



## Physical, Bioactive and Textural Properties of Oleaster (*Elaeagnus angustifolia* L.) Fruit from Different Locations in Turkey

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### ABSTRACT

The objective of this study was to evaluate the physical, bioactive and textural properties of oleaster fruits grown in different locations of Turkey. The oleaster fruits were obtained from Aksaray, Niğde and İzmir cities and their crumb and crust parts were analyzed individually and freshly. In terms of color, the crust and crumb of oleaster fruits from İzmir had the darkest color with  $L^*$  values of  $46.81 \pm 4.06$  and  $78.91 \pm 4.97$  among all tested fruits from different locations, respectively. Total of phenolic (TP), flavonoid (TF) and tannin (TT) content (C) and as well antioxidant activities (AA) of oleaster fruits were determined for the crust and crumb of oleaster fruits. The highest TPC ( $22.30 \pm 1.75$  mg gallic acid equivalent/g DM), TFC ( $16.24 \pm 1.49$  mg catechin equivalent/g DM) and AA ( $14.05 \pm 0.55$   $\mu$ mol trolox equivalent/g DM) by DPPH were found in the crust of Aksaray oleaster fruits. In addition, the crumb of Aksaray oleaster fruit had the highest TPC ( $16.44 \pm 1.67$  mg gallic acid equivalent/g DM) among the crumbs of oleaster fruits from different locations. Furthermore, there was no significant difference among the texture of crust and crumb of oleaster fruits obtained from different locations. Results showed the growing location of oleaster fruits had a significant influence on the physical and bioactive properties of fruits. Also, this study indicated that oleaster fruits were rich in bioactive compounds; therefore, they could be incorporated into foods to design functional foods.

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## Introduction

Oleaster (*Elaeagnus angustifolia* L.) or Russian olive, which has reddish- or yellowish-brown elliptic fruit and hard skin, belongs to Elaeagnaceae family. It is cultivated in Europe, Asia and North America (Öztürk et al., 2018). Total oleaster production of Turkey was reported as 4141 tons (TÜİK, 2019). Its significant amount is produced in the Central Anatolia region while the rest is provided from the Aegean region (Durmuş and Yiğit, 2003).

Oleaster contains carbohydrates, protein, vitamins and minerals (Yıldırım et al., 2015). The dominant sugars were identified as fructose (27%) and glucose (22.3%) (Ayaz and Bertoft, 2001). Also, oleaster fruit is rich in phenolic acids, flavonoids and tannins (Abizov et al., 2008; Ayaz and Bertoft, 2001; Bucur et al., 2009; Zeng et al., 2009). Among phenolic acids, 4-hydroxybenzoic acid and caffeic acid were found to be the major phenolic compounds in oleaster fruit (Ayaz and Bertoft, 2001).

Since the oleaster has been consumed either fresh or dried as an appetizer, the use of oleaster fruit has not received enough attention in food industry. In fact, the

sweet taste and dry texture of oleaster fruit enable to use in the form of flour in food. Therefore, some researchers incorporated the oleaster flour into various food such as ice cream (Çakmakçı et al., 2015), yoghurt (Öztürk et al., 2018), cookies (Sahan et al., 2019) and doughnut (Sarraf et al., 2017) as an alternative functional ingredient.

Due to its composition, oleaster has several health benefits such as antimicrobial, anti-inflammatory (Ahmadiani et al., 2000) and antioxidant (Faramarz et al., 2015; Wang et al., 2013). However, the physical, chemical and bioactive properties of the oleaster fruit may differ due to the soil, climate and ecological condition in which it is grown (Saboonchian et al., 2014).

The objective of this study was to investigate the physical, bioactive and textural properties of oleaster fruits obtained from different locations of Turkey. The information provided from this study could be useful for researchers and as well food industry regarding selecting the raw material from a specific location when a functional food would like to be designed with the oleaster fruit.

## Materials and Methods

### Materials

The oleaster (*Elaeagnus angustifolia* L.) fruits were collected from the local gardens in İzmir, Aksaray and Niğde in Turkey. Folin & Ciocalteu's phenol reagent, Folin-Denis' reagent, gallic acid, sodium bicarbonate, 2,2-Diphenyl-1-picrylhydrazyl, trolox, catechin, sodium nitrate, aluminum chloride, 2,4,6-Tris (2-pyridyl)-s-triazine, iron chloride and methanol were bought from Merck (Darmstadt, Germany).

