

The effect of different drying methods on nutritional composition and antioxidant activity of purslane (*Portulaca oleracea*)

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Abstract: The aim of this study was to determine the effect of different drying methods on the nutritional content and antioxidant activity of purslane. Two different purslane samples have been dried using four different methods (sun, vacuum, hot air, and freeze drying). Dried and fresh samples were analyzed for their dry matter, β -carotene content, chlorophyll a and chlorophyll b contents, total flavonoid content, total flavonol content, total phenolic content, %DPPH radical scavenge activity, metal chelating activity, and color. The dry matter content of fresh purslane was 3.86%–5.28%. The β -carotene, chlorophyll a and b amounts varied from 61.31 to 67.08 mg/100 g, 103.11 to 138.11 mg/100 g and 56.14 to 62.06 mg/100 g, respectively on dry weight basis. The total flavonoid, total flavonol, and total phenolic contents were 9.61–28.20 mg RE (rutin equivalent)/g DW (dry weight), 3.48–17.27 mg RE/g, and 14.86–17.95 mg GAE (gallic acid equivalent)/g DW, respectively. DPPH scavenging activity ranged from 158.19 to 168.22 μ g/mL, and metal chelating activity varied between 5.75% and 22.44%. Fresh purslane color values L^* , a^* , and b^* ranged from 33.41 to 35.25, –6.70 to –7.28, and 13.51 to 14.60, respectively. Dry matter content, total phenolic content, antioxidant activity, β -carotene, flavonoid, flavonol, and color (L^* , a^* , and b^*) values were significantly affected by drying method. Drying methods caused a significant decrease in β -carotene, total flavonoid, total flavonol, and total phenolic contents of purslane. On the other hand, an increase in dry matter, metal chelating, chlorophyll a and chlorophyll b have been observed as a result of drying. Considering the variations in the effects of drying methods on the examined parameters and the disadvantages of some drying methods; in addition to the reasonable results obtained by hot air drying. Hot-air drying process could be suggested as a recommendable drying process for purslane.

Key words: Purslane, drying methods, phenolic content, and antioxidant activity

1. Introduction

Purslane (*Portulaca oleracea* L.) is a plant that belongs to the family Portulacaceae (Dweek, 2001; R veyde, 2013). It is known by various names worldwide. The variety of names can give an idea about the wide geographical distribution and the history of its cultivation. It is believed that it has been cultivated for more than 4000 years (FAO, 1994). In ancient Greece, purslane was used in treatment of gynecological diseases, stomach pain, hemorrhoids as well as in wound treatment, so it has been accepted as an important medicinal plant. Purslane has been used as a vegetable, medicinal and aromatic herb since the ancient Egyptians, and it was a well-known plant in England during the Middle Ages (Dweek, 2001). The Middle East and India are known as the homelands of purslane. This plant is also considered to be native to the Himalaya Mountains, Iran, South Russia, and Anatolia (Kařkar, 2009).

Purslane stem is hairless, smooth, and decumbent with alternate and stalkless leaves which are arranged in green and yellow colored clusters. It has been reported that fresh

purslane contains up to 0.25% noradrenaline. It is also rich in vitamins (A, B1, B2, B6, C, E, niacin, nicotinic acid, beta carotene, riboflavin, folate etc.), minerals (especially K, Ca, Fe, Mg, Na, P, Cu, and Mn), unsaturated fatty acids (especially omega-3 fatty acids), glutathione, glutamic acid, and aspartic acid. Moreover, purslane contains important polysaccharides such as carbohydrates, starch and cellulose (Dweek, 2001; Liu et al., 2009;  oruh and Erciřli, 2011; Unsal et al., 2015; G ng ren et al., 2017; Butnariu, 2018).

Apart from being consumed as food, purslane has traditionally been used as a medicinal herb. It has a wide range of pharmacological properties ranging from being antidiabetic, antiviral to antitumoral as well as balancing triglycerides and cholesterol in the blood (Sharma and Prasad 2003; Dong et al., 2010; El-Sayed, 2011; Shen et al., 2013; Zhao et al., 2013; Zidan et al., 2014; Montoya-Garc a et al., 2018). Purslane has also been reported to show antiinflammatory, anticancer, antioxidant, and analgesic properties (Lim and Quah, 2007; Siriamornpun

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and Suttajit, 2010; Erkan, 2012; Lee et al., 2012; Lee et al., 2014; Zhou et al., 2015; Ahangarpour et al., 2016; Rafeian-Kopaei and Alesaeidi, 2016; Vincenzo et al., 2018). It has been listed by WHO as one of the most used medicinal plant due to its various health benefits (Liu et al., 2000; Simopoulos et al., 2005; Xu et al., 2006; Zhu et al., 2010; Uddin et al., 2014; Vincenzo et al., 2018).

