi	40.8755 043.0321
Asteraceae	*Arctium minus*	Deve tabanı	40.5201 042.9614
Malvaceae	*Malva neglecta*	Ebemgümeci	40.7010 043.1730
Polygonaceae	*Polygonum alpinum*	Eşkiman-at kulağı	40.8997 043.0419
Polygonaceae	*Rumex crispus*	Evelik	40.5736 043.0399
Papaveraceae	*Glaucium grandiflorum*	Haşhaş	40.8995 043.0422
Urticaceae	*Urtica dioica*	Isırgan	40.8299 043.0819
Apiaceae	*Falcaria falcarioides*	Kazayağı	40.5196 042.9603
Apiaceae	*Artemisia absinthium*	Kelemenkeşir	40.4713 043.3271
Umbelliferae	*Astrodaucus orientalis*	Kımı	40.7072 043.1762
Polygonaceae	*Polygonum cognatum*	Kuşekmeği	40.5424 042.9994
Polygonaceae	*Rumex tuberosus*	Kuzukulağı	40.5424 042.9979
Lamiaceae	*Salvia aethipois*	Öküzpöçüğü	40.5210 042.9602
Apiaceae	*Heracleum spondylium*	Tavşan topuğu	40.9004 043.0378
Amaranthaceae	*Atriplex tatarica*	Unluca	40.5749 043.0396
Brassicaceae	*Capsella bursa-pastoris*	Yabani tere-acıgıcı	40.1515 043.6525
Lamiaceae	*Mentha spicata*	Yarpuz	40.1509 043.6542
Asteraceae	*Tragopogon reticulatus*	Yemlik	40.8783 043.0329

105°C for 1 day, and their dry weights were calculated (Cemeroğlu, 2010).

Ash content

The amount of ash left after burning the plant sample indicates the total mineral content of the plant. A specific amount of the sample was placed in ash crucibles and subjected to a pre-ash treatment over a burner before being placed in an ash furnace. The burning process lasted for 8 hours, and the calculation was based on the percentage weight loss (Cemeroğlu, 2010).

pH

The pH was determined according to Cemeroğlu (2010). For this purpose, approximately 10 g of dried sample was taken and rehydrated in 90 mL of distilled water for 1 day

at +4°C. The mixture was then homogenized by grinding in a mortar and filtered through coarse filter paper. The pH of the resulting filtrate was directly measured using a pH meter (OHAUS Starter 3100, USA).

Titration acidity

Titration acidity was determined potentiometrically using a pH meter (OHAUS Starter 3100;USA). For this purpose, the samples were titrated with a 0.1 N NaOH solution until the pH reached 8.1, and the titration acidity (g anhydrous citric acid/1000 mL) was calculated from the amount of base solution used (Cemeroğlu, 2010).

Preparation of samples for analysis

A 2 g sample of each plant species was weighed, and 20 mL of methanol was added. The mixture was homogenized at 20,000 rpm using an Ultra Turrax device. It was then placed in an ultrasonic water bath for 30 minutes. Afterward, the mixture was centrifuged at 6000 rpm (4200 × g) for 15 minutes. The supernatant was filtered using Whatman No. 42 filter paper. This extract was used for the analysis of TPC, DPPH, FRAP, ABTS, total flavonoid (Tflavonoid), total flavonol (Tflavonol), and CUPRAC levels (Stankovic, 2011).

Determination of the TPC

One milliliter of the prepared sample extract was transferred to a calibrated test tube. Then, 0.5 N Folin–Ciocalteu reagent and 10% Na_2CO_3 solution were added, and the volume was adjusted to 2.5 mL with distilled water. The tubes were incubated at room temperature for 30 minutes, and the absorbance was measured at 760 nm. The TPC was calculated in mg GAE/100 g of the sample using a freshly prepared gallic acid standard curve (Gülçin *et al.*, 2012).