### Moisture Content Assay

The moisture content of fresh oleaster fruits was determined according to AOAC method. The fresh oleaster fruit ( $W_1$ ) were weighed into cups and hold at 80°C for 24 h in the oven. After reaching constant weight, the cups were measured ( $W_2$ ) and the moisture content (%) was calculated using Eq. (1);

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

### Color Assay

Color parameters ( $L^*$  (lightness),  $a^*$  (redness-greenness) and  $b^*$  (yellowness-blueness)) of oleaster fruits were detected by a digital portable color meter (CR-400, Konica Minolta, Japan). Each measurement was repeated five times.

### Bioactive Compounds Extraction

The extraction of bioactive compounds from oleaster fruit samples was performed according the method stated by Bennett et al. (2011). The oleaster fruit samples (1 g) were mixed with 80% methanol and then, the mixture was sonicated for 20 min at 25°C (Selecta Ultrasons HD, Barcelona). Afterwards, it was centrifuged at 3500 g for 15 min (Universal 320 R, Hettich, Tuttlingen, Germany) and filtered. The extracts were used as fresh for all analyses.

### Total Phenolic Content Assay

Folin-Ciocalteu assay was used to determine total phenolic content (TPC) of oleaster fruit samples (Irakli et al., 2018). In this assay, Folin & Ciocalteu reagent (0.5 mL) was added onto the extract (0.5 mL) and then, mixed with  $\text{Na}_2\text{CO}_3$  solution (3 mL). The obtained mixture was incubated at dark for 30 min. After the incubation, the absorbance values were read using the spectrophotometer (UV-1800, Shimadzu, Japan). TPC results were indicated as mg gallic acid equivalent/g dry matter of oleaster fruit (mg GAE/g DM). The assay was conducted in triplicate.

### Total Flavonoid Content Assay

Total flavonoid content (TFC) of oleaster fruit samples was carried out using the procedure of M'hiri et al. (2015). The extract (0.3 mL) was mixed with 5%  $\text{NaNO}_3$  (0.3 mL) solution. Then, 10%  $\text{AlCl}_3$  solution (0.3 mL) was added to the mixture. After the incubation for 10 min, 10%  $\text{NaOH}$  solution (4 mL) was poured onto the mixture. The absorbance values were read at 510 nm using the spectrophotometer. The analysis was run in triplicate and TFC was given as mg catechin equivalent/g dry matter of oleaster fruit (mg CE/g DM).

### Total Tannin Content Assay

Total tannin content (TTC) of oleaster fruit samples was carried out using the method given by Li et al. (2015). The extract (0.2 mL) was mixed with Folin-Dennis' reagent (1.25 mL), then 10%  $\text{Na}_2\text{CO}_3$  solution (2.5 mL) was added and the volume of the mixture was completed to 25 mL with distilled water. This mixture was held at dark for 30 min and the absorbance values were recorded at 700 nm using the spectrophotometer. Results were expressed as mg tannic acid equivalent/g dry matter of oleaster fruit (mg TAE/g DM). This analysis was performed in triplicate.

### Antioxidant Activity Assay (DPPH Method)

Antioxidant activity (AA) assay of oleaster fruit samples was performed using the method of Aghraz et al. (2018). DPPH of 2 mL (in 100% methanol) was mixed with the extract (0.1 mL) and the mixture was kept at dark for 30 min. The absorbances were read at 517 nm using the spectrophotometer. The assay was carried out in triplicate. AA was calculated as  $\mu\text{mol}$  trolox equivalent/g dry matter of oleaster fruit ( $\mu\text{mol TE/g DM}$ ).

### Antioxidant Activity Assay (FRAP Method)

AA of oleaster fruit samples was also determined by FRAP method (Szydłowska-Czerniak et al., 2008). First of all, FRAP reagent consisted of 20 mM  $\text{FeCl}_3$  (2.5 mL), 10 mM TPTZ solution (2.5 mL) and 0.1 M acetate buffer (25 mL) was prepared. Afterwards, FRAP reagent (2 mL) added onto the extract (0.3 mL) and then it was completed to total volume of 10 mL with distilled water. The absorbance values were obtained at 593 nm using a spectrophotometer. Results were expressed as  $\mu\text{mol TE/g DM}$ . The assay was run in triplicate.

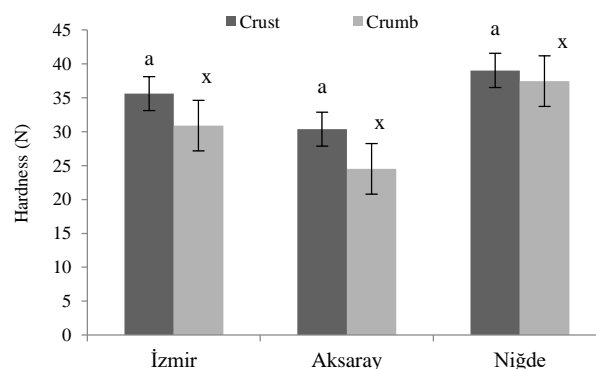


Figure 1. Hardness values of oleaster fruits from different locations of Turkey

(Statistical evaluation was not conducted between crust and crumb of same samples)