Fruits and vegetables are highly susceptible to microbial and chemical spoilage due to their high moisture content (Cemeroglu et al., 2009). Fruits and vegetables as highly perishable products—require some kind of processing in order to maintain their storage stability and extending shelf life. For this purpose, many preservation methods such as drying, usage of preservatives, osmotic pretreatment, fermentation, blanching and boiling, application of electric field and high hydrostatic pressures are commonly used. However, some of these methods have limitations when applied alone in terms of their cost, duration, and acceptability of the product (İlter and Çoban, 1996; Moreno et al., 2000; Maskan, 2001; Khin et al., 2007; Erkmén, 2010; Ilcalı and İcier, 2010; Ahmet et al., 2015).

Drying is a traditional and important method used in food preservation since ancient times in which food moisture is reduced by evaporation or sublimation. Water activity reduction as a result of drying minimize the chemical, enzymatic, and microbiological changes and consequently extend the shelf life of food items (Lewicki and Jakubczyk, 2000; Louise et al., 2012). In addition, moisture removal during drying process reduces the weight and volume of food items which leads to reduction in transportation and storage costs (Okos et al., 1992; Youssef and Mokhtar, 2014).

Sun drying is known as the oldest drying method. In regions where climate is suitable for sun drying, high-quality products could be obtained using solar energy as an alternative to the expensive drying methods (Meier, 1985). However, sun drying is a very slow process and requires large areas, which makes it unsuitable and insufficient for many food items. In addition, the long exposure to sunlight in open environment affects the final product's quality by dust contamination, insect infestation, and product loss by birds and other animals (Soysal, 2004).

Vacuum drying is an alternative drying method which is suitable for foods that require longer drying time such as fruits (Yongsawatdigul and Gunasekaran, 1995). Previous studies showed that drying under vacuum reduces the required time compared to other methods. Reduced pressure facilitates water evaporation from food items at low temperatures, in comparison with atmospheric conditions. Furthermore, removing moisture at low pressure and thus low oxygen partial pressure minimizes oxidation reactions. Consequently, color, texture, and

aroma are well-maintained in vacuum-dried products (Zhong and Lima, 2003).

Freeze drying is considered the most suitable drying method compared to other drying methods, due to the high quality of dried products. Moreover, it is known to have high extraction efficiency as revealed by many studies; extract of freeze-dried products showed higher bioactive component contents than extract of those dried by hot air ovens (Dorta et al., 2012; Pinela et al., 2012; Youssef and Mokhtar, 2014).

So far, there has been limited information related to purslane drying and the effect of different drying methods on purslane properties are not investigated thoroughly. Thus, this study was initiated to determine the nutritional composition and antioxidant activities of fresh purslane and dried samples obtained by four different drying methods.

2. Materials and methods

2.1. Materials

Two different purslane (*Portulaca oleracea* L.) samples, which are produced and marketed commercially in two different cities of Turkey (Antalya and Mersin), were collected and used as materials in this study (Figure). Mersin samples had large and dense leaves whereas the leaves of Antalya samples were thinner and sparser. Purslane samples were cleaned, cut into small pieces (~3 cm) to facilitate drying and divided into four groups (for each group about 300 g) and dried using four different drying methods such as vacuum drying, hot air drying, freeze drying, and sun drying. The dried samples were ground and kept in sealed glass jars at +4 °C in the dark for further analysis. The end of drying process was determined depending on preliminary tests, where small amount (about 20 g) of purslane sample was dried by each drying method until dry matter content reached 10%. Consequently, the drying time was determined as 12 h, 24 h, 72 h, and 1 week for vacuum drying, hot air drying, freeze drying, and sun drying methods, respectively.

2.2. Methods

2.2.1. Drying methods

2.2.1.1. Drying under vacuum

Vacuum drying was performed in a Precise vacuum oven (WiseVen, model WOV – 30, Japan). The oven was made of stainless steel and its temperature can be increased up to 200 ± 1.0 °C. The interior dimensions of the oven cavity were 300 × 330 × 300 mm. Purslane samples were placed in a thin layer and dried at 50 °C for about 12 h.

2.2.1.2. Hot air drying

Hot air drying was carried out in a hot air oven (Memmert, Model: UN55). The interior dimensions of the oven cavity were 400 × 400 × 300 mm, and the maximum