Determination of antioxidant activity by the DPPH method

Thirty-nine milligrams of DPPH radical was weighed and diluted with ethanol to make a final volume of 100 mL. A quantity of 0.1 mL of the sample extract was transferred to test tubes, followed by the addition of 0.5 mL of DPPH solution and methanol to make the total volume 2.5 mL. The test tubes were capped, vortexed, and allowed to stand in the dark for 30 minutes. The absorbance was measured at 517 nm against a blank. DPPH radical scavenging activity was calculated in mg TEAC/100 g of the sample using a freshly prepared Trolox standard curve (Spada *et al.*, 2008).

Determination of antioxidant activity by the ABTS method

The $ABTS^+$ radical scavenging activity was determined according to Köksal *et al.* (2009). $ABTS^+$ radicals were generated by mixing 2 mM ABTS (2,2´-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)) solution with 2.45 mM potassium persulfate solution and allowing it to stand for 16 hours at room temperature in the dark. Before analysis, the solution was diluted to an absorbance of 700–800 at 734 nm. A quantity of 0.1 mL of the sample extract was transferred to test tubes, and the total volume was adjusted to 1.9 mL with distilled water. Then, 0.5 mL of $ABTS^+$ solution was added to each tube. Each tube was vortexed and incubated at room temperature and left in the dark for 30 minutes, and the absorbance was read at 734 nm. ABTS radical scavenging activity was calculated in mg TEAC/100 g of the sample using a freshly prepared Trolox standard curve.

Determination of Ferric (III) reducing ability of plasma (FRAP)

The FRAP method is based on the reduction of Fe^{3+}-TPTZ complex under acidic conditions. A fresh TPTZ solution (2.25 mL, 40 mM in 10 mM TPTZ in HCl) was prepared, and then mixed with an acetate buffer (25 mL, 0.3 M, pH 3.6) and FeCl3 solution (2.25 mL, 20 mM). Extract solutions with concentrations ranging from 10 to 30 µg/mL were prepared in 5 mL of the appropriate buffer solution, mixed, and incubated at 37°C for 30 minutes. The reduction of Fe^{2+}-TPTZ complex results in the formation of a deep blue color, and the absorbance was measured at 593 nm. FRAP values were calculated in mg TEAC/100 g of the sample using a freshly prepared Trolox standard curve (Göçer & Gülçin, 2011).

Determination of the Tflavonoid content

A quantity of 0.5 mL of the sample was taken, and 0.15 mL of 5% $NaNO_2$ solution was added. After 6 minutes, 0.15 mL of 10% $AlCl_3$ solution was added. After another 6-minute wait, 0.5 mL of 4% NaOH solution was added, and the volume was increased to 2.5 mL with distilled water. The absorbance was measured at 510 nm after 15 minutes of homogenization. The Tflavonoid content was calculated in mg QE/100 g of the sample using a freshly prepared Quercetin standard curve (Youssef & Mokhtar, 2014).

Determination of the Tflavonol content

A quantity of 0.5 mL of the sample extract was mixed with 0.5 mL of 2% aluminum chloride and 0.5 mL of 5% sodium acetate, and the total volume was increased to 2.5 mL with distilled water. The absorbance was measured at 425 nm. The Tflavonol content was calculated in mg QE/100 g of the sample using a freshly prepared Quercetin standard curve (Almaraz-Abarca *et al.*, 2007).

Determination of the Cu (II) reducing antioxidant capacity (CUPRAC)

A quantity of 0.1 mL of the sample extract was transferred to test tubes. Then, 0.5 mL of 0.01 mM $CuCl_2.2H_2O$, 0.5 mL of 7.5×10-3 mM Neocuproine, 0.5 mL of 1 M ammonium acetate (pH = 7.0), and 0.9 mL of distilled water were added to increase the total volume to 2.5 mL. The test tubes were kept in the dark at room temperature for 30 minutes, and the absorbance was measured at 450 nm using a spectrophotometer. CUPRAC values were calculated in mg TEAC/100 g of the sample using a freshly prepared Trolox standard curve (Apak *et al.*, 2004).