Table 1. The color values of crust and crumb of oleaster fruits

Location	$L^*$	$a^*$	$b^*$
Crust			
İzmir	46.81 <sup>b</sup> ±4.06	19.80 <sup>a</sup> ±1.98	24.27 <sup>b</sup> ±3.31
Aksaray	61.54 <sup>a</sup> ±4.71	13.16 <sup>b</sup> ±3.68	33.26 <sup>a</sup> ±3.50
Niğde	58.96 <sup>a</sup> ±7.91	15.83 <sup>b</sup> ±4.62	34.52 <sup>a</sup> ±8.32
Crumb			
İzmir	78.91 <sup>y</sup> ±4.97	2.98 <sup>x</sup> ±1.46	17.92 <sup>z</sup> ±2.81
Aksaray	81.85 <sup>x</sup> ±1.96	1.48 <sup>y</sup> ±0.78	26.88 <sup>x</sup> ±2.42
Niğde	82.59 <sup>x</sup> ±3.66	1.51 <sup>y</sup> ±0.73	20.86 <sup>y</sup> ±1.41

Same superscript in a column indicates no significant differences ( $P > 0.05$ ).

Table 2. Total phenolic, flavonoid, tannin contents and antioxidant activities of different oleaster fruits

Region	TPC (mg GAE/g DM)	TFC (mg CE/g DM)	TTC (mg TAE/g DM)	AA by DPPH ( $\mu$ mol TE/g DM)	AA by FRAP ( $\mu$ mol TE/g DM)
Crust					
İzmir	15.91 <sup>b</sup> ±8.73	5.99 <sup>b</sup> ±0.45	61.88 <sup>a</sup> ±2.38	6.28 <sup>c</sup> ±1.50	4.86 <sup>a</sup> ±1.09
Aksaray	22.30 <sup>a</sup> ±1.75	16.24 <sup>a</sup> ±1.49	63.67 <sup>a</sup> ±1.02	14.05 <sup>a</sup> ±0.55	6.65 <sup>a</sup> ±0.55
Niğde	13.43 <sup>b</sup> ±1.20	7.69 <sup>b</sup> ±1.30	54.32 <sup>a</sup> ±5.72	8.37 <sup>b</sup> ±0.26	4.44 <sup>a</sup> ±0.35
Crumb					
İzmir	12.42 <sup>xy</sup> ±1.94	6.54 <sup>x</sup> ±2.68	49.58 <sup>x</sup> ±3.18	5.01 <sup>z</sup> ±0.17	1.99 <sup>y</sup> ±1.08
Aksaray	16.44 <sup>x</sup> ±1.67	3.10 <sup>x</sup> ±0.01	23.85 <sup>x</sup> ±0.01	6.01 <sup>y</sup> ±0.11	n.d.
Niğde	10.58 <sup>y</sup> ±1.12	5.64 <sup>x</sup> ±0.90	58.28 <sup>x</sup> ±6.06	11.56 <sup>x</sup> ±0.32	4.82 <sup>x</sup> ±0.03

Same superscript in a column indicates no significant differences ( $P > 0.05$ ). TPC: Total phenolic content, AA: Antioxidant activity, TFC: Total flavonoid content, TTC: Total tannin content, GAE: Gallic acid equivalent, CE: Catechin equivalent, TE: Trolox equivalent, TAE: Tannic acid equivalent, DM: Dry matter (it should be added after TAE: Tannic acid equivalent), n.d.=not determined

### Texture Profile Analysis

Hardness of the crust and crumb of the oleaster fruits was measured by CT3 Texture Analyzer (Brookfield, Germany). Texture profile analysis was conducted, and conditions were specified as follows; the load cell of 4500 g, 0.067 N of trigger load, 1 mm/s test speed and 60% of the distance were used in the compression mode.

### Statistical Analysis

The physical, bioactive and textural properties of oleaster fruit samples were analyzed using an analysis of variance test (one-way ANOVA). Duncan test was applied to compare the means of each assay using SPSS 18 trial version (SPSS Inc., Chicago, IL).