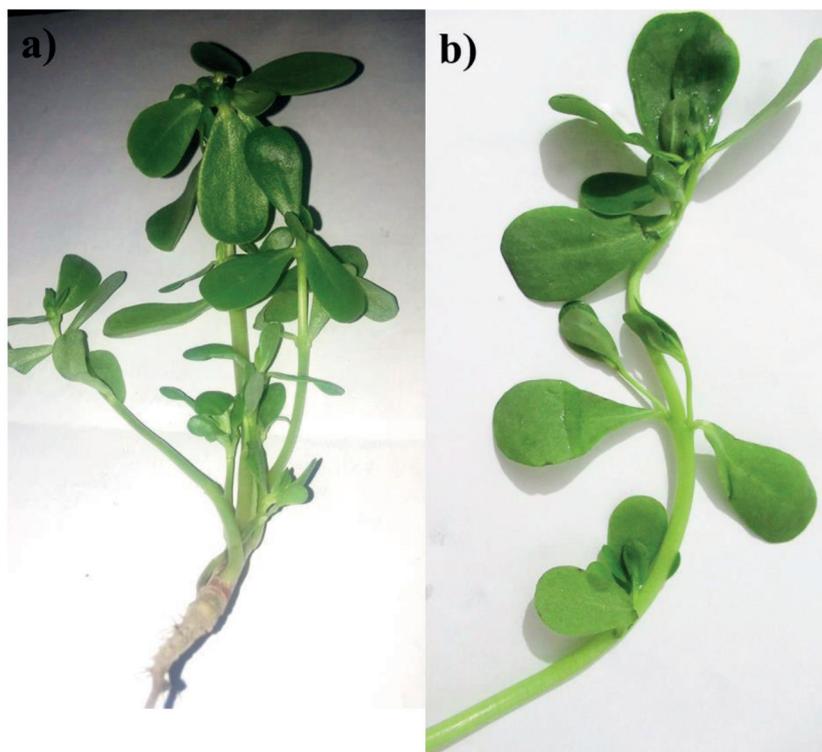


Figure. Purslane samples: a) Antalya sample, b) Mersin sample.

working temperature was 300 °C with a sensitivity of ± 1 °C. Accumulated moisture during drying process was discharged by natural ventilation. Purslane samples were placed in a thin layer and dried at 50 °C for about 24 h.

2.2.1.3. Freeze drying

Purslane samples were placed immediately in a deep freezer (-40 °C) (VWR® symphony™ Ultra-Low Temperature Freezer Supplier: VWR International). Frozen samples were then transferred to freeze dryer bottles and freeze dried for approximately 72 h using a freeze dryer (Operon brand, min. -86 °C, ALPHA 1-2 / LD Plus).

2.2.1.4. Sun drying

For sun drying, samples were spread on a single layer and placed in a room where they were exposed to direct sunlight. Drying was carried out for 1 week and the average room temperature was about 25 °C.

2.3. Preparation of the samples for analysis

5 g of the dried samples were mixed with 100 mL of methanol and shaken (200 rpm) at darkness at room temperature for 1 night, using orbital shaker (Stuart-SSL1). The mixture was filtered through Whatman filter paper (No:1). The residue was reextracted with 50 mL of methanol and shaken for 2 h. The filtrates were then combined and adjusted to a final volume of 50 mL, using the rotary evaporator at 45 °C. The obtained extract was used for determining total phenolic content, total flavonoid

and total flavonol contents; in addition to DPPH and metal chelating activities (Stankovic, 2011).

2.4. Determination of total phenolic content (TPC)

0.1 mL of sample extracts were mixed with 1 mL Folin-Ciocalteu reagent followed by an addition of 1.5 mL Na_2CO_3 solution (20 %, w / v). The final volume was then adjusted to 10 mL with distilled water. The tubes were incubated at room temperature for 1 h and then the absorbance was measured at 760 nm. Gallic acid was used to create the standard curve and the TPC amount was expressed as mg GAE/g of dried sample.

2.5. Determination of DPPH radical scavenging activity

DPPH solution was prepared by dissolving 39 mg of DPPH in 100 mL ethyl alcohol. 10, 20, 30, and 40 μL of the sample extracts were mixed with 0.5 mL of DPPH solution and adjusted to a final volume 3 mL by ethyl alcohol. The mixture was vortexed and left for 30 min in the dark. After that, absorbance was measured at 517 nm. IC_{50} (concentration of the extract needed to cause a 50% decrease in DPPH radical inhibition) values were calculated from DPPH radical inhibition percentage versus concentration curve. % DPPH radical inhibition was calculated as follows (Spada et al., 2008).

$$\% \text{ inhibition} = [(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}}] \times 100$$

A_{control} : Absorbance value of DPPH solution without the sample (control)

A_{sample} : Absorbance value of DPPH solution with the sample

2.6. Determination of metal chelation activity

3.7 mL of distilled water and 100 μL of 2 mM FeCl_2 solution were added to 1 mL of the extract solution in a test tube. After incubation for 30 min at room conditions, 200 μL of 5 mM ferrozine solution was added, and the whole mixture was vortexed and let stand for 10 min. The absorbance of the mixture was measured at 562 nm. Deionized water was used instead of the extract to prepare control (blank) (Dinis et al., 1994).

Metal chelation activity (%) was calculated using the following formula:

% Chelation Activity = (Control absorbance – Sample absorbance / Control absorbance) \times 100

2.7. Determination of β -carotene and chlorophyll

200 mg of dried purslane plants were ground to fine powder and mixed with 10 mL aceton-hexan (4:6) mixture, and let stand for 5 min. The mixture was filtered through Whatman filter paper (No: 102). The absorbance of the resulting solution was measured at 453, 505, 645, and 663 nm after dilution with acetone-hexane mixture (Youssef and Mokhtar, 2014).