Statistical analysis

The experiment had a completely randomized design with four replications. To compare the mean values of the data obtained from the characterization of the nutritional content properties of the wild plants studied, analysis of variance (ANOVA) was performed using SPSS 25® software, and Duncan's test was applied. Principal component analysis (PCA) was performed using the SIMCA 14.1 software (UMETRICS, Umea, Sweden).

Results and Discussion

In this study, the moisture content (%), ash content (%), pH, and titration acidity (%) parameters of 20 different plant samples were analyzed (Table 2).

The highest dry matter content was observed in *Urtica dioica* at 25.89 ± 0.54%, while the lowest value was recorded in *Hylotelephium telephium* at 7.41 ± 0.42%. *Urtica dioica* was found to have significantly higher dry matter content than the other samples ($p<0.01$). The highest ash content was found in *Atriplex tatarica* at 4.13 ± 0.01%, while the lowest value was observed

Table 2. Total dry matter, ash content, pH, and titration acidity values of edible wild plant samples.

Samples/analyses	TDM (%)	Ash (%)	pH	Titration acidity (%)
Onopordum acanthium	15.04±0.18^{gh}	2.84±0.04^{e}	6.15±0.01^{fg}	0.21±0.02^{efg}
Hylotelephium telephium	7.41±0.42^{k}	1.07±0.02^{o}	5.09±0.01^{j}	0.28±0.01^{cd}
Achillea arabica	22.10±0.50^{cd}	3.55±0.03^{c}	6.23±0.05^{f}	0.14±0.01^{ijk}
Arctium minus	17.39±0.50^{f}	3.06±0.04^{d}	6.27±0.01^{ef}	0.20±0.02^{fgh}
Malva neglecta	14.72±0.33^{gh}	2.66±0.03^{g}	6.48±0.01^{cde}	0.31±0.01^{c}
Polygonum alpinum	22.53±1.16^{c}	1.75±0.03^{m}	4.54±0.01^{k}	0.84±0.10^{a}
Rumex crispus	12.10±0.58^{j}	2.32±0.02^{j}	6.55±0.01^{cd}	0.15±0.00^{hij}
Glaucium grandiflorum	21.14±1.42^{d}	0.84±0.02^{p}	5.72±0.01^{i}	0.23±0.02^{ef}
Urtica dioica	25.89±0.54^{a}	3.85±0.02^{b}	8.53±0.01^{a}	0.03±0.01^{m}
Falcaria falcarioides	19.35±0.50^{e}	2.27±0.02^{k}	6.51±0.01^{cd}	0.10±0.01^{kl}
Artemisia absinthium	22.09±0.64^{cd}	2.36±0.03^{ij}	6.17±0.01^{fg}	0.16±0.01^{ghi}
Astrodaucus orientalis	21.89±0.58^{cd}	3.06±0.03^{d}	6.33±0.01^{def}	0.21±0.01^{ef}
Polygonum cognatum	24.29±0.77^{b}	2.50±0.02^{h}	5.99±0.01^{gh}	0.24±0.01^{de}
Rumex tuberosus	17.25±0.55^{f}	1.29±0.03^{n}	4.15±0.01^{l}	0.72±0.02^{b}
Salvia aethipois	14.43±1.02^{hi}	2.40±0.02^{i}	5.91±0.57^{hi}	0.16±0.01^{ghi}
Heracleum spondylium	22.47±0.28^{c}	3.02±0.01^{d}	5.88±0.01^{hi}	0.29±0.01^{c}
Atriplex tatarica	15.79±0.41^{g}	4.13±0.01^{a}	7.16±0.01^{b}	0.09±0.01^{l}
Capsella bursa-pastoris	13.40±1.01^{i}	1.93±0.02^{l}	6.61±0.01^{c}	0.15±0.01^{ij}
Mentha spicata	19.51±0.75^{e}	2.76±0.03^{f}	6.53±0.01^{cd}	0.11±0.01^{jkl}
Tragopogon reticulatus	11.69±0.60^{j}	2.37±0.03^{ij}	6.37±0.01^{cdef}	0.16±0.00^{hi}
Sig.	**	**	**	**