β -carotene (mg/100 mL) = $0,216 \cdot A_{663} - 1,220 \cdot A_{453} - 0,304 \cdot A_{505} + 0,452 \cdot A_{645}$

Chlorophyll a (mg/100 mL) = $0,999 \cdot A_{663} - 0,0989 \cdot A_{645}$

Chlorophyll b (mg/100 mL) = $-0,328 \cdot A_{663} + 1,77 \cdot A_{645}$

2.8. Determination of total flavonoid content

For the determination of total flavonoid content, 0.5 g of sample extract was mixed with 2 mL of distilled water and 0.15 mL NaNO_2 (5%). After the mixture was let stand for 6 min, 0.15 mL of AlCl_3 (10%) solution was added. After incubation for 6 min, 2 mL NaOH (4%) was added. Finally, the mixture was adjusted to a final volume of 5 mL by distilled water and vortexed. After 15 min, the absorbance was measured at 510 nm. Rutin was used to obtain a standard curve (Youssef and Mokhtar, 2014).

2.9. Determination of total flavonol content

0.5 mL of sample extract was mixed with 0.5 mL of 2% AlCl_3 and 0.5 mL of sodium acetate (5%). The mixture was then adjusted to a final volume of 10 mL with distilled water. The absorbance was measured at 425 nm. The total flavonol content was expressed as Rutin Equivalent (mg RE/g dried sample) and Quercetin Equivalent (mg QE/g dried sample) extract (Almaraz-Abarca et al., 2007).

2.10. Color

Purslane samples were placed on a white background and color values were determined by Minolta colorimetry device (Chroma Meter, CR-200 Japan). Based on three-dimensional color measurement, the values were expressed as L^* , a^* , and b^* . Prior to color measurement, the device was calibrated using the device's calibration scale (Youssef

and Mokhtar, 2014).

L^* ; 0 = black, 100 = white darkness/lightness, on (Y) axis

a^* ; + a red, – a green, on (X) axis

b^* ; + b yellow, – b blue, on (Z) axis

2.11. Statistical analysis

All experiments were carried out in triplicate and the results were expressed as mean \pm standard deviation. 2×5 completely randomized full factorial design was used in this study (2 different purslanes \times 4 drying methods (+) fresh purslane samples). Variance analysis was performed and the differences between data were determined by Duncan Multiple Comparison Test using SPSS program (version 20 IBM SPSS). The differences were considered statically significant at 5% level ($p < 0.05$).

3. Results and discussion

Dry matter contents of the fresh purslane plant from Antalya (5.27%) were significantly higher than those from Mersin (3.85%) (Table 1). Our findings were nearly similar to those obtained in previous studies: 2.7% and 5.28%–7.24% (Akdeniz, 2007). On the other hand, a higher dry matter content of fresh purslane has been reported by other authors, where it accounted for 7.75% and 7.13% (Ismail et al., 2015). These differences may result from different cultivar, growing conditions, or climate.

As expected, all drying methods caused significant increase ($p < 0.01$) in dry matter content in both samples. Dry matter content of dried purslane obtained by different drying methods ranged from 86.64% to 97.61% for hot air and vacuum drying of Mersin samples, respectively. Similarly, Youssef and Mokhtar (2014) has reported that the dry matter content of purslane leaves dried by hot air and freeze drying were 93.37% and 95.65%, respectively. According to Ismail et al. (2015), dry matter contents of sun-dried purslane samples were also over 90%. Our results showed that even though samples from Antalya that were dried with vacuum oven had higher dry matter content compared to other drying methods, no significant differences ($p < 0.01$) were observed between them, whereas dry matter content of Mersin sample varied significantly, depending on the drying methods (Table 1).

The variation in the dry matter content of the samples dried by different methods may be due to the subjective decision of the end point of drying process. Indeed, there is no specific standard regarding the moisture content of dried vegetables. They are generally dried until their moisture content reached 10%, which ensure preservation and maintain appropriate storage conditions.

Sun-dried sample from Mersin exhibited the lowest β -carotene content (12.27 mg/100 g), whereas the fresh samples from Antalya had the highest (67.07 mg/100 g) β -carotene content (Table 1). However, there was no significant difference between the two studied samples

Table 1. Total dry matter, β -carotene, chlorophyll-a and b contents of fresh and dried purslane samples.

Processing	Dry matter (%)		β -carotene (mg/100 g)		Chlorophyll-a (mg/100 g)		Chlorophyll-b (mg/100 g)	
	Antalya	Mersin	Antalya	Mersin	Antalya	Mersin	Antalya	Mersin
Fresh	5.28 \pm 0.55 ^{ba}	3.86 \pm 0.39 ^{eb}	67.08 \pm 24.05 ^{aa}	61.31 \pm 17.96 ^{aa}	103.11 \pm 33.33 ^{ca}	138.11 \pm 44.21 ^{bcA}	56.14 \pm 23.319 ^{bcA}	62.06 \pm 16.78 ^{aA}
Freeze drying	94.75 \pm 2.51 ^{aA}	93.17 \pm 0.40 ^{cA}	50.33 \pm 2.94 ^{abA}	57.80 \pm 0.99 ^{ab}	192.58 \pm 1.53 ^{aA}	180.56 \pm 3.27 ^{abB}	79.34 \pm 4.12 ^{aA}	78.38 \pm 5.95 ^{aA}
Sun drying	95.08 \pm 0.32 ^{aB}	96.37 \pm 0.22 ^{ba}	13.99 \pm 1.19 ^{ca}	12.27 \pm 0.70 ^{cA}	123.79 \pm 1.07 ^{bcA}	74.33 \pm 3.93 ^{dB}	59.90 \pm 2.26 ^{abcA}	34.84 \pm 2.30 ^{cB}
Vacuum oven drying	96.89 \pm 0.22 ^{aA}	97.61 \pm 0.95 ^{aA}	54.03 \pm 6.23 ^{abA}	61.40 \pm 4.55 ^{aA}	181.43 \pm 19.10 ^{aA}	189.05 \pm 10.73 ^{aA}	76.47 \pm 8.14 ^{abA}	76.40 \pm 1.51 ^{aA}
Hot air drying	95.49 \pm 0.22 ^{aA}	86.64 \pm 0.30 ^{dB}	33.21 \pm 3.29 ^{bcA}	35.62 \pm 10.81 ^{ba}	141.92 \pm 16.99 ^{ba}	130.07 \pm 32.20 ^{cA}	43.42 \pm 6.03 ^{cA}	39.62 \pm .52 ^{ba}

Averages marked with the same lower case in the same column are not statistically different ($p < 0.05$); averages marked with the same capital letter in the same line are not statistically different ($p > 0.05$).

*Results are given on dry weight basis.

(fresh and dried) except for freeze-dried ones. On the other hand, both freeze drying and vacuum drying showed minimal impact on β -carotene content compared to other drying methods according to our results (Table 1). Generally, drying process reduces the β -carotene content of food materials. This loss has to do with the inclusion of several conjugated double bonds which makes the carotenoids easily oxidizable. In fact, the susceptibility of carotenoids to oxidation depends on the ambient conditions and increases by physical damage of the tissues and extraction processes. Processes such as boiling, freezing, and drying may decrease the oxidative changes of carotenoids. Uddin et al. (2014) and Alam et al. (2015) reported β -carotene contents of fresh purslane to be 38.2–43.5 mg/100 g and 52–328 mg/100 g, respectively.

Chlorophyll pigments are responsible for the green color of all vegetables tissues. Chlorophyll is mainly found in two types, as chlorophyll-a and chlorophyll-b which are present at a ratio of nearly 3:1 in higher plant tissues. The difference between chlorophyll-a and chlorophyll-b arises from the groups attached to the 3rd position of chlorin ring. Chlorophyll-a contains a methyl group instead of an aldehyde group at the 3rd position of its chlorin ring (Cemeroğlu et al., 2018). The dried samples by four studied methods were significantly higher in their content of chlorophyll-a than the raw samples. Mersin samples which dried in the sun showed the lowest (74.33 mg/100 g) chlorophyll-a content, whereas Antalya samples which were dried by freeze dryer had the highest content (192.58 mg/100 g). Similarly, Youssef and Mokhtar (2014) reported an increment in chlorophyll-a content of purslane leaves as a result of drying, where the fresh leaves contained 50.75 mg/100g chlorophyll-a while it varied between 50 and 80 mg/100 g after applying different drying methods. This

increment may be due to the changes that occurred in the plant matrix as a result of drying process which possibly increase the extractability of such substances. Hassan (2014) found the chlorophyll-a content of fresh purslane as 32.23 mg/100 g.

In fresh purslane samples collected from Antalya and Mersin, the chlorophyll-b content was found to be 56.14 mg/100 g and 62.06 mg/100 g, respectively. These values were higher than that observed by Hassan (2014) who found it to be 21.63 mg/100 g. In the present study, chlorophyll-b content either significantly ($p < 0.05$) decreased or did not change after drying process. The sun-dried Mersin samples had the lowest (34.84 mg/100 g) chlorophyll-b content, whereas the highest content (79.34 mg/100 g) was observed in freeze-dried Antalya samples (Table 1). In a study conducted by Youssef and Mokhtar (2014), it was found that chlorophyll-b content of fresh purslane was 19.12 mg/100 g, whereas it ranged from 70 to 110 mg/100 g, after drying by different methods.

Phenolic compounds are defined as molecules containing at least one benzene ring to which one or more hydroxyl groups are attached. A significant portion of the phenolic compounds are associated with a variety of flavor properties, particularly astringency. Phenolic compounds found in plant-based foods are divided into two main groups: 'phenolic acids' and 'flavonoids'.