Note: a–o means with different letters in the same column are significantly different ($p< 0.05$). *$p< 0.01$.

in *Glaucium grandiflorum* at 0.84 ± 0.02%. Significant statistical differences were found in the ash content ($p<0.01$). The highest pH value was measured in *Urtica dioica* at 8.53 ± 0.01, while the lowest pH value was found in *Rumex tuberosus* at 4.15 ± 0.01. Significant differences were found in the pH values of the plants ($p<0.01$). The highest titration acidity was observed in *Polygonum alpinum* at 0.84 ± 0.10%, while the lowest value was recorded in *Urtica dioica* at 0.03 ± 0.01%. Statistically significant differences were found in the acidity values ($p<0.01$). Çolakoğlu and Tömek (1975) reported that the pH value of wild herbs ranged between 6.08 and 6.46. Studies by Çolakoğlu and Bilgir (1977) also indicated that the pH value varied between 5.90 and 7.20. Different results can be obtained for the same species in different studies. This can be because of ecological factors, sampling methods, or differences in analysis techniques.

In this study, the TPC, Tflavonol, Tflavonoid content, and antioxidant activities (FRAP, DPPH, ABTS, and CUPRAC) were determined in 20 different plant samples, and the results were statistically evaluated (Table 3). The findings revealed significant differences in bioactive compounds and antioxidant activities among the plants ($p<0.01$). The highest TPC was found in *Rumex tuberosus* at 68.12 ± 0.05 mg GAE/100 g. This value was higher than those of *Polygonum alpinum* (66.27 ± 0.07 mg GAE/100 g) and *Heracleum spondylium* (48.02 ± 0.08 mg GAE/100 g) samples. The lowest TPC value was measured at 6.58 ± 0.12 mg GAE/100 g in *Onopordum acanthium*. In a study conducted by Feduraev *et al.* (2022), the TPC of some wild *Rumex* species (Polygonaceae) was reported to range between 23 and 131 mg GAE/g. Similarly, Kordali *et al.* (2021) determined the TPC of plant species belonging to the Malvaceae family to be between 5.34 and 7.92 mg GAE/g. These differences in TPC can be attributed to the genetic, environmental, and ecological factors influencing the synthesis of phenolic compounds in the plants.

In terms of Tflavonol content, the highest value was recorded in *Heracleum spondylium* at 10.55 ± 0.01 mg QE/100g, while the lowest value was observed in *Hylotelephium telephium* at 0.77 ± 0.02 mg QE/100g. For Tflavonoid content, *Heracleum spondylium* showed the highest value at 46.59 ± 0.08 mg QE/100 g. In addition, they defend against insects and contribute to personal health and diet. Flavonoids, flavonols, tannins, and other polyphenolic compounds are also valuable antioxidant components of these wild edible vegetables (Samancioğlu *et al.*, 2016). Flavonoids are important specialized metabolites involved in plant signaling and defense and emerge as essential components that provide significant health benefits to humans. Flavonoids are nonessential nutrients that provide an extra nutraceutical value to human diet. Their health benefits have historically been recognized in different cultures. Flavonoids, including flavones, are gaining increasing attention because of their anti-inflammatory, antimicrobial, and anticancer activities (Jiang *et al.*, 2016). Previous studies have also reported that wild herbs consumed as vegetables are rich in phenolic and flavonoid content (Alan *et al.*, 2022; Ereifej *et al.*, 2015; Mwamatope *et al.*, 2023; Öztürk *et al.*, 2022; Pinela *et al.*, 2017; Samtiya *et al.*, 2021). This result highlights the impact of flavonoids on antioxidant activity and indicates that plants like *Heracleum spondylium* are rich in bioactive components.