Flavonoids, also known as 'Flavan derivatives', are the most common and most important group of phenolic compounds in plants. The basic chemical structure of flavonoids is a skeleton of diphenylpropane ($C_6C_3C_6$). In this study, the total flavonoid content of fresh Antalya sample (9.61 mg RE/g) was found to be significantly lower than the content of Mersin sample (28.20 mg RE/g). The results obtained were higher than those previously

observed by Uddin et al. (2014), Alam et al. (2015), and Petropoulos et al. (2015). These significant variations may result from different genotypes or different location as indicated by Alam et al. (2015) and Petropoulos et al. (2015). On the other hand, a significant decrease was observed in flavonoid content due to drying process, except for freeze-dried Antalya samples. Flavonoid contents of dried purslane ranged from 5.57 to 19.01 mg RE/g in Mersin samples which were dried by vacuum oven and hot air dryer, respectively (Table 2). Similar loss of flavonoids as a result of drying had been reported by Youssef and Mokhtar (2014). Hassan (2014) reported that the total flavonoid content of purslane dried at 60 °C in hot air was 95.94 mg QE/100 g.

The flavonol content of fresh Antalya sample (3.48 mg RE/g; 6.24 mg QE/g) was significantly lower than the flavonol content of fresh Mersin sample (17.27 mg RE/g; 12.18 mg QE/g). On the other hand, the hot air-dried Antalya samples had the lowest content of flavonols (0.10 mg RE/g and 0.28 mg QE/g), whereas the freeze-dried

Mersin samples had the highest (9.58 mg RE/g and 10.54 mg QE/g) values. Drying process caused a significant decrease in flavonol content of purslane. Among the studied methods freeze drying and drying under vacuum for Antalya samples had the superiority for preserving flavonols compared to other drying methods, whereas freeze drying and hot air drying showed the best results for Mersin samples.

In this study, total phenolics contents of fresh purslane obtained from Antalya and Mersin were found to be 14.86 mg GAE/g and 17.95 mg GAE/g, respectively, with a significant difference between them (Table 3). Similar results with slight variations were reported by Youssef and Mokhtar (2014), who found that the total phenolics in fresh purslane was 14.47 mg GAE/g and Petropoulos et al. (2015), who found that the total phenolics in purslane were in the range of 9–12 mg GAE/g.

Total phenolic content of purslane significantly decreased after drying process. Among dried samples, sun-dried Antalya samples were found to contain the lowest

Table 2. Total flavonoid and total flavonol contents of fresh and dried purslane.

Processing	Total flavonoid (mg RE/g)		Total flavonol (mg RE/g)		Total flavonol (mg QE/g)	
	Antalya	Mersin	Antalya	Mersin	Antalya	Mersin
Fresh	9.61 ± 0.85 ^{CB}	28.20 ± 2.11 ^{AA}	3.48 ± 0.73 ^{AB}	17.27 ± 3.75 ^{AA}	6.24 ± 0.85 ^{AA}	12.18 ± 4.39 ^{AA}
Freeze drying	10.90 ± 0.78 ^{BA}	12.33 ± 0.78 ^{CA}	0.67 ± 0.30 ^{BB}	9.58 ± 0.41 ^{BA}	1.02 ± 0.35 ^{BB}	10.54 ± 0.48 ^{AA}
Sun drying	6.13 ± 0.21 ^{EA}	17.13 ± 1.21 ^{BB}	0.35 ± 0.38 ^{BB}	4.64 ± 0.92 ^{CA}	0.59 ± 0.51 ^{BB}	4.79 ± 1.07 ^{BCA}
Vacuum oven drying	8.13 ± 0.75 ^{DA}	5.57 ± 0.32 ^{DB}	0.80 ± 0.69 ^{BA}	2.31 ± 0.94 ^{DA}	1.09 ± 0.94 ^{BA}	2.07 ± 1.10 ^{CA}
Hot air drying	13.23 ± 0.40 ^{AB}	19.01 ± 0.61 ^{BA}	0.10 ± 0.09 ^{BB}	6.10 ± 0.93 ^{CD}	0.28 ± 0.23 ^{BB}	6.43 ± 1.08 ^{BA}

Averages marked with the same lower case in the same column are not statistically different ($p > 0.05$); averages marked with the same capital letter in the same line are not statistically different ($p > 0.05$).

*Results are given on dry weight basis.

Table 3. Total phenolics content, DPPH, and metal chelation activity values of fresh and dried purslane samples.

Processing	Total phenolic content (mg GAE/g)		DPPH (IC ₅₀ , µg/mL)		Metal chelation (%)	
	Antalya	Mersin	Antalya	Mersin	Antalya	Mersin
Fresh	14.86 ± 0.04 ^{AB}	17.95 ± 0.84 ^{AA}	158.19	168.22	5.75 ± 2.01 ^{CB}	22.44 ± 0.76 ^{CA}
Freeze drying	5.22 ± 0.09 ^{DB}	6.34 ± 0.36 ^{CA}	673.65	557.58	46.13 ± 0.68 ^{AB}	64.59 ± 3.07 ^{abA}
Sun drying	3.85 ± 0.04 ^{EB}	6.73 ± 0.64 ^{CA}	1436.63	390.69	5.63 ± 1.82 ^{CB}	66.60 ± 5.15 ^{AA}
Vacuum oven drying	5.44 ± 0.18 ^{CA}	4.40 ± 0.16 ^{DB}	802.38	983.70	41.57 ± 4.50 ^{AB}	61.88 ± 2.60 ^{abA}
Hot air oven drying	6.53 ± 0.11 ^{BB}	9.32 ± 0.25 ^{BA}	704.19	283.06	34.21 ± 3.38 ^{BB}	56.03 ± 7.83 ^{BA}

Averages marked with the same lower case in the same column are not statistically different ($p > 0.05$); averages marked with the same capital letter in the same line are not statistically different ($p > 0.05$).

*Results are given on dry weight basis.

amount (3.85 mg GAE/g) of total phenolic content, whereas the hot-air-dried Mersin samples showed the highest (9.32 mg GAE/g) amount. Youssef and Mokhtar (2014) dried purslane leaves using different methods; they reported a degradation in total phenolics after drying, which varied significantly according to drying methods. In accordance with their results, the hot-air drying at 50°C and freeze-drying purslane leaves caused losses of total phenolics at ratios of 33.75% and 36.18%, respectively, compared to the fresh leaves. Our results also revealed that hot-air drying resulted in minimum loss of total phenolics in purslane, compared to other drying methods (Table 3). One reason for the superiority of air-drying versus the other drying methods (even freeze drying) in protecting total phenolics may be due to the fact that a greater amount of phenolic substances were infused into the extract during the extraction of air-dried purslane sample; thus, higher TPC values were obtained accordingly. In other words, some bound phenolic compounds might be released during the process, so they become more amenable for extraction. Another possible explanation for the superiority of air-drying method may be related with the formation and accumulation of Maillard reaction products. These products have been shown to react with Folin-Ciocalteu reagent and exhibit antioxidant activities (Udomkun et al., 2015; Kim et al., 2021). Similarly, Martínez-Las Heras et al. (2014) reported a significant effect of drying method on the extraction of phenolic compounds during infusion, where the extract obtained from hot-air-dried persimmon leaves (100 °C) showed higher total phenolics content than extract from lyophilized leaves.

Half maximal inhibitory concentration (IC_{50}) value is defined as the concentration of substance required to inhibit a biological process by half. In case of DPPH radical scavenge activity, IC_{50} indicates how much extract is needed to scavenge 50 % of DPPH radical. The IC_{50} value is inversely proportional to the antioxidant activity of the sample (% DPPH free radical scavenging activity), i.e. the lower IC_{50} value, the higher antioxidant activity. The IC_{50} values of fresh purslane obtained from Antalya and Mersin was found to be 158.19 and 168.22 $\mu\text{g/mL}$, respectively. Alam et al. (2015) indicated that the IC_{50} values of thirteen accessions of purslane were in the range of 2.52–3.29 mg/mL, whereas the IC_{50} values of six different genotypes of common purslane ranged from 6.4 to 19.9 mg/mL as reported by Petropoulos et al. (2015). The purslane samples investigated in the present study seemed to have higher antioxidant activity than those reported in the previous studies (Alam et al. 2015; Petropoulos et al. 2015). Differences observed may result from variations in polyphenol content, which is considered an important index for natural antioxidants and varied depending on many external factors such as growing conditions, climate,

harvesting time, and storage conditions (Heimler et al., 2007). Youssef and Mokhtar (2014) indicated that drying methods caused a significant decrease in the antioxidant activity of purslane leaves measured by DPPH assay. Similarly, all drying methods applied in our study showed negative effect on antioxidant activity of purslane plant (Table 3). As seen from Table 3, all dried samples had higher IC_{50} value than fresh samples. Due to the fact that there is an inverse relationship between IC_{50} value and antioxidant activity, the fresh purslane samples had higher % DPPH radical scavenging activity compared to dried samples. On the other hand, among dried samples, hot-air-dried Mersin samples had the lowest IC_{50} (283.06 $\mu\text{g/mL}$), whereas the highest value was observed in sun-dried Antalya sample (1436.63 $\mu\text{g/mL}$). Regarding the effect of drying methods on the antioxidant activity of each purslane sample separately, hot-air-dried Mersin sample ($IC_{50} = 283.06 \mu\text{g/mL}$) was found to have the highest antioxidant activity, while freeze-dried Antalya sample ($IC_{50} = 673.65 \mu\text{g/mL}$) showed the highest antioxidant activity followed by hot-air-dried samples ($IC_{50} = 704.19 \mu\text{g/mL}$). Thus, hot air drying could be suggested as an appropriate drying method that maintains the antioxidant activity of purslane. This might be related with nonenzymatic reactions that occur during the hot-air drying, which result in formation of new compounds that have an antioxidant activity. It is worth to mention that, depending on the increasing infusion rate as a result of drying processes, antioxidant activity of dried samples was found to be high in accordance with the high amount of phenolic substances infused into the extracts.