When evaluating the results of antioxidant activity, *Rumex tuberosus* exhibited the highest values in DPPH (7.13 ± 0.07 mg TEAC/100 g), ABTS (9.52 ± 0.01 mg TEAC/100 g), and CUPRAC (33.13 ± 0.05 mg TEAC/100 g) tests. *Polygonum alpinum* displayed the highest value in the FRAP method at 2.66 ± 0.00 mg TEAC/100 g. On the other hand, plants such as *Onopordum acanthium* and *Capsella bursa-pastoris* showed low activity in all antioxidant tests. In their study on the variability of phenolic compound accumulation and antioxidant activity in some wild *Rumex* species (Polygonaceae), Feduraev *et al.* (2022) reported the DPPH, ABTS, and FRAP values to range from 3.1 to 69 mg TE/g, 5.1 to 63 mg TE/g, and 3.9 to 61 mg TE/g, respectively. Karakaş *et al.* (2025) reported the ABTS, DPPH, and CUPRAC values of *Polygonum* species to range from 25.90 to 832.9 μg/mL, 41.26 to 746.11 μg/mL, and 15.21 to 133.45 μg/mL, respectively. Among the secondary metabolites produced by plants, phenolics are the best contributors to bitter, sour, or astringent tastes (these compounds primarily accumulate in leaves and stems but also accumulate in flowers and roots).

PCA of wild edible plants

PCA was performed to differentiate the wild edible plant samples based on their biochemical properties and antioxidant capacities. The score scatter plot, loading scatter plot, and biplot of the samples are shown in Figures 1A–C, respectively. The first two principal components (PC1 = 66.5% and PC2 = 20.5%) explained 87% of the total variance. The score scatter plot (Figure 1A) clearly shows that *Heracleum spondylium*, *Rumex tuberosus*, and *Polygonum alpinum* are distinctly separated from the other plant samples, indicating their unique biochemical and antioxidant properties. The loading scatter plot (Figure 1B) demonstrates that ABTS, TPC, DPPH, FRAP, CUPRAC, flavonol, and flavonoid are clustered on the right side, suggesting a strong positive correlation among these parameters. The biplot (Figure 1C) further confirms that these three plant species exhibit higher antioxidant and phenolic values, setting them apart from the other wild edible plants analyzed in this study.

Table 3. Total phenolic content, total flavonol, total flavonoid content, and antioxidant activity values of edible plant samples.