The metal chelating activity of fresh, freeze-dried, sun-dried, dried under vacuum, and hot-air oven dried purslane were found to be 5.75%, 46.12%, 5.63%, 41.56%, and 34.20%, respectively, for Antalya samples, whereas they were 22.44%, 64.59%, 66.60%, 61.88%, and 56.02%, respectively, for Mersin samples. In a study conducted by Peksel et al. (2006) a wide range of metal chelating activity have been reported, which was between 10% and 50%. Güngören et al. (2017) investigated the antioxidant activity of wild purslane obtained from different regions and cultivated form of purslane, a wide range (0.37%–87.61%) of Fe^{+2} ions chelating activity was also reported in this study. Our results revealed that significant differences ($p < 0.05$) were detected between fresh and dried samples regarding metal chelating activity. Substances with high metal chelating capacity bind transition metals and show a protective antioxidant effect. Table 4 shows that applied drying methods resulted in statistically significant ($p < 0.05$) effects on color parameters of purslane. All drying methods caused an increment in lightness of purslane, where dried purslane presented higher L^* values compared to fresh samples. Similarly, a significant increment was observed in b^* value (yellowness) as a result of drying

Table 4. Color comparison analysis results of fresh and dried purslane samples.

Antalya				Mersin		
Processing	<i>L</i> *	<i>a</i> *	<i>b</i> *	<i>L</i> *	<i>a</i> *	<i>b</i> *
Fresh	33.41 ± 4.59 ^d	-7.28 ± 1.28 ^c	13.51 ± 2.48 ^c	35.25 ± 7.22 ^c	-6.70 ± 1.24 ^d	14.60 ± 3.20 ^c
Freeze dried	63.07 ± 2.56 ^a	-10.83 ± 0.41 ^d	21.35 ± 0.61 ^a	55.37 ± 2.57 ^a	-7.56 ± 0.35 ^d	21.95 ± 0.68 ^a
Sun dried	48.15 ± 3.49 ^b	-2.77 ± 0.80 ^b	19.74 ± 1.16 ^{ab}	49.76 ± 1.41 ^b	-3.63 ± 0.66 ^c	20.75 ± 0.71 ^a
Vacuum oven drying	45.71 ± 2.21 ^{bc}	-1.84 ± 0.18 ^{ab}	19.80 ± 0.47 ^{ab}	45.68 ± 1.20 ^{bc}	-1.62 ± 0.42 ^b	21.09 ± 0.10 ^a
Hot air drying	45.22 ± 2.34 ^{bc}	-1.29 ± 0.52 ^a	14.87 ± 2.86 ^c	37.47 ± 2.23 ^{ce}	-0.04 ± 0.45 ^a	15.80 ± 0.57 ^b

Averages marked with the same lower case in the same column are not statistically different ($p > 0.05$).

process. Moreover, all dried samples had higher *a** values than fresh purslane except for freeze-dried samples which presented a lower *a** values as compared with fresh ones. The increase in *a** values (less greenness) could possibly be attributed to the nonenzymatic browning reactions that occur when high temperature processes such as drying are applied.

4. Conclusion

This study revealed that the effectiveness of drying methods varies considerably in terms of antioxidant properties and nutritional composition of purslane. Since each drying process has different effects on each examined component, it is difficult to determine an ideal drying process that can preserve the functional quality and value of this plant. However, regarding the majority of parameters examined in this study; freeze drying and drying under vacuum may have superiority over other methods. Sun drying showed the lowest negative effect on the metal chelation activity of purslane. Furthermore, the inherent disadvantages of this method such as long time, large area requirement, and the high risk of contamination make it an unsuitable method for drying purslane. On the other hand, considering the variations in the effects of drying methods on examined parameters and the high costs of freeze drying and vacuum drying processes, in addition

to the reasonable results obtained by hot air drying which were close to those obtained with vacuum drying, hot-air drying process could be suggested as a recommendable drying process for purslane. Thus, purslane, which is consumed fresh or cooked, could be easily incorporated into the daily diet as a dry product especially during off-season period. Consequently, the consumption of this valuable product could spread throughout the year so that people can benefit from its nutritional properties. Furthermore, similar research is needed to investigate the effect of different processes on omega-3 fatty acids content of purslane.

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Author contributions

Conceptualization, İ.G.Ş.; methodology, İ.G.Ş., H.İ.B., and E.A.; validation, İ.G.Ş.; investigation, H.İ.B., and E.A.; writing original draft preparation, H.İ.B., and E.A.; writing review and editing, İ.G.Ş.; supervision, İ.G.Ş. All the authors have read and agreed to the published version of the manuscript.

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