Samples/analyses	TPC (mg GAE/100g)	Tflavonol (mg QE/100 g)	Tflavonoid (mg QE/100 g)	FRAP (mg TEAC/100 g)	DPPH (mg TEAC/100 g)	ABTS (mg TEAC/100 g)	CUPRAC (mg TEAC/100 g)
Onopordum acanthium	6.58±0.12^{s}	2.02±0.03^{o}	5.75±0.10^{p}	0.29±0.00^{t}	2.45±0.05^{l}	2.05±0.01^{s}	6.90±0.04^{s}
Hylotelephium telephium	7.99±0.09^{r}	0.77±0.02^{r}	1.44±0.26^{r}	0.52±0.00^{r}	0.86±0.04^{m}	2.75±0.01^{l}	7.11±0.04^{s}
Achillea arabica	20.71±0.08^{h}	3.51±0.03^{h}	35.40±0.23^{e}	1.37±0.00^{f}	3.36±0.08^{h}	3.78±0.01^{f}	22.63±0.02^{f}
Arctium minus	9.70±0.03^{n}	2.66±0.01^{m}	14.09±0.32^{k}	0.65±0.00^{m}	0.82±0.02^{mn}	2.69±0.00^{n}	13.65±0.02^{l}
Malva neglecta	9.18±0.15^{o}	2.96±0.02^{k}	13.41±0.17^{l}	0.63±0.00^{o}	0.84±0.21^{mn}	2.65±0.01^{o}	12.93±0.03^{m}
Polygonum alpinum	66.27±0.07^{b}	9.01±0.01^{b}	38.62±0.15^{b}	2.66±0.00^{a}	12.28±0.02^{a}	10.17±0.01^{a}	38.08±0.02^{a}
Rumex crispus	16.26±0.01^{l}	3.14±0.01^{j}	12.98±0.11^{m}	0.62±0.00^{p}	0.55±0.05^{p}	2.66±0.01^{o}	12.80±0.05^{n}
Glaucium grandiflorum	19.23±0.03^{i}	1.08±0.02^{p}	7.98±0.34^{o}	0.83±0.00^{l}	2.15±0.04^{j}	3.64±0.01^{g}	12.04±0.05^{o}
Urtica dioica	10.74±0.06^{m}	2.75±0.01^{l}	13.39±0.08^{l}	0.64±0.00^{n}	1.17±0.04^{l}	2.61±0.00^{r}	14.88±0.03^{k}
Falcaria falcarioides	8.45±0.07^{p}	2.77±0.00^{l}	14.43±0.20^{k}	0.45±0.00^{s}	0.74±0.04^{no}	2.64±0.01^{p}	9.80±0.03^{p}
Artemisia absinthium	16.47±0.16^{k}	3.41±0.02ı	15.07±0.11^{j}	0.86±0.00^{k}	1.81±0.01^{k}	2.77±0.00^{k}	17.29±0.05^{j}
Astrodaucus orientalis	18.99±0.05^{j}	5.14±0.01^{f}	24.53±0.30^{g}	1.27±0.00^{g}	2.15±0.04^{j}	3.56±0.01^{h}	17.34±0.04^{j}
Polygonum cognatum	35.03±0.02^{d}	6.44±0.00^{c}	36.89±0.28^{d}	1.81±0.00^{d}	5.48±0.04^{d}	5.30±0.00^{c}	29.65±0.05^{c}
Rumex tuberosus	68.12±0.05^{a}	6.22±0.02^{d}	37.55±0.12^{c}	2.49±0.00^{b}	7.13±0.07^{c}	9.52±0.01^{b}	33.13±0.05^{b}
Salvia aethipois	10.79±0.05^{m}	3.40±0.03ı	19.66±0.35^{h}	0.95±0.00^{j}	0.83±0.04^{mn}	3.02±0.01^{j}	18.50±0.05^{h}
Heracleum spondylium	48.02±0.08^{c}	10.55±0.01^{a}	46.59±0.08^{a}	1.91±0.00^{c}	7.89±0.07^{b}	4.93±0.00^{d}	28.40±0.04^{d}
Atriplex tatarica	22.23±0.09^{g}	4.83±0.02^{g}	17.03±0.23ı	0.97±0.00ı	4.09±0.02^{f}	2.72±0.00^{m}	18.12±0.02ı
Capsella bursa-pastoris	9.08±0.14^{o}	2.06±0.04^{n}	9.15±0.29^{n}	0.43±0.00ş	0.68±0.08^{o}	2.60±0.01^{r}	8.98±0.06^{r}
Mentha spicata	24.62±0.04^{f}	5.95±0.02^{e}	34.94±0.30^{f}	1.55±0.00^{e}	4.90±0.05^{e}	4.24±0.00^{e}	21.48±0.06^{g}
Tragopogon reticulatus	26.65±0.04^{e}	5.96±0.02^{e}	35.49±0.20^{e}	1.26±0.00^{h}	3.77±0.01^{g}	3.26±0.01^{i}	23.89±0.04^{e}
Sig.	**	**	**	**	**	**	**

Note: a–t means with different letters in the same column are significantly different ($p< 0.05$). *$p< 0.01$.

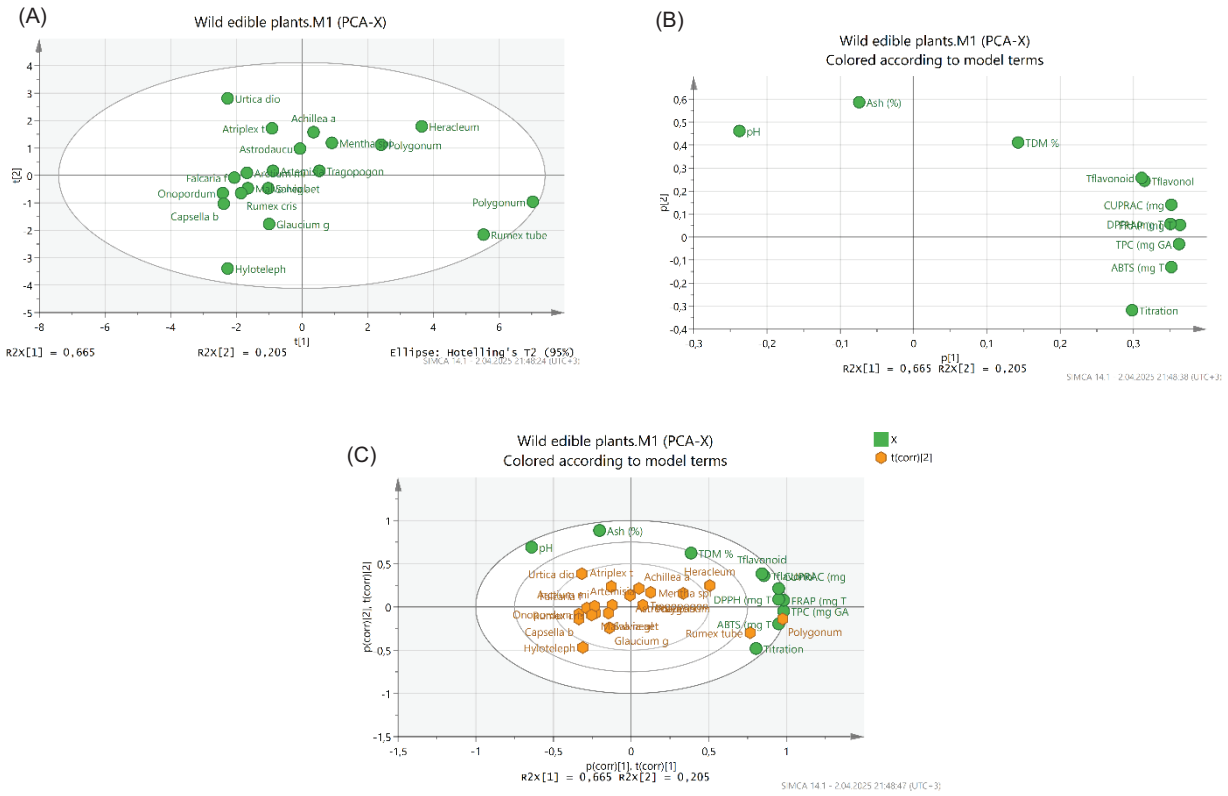

Figure 1. The score scatter plot (A), loading scatter plot (B), and biplot (C) of PCA analysis (PC1 vs. PC2) for the components in the samples.

Conclusions

Based on these data, distinct differences have been observed between the physical and chemical components of the samples and their antioxidant activities. Generally, samples such as *Polygonum alpinum*, *Rumex tuberosus*, and *Heracleum spondylium* are found to have higher antioxidant capacities, with *Polygonum alpinum* and *Rumex tuberosus* also exhibiting notably high TPC and Tflavonoid values. On the other hand, samples like *Hylotelephium telephium* and *Falcaria falcarioides* demonstrated lower antioxidant activities but still possessed certain potential in terms of various components. In conclusion, these data indicate that different plants have significant potential in terms of antioxidant capacity and contain valuable bioactive compounds that can be used in various food or pharmaceutical industry products. Such analyses will pave the way for further research, especially in the fields of functional foods and natural therapies.

Data Availability Statement

Data are contained within the article.

Author Contributions

Conceptualization was done by E.Y., M.E., and M.T; methodology was the responsibility of E.Y. and E.M.; software was looked into by H.İ.B.; validation was done by M.E., E.Y., and E.M.; formal analysis was taken care of by E.Y., M.T., and H.İ.B; investigation was done by E.Y.; resources were handled by E.M.; writing—original draft preparation was done by E.M, H.İ.B, and E.Y.; writing—review and editing were done by E.M. and E.Y.; visualization was the responsibility of E.M.; supervision was taken care of E.M. and E.Y.; and project administration was looked into by E.Y. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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