## Results and Discussion

### The Color Parameters

The color values ( $L^*$ ,  $a^*$  and  $b^*$ ) of crust and crumb of oleaster fruits were shown in Table 1.  $L^*$ ,  $a^*$  and  $b^*$  values of the crust of oleaster fruits from İzmir were significantly different ( $P < 0.05$ ) from those from those of Aksaray and Niğde. The same trend was also seen for the crumb of oleaster fruits from İzmir. The lowest  $L^*$  ( $46.81 \pm 4.06$ ) and  $b^*$  ( $24.27 \pm 3.31$ ) and highest  $a^*$  ( $19.80 \pm 1.98$ ) were measured for the crust of oleaster fruits from İzmir. In general, higher  $L^*$  and lower  $a^*$  values were determined for the crumb of oleaster fruits when compared to the ones of crust of oleaster fruits. The increase in  $L^*$  values in the crumb could be related to direct sun exposure of crumb of oleaster fruits.

### The Bioactive Properties

The bioactive properties (TPC, TFC, TTC, and AA) of crust and crumb of oleaster fruit extracts were given in Table 2. In this study, the crust and crumb of oleaster fruit were evaluated separately since there has been an interest to use the crumb part of oleaster fruits in the flour form in the literature. However, the crust of oleaster fruit could be valorized by mixing with the crumb or individually. The crust and crumb of extracts of the oleaster fruit from Aksaray had the highest TPC ( $22.30 \pm 1.75$  mg GAE/g DM and  $16.44 \pm 1.67$  mg GAE/g DM, respectively). These results were similar to the findings of Çakmakçı et al. (2015) who reported TPC of the flour and crust lyophilized oleaster extract as 27.78 and 31.11 mg GAE/g, respectively. Hassanzadeh and Hassanpour (2018) found the mean value of TPC of peel and pulp of oleaster grown

in Iran as 518.07 and 480.16 mg GAE/100 g fresh weight, respectively. In another study, TPC of extract obtained from oleaster grown in Tunisia was reported as  $84.04 \pm 0.01$  mg GAE/g DM (Hanene et al., 2015). Our findings and results of previous studies clearly demonstrated that the TPC of oleaster fruits may change with the cultivars, genotypes, climate conditions and geographical locations (Hassanzadeh and Hassanpour, 2018).

TFC of the extracts obtained from the crust and crumb of oleaster fruit varied between  $5.99 \pm 0.45$  and  $16.24 \pm 1.49$  mg CE/g DM, and  $3.10 \pm 0.01$  and  $6.54 \pm 2.68$  mg CE/g DM, respectively. TFC of crust of Aksaray oleaster fruit was significantly higher than those from İzmir and Niğde oleaster fruits; however, TFC of oleaster crumb from different locations were not significantly different. The highest TFC ( $16.24 \pm 1.49$  mg CE/g DM) was observed in the extracts obtained from Aksaray oleaster crust. Faramarz et al. (2015) reported TFC of peel and pulp of Iranian oleaster as 0.64–1.13 mg and 0.62–1.90 mg CE/g which was lower than our findings. TFC of flour and crust lyophilized oleaster extract was determined as 36.36 and 32.73 mg quercetin equivalents/g, respectively (Çakmakçı et al., 2015). In the study of Hassanzadeh and Hassanpour (2018), TFC of peel and pulp of Iranian oleaster was reported as 121.55 and 148.52 mg CE/100 g fresh weight, respectively. The variations in the TFC of oleaster in various studies could be explained with the differences in the genetic, climate or environmental conditions.

Interestingly, there was no significant change among the TTC of extracts obtained from the crust and as well crumb of oleaster fruits from different locations. The TTC changed between  $54.32 \pm 5.72$  and  $63.67 \pm 1.02$  mg TAE/g DM, and  $23.85 \pm 0.01$  and  $58.28 \pm 6.06$  mg TAE/g DM for the extract of the crust and crumb of oleaster fruits, respectively. These results were consistent with the findings of Hanene et al. (2015) who reported condensed tannin as  $40.08 \pm 0.01$  mg CE/g DM in the extract of Tunisian oleaster.

AA of extracts from oleaster fruit crust and crumb was determined using DPPH and FRAP method. There was a significant change among the AAs of crust and crumb of oleaster fruits. The AA values detected by DPPH method were in the range of  $6.28 \pm 1.50$  and  $14.05 \pm 0.55$   $\mu$ mol TE/g DM, and  $5.01 \pm 0.17$  and  $11.56 \pm 0.32$   $\mu$ mol TE/g DM for the extract of crust and crumb of oleaster fruits, respectively. The highest AA ( $14.05 \pm 0.55$   $\mu$ mol and  $11.56 \pm 0.32$   $\mu$ mol TE/g DM) of the extract of crust and crumb was seen in Aksaray and Niğde oleaster fruits. This could be expected

due to the high TPC of Aksaray oleaster. Çakmakçı et al. (2015) found the IC<sub>50</sub> value by DPPH method as 34.65 and 34.72 µg/mL for the flour and crust lyophilized oleaster extract. Hassanzadeh and Hassanpour (2018) showed the mean AA measured by DPPH for the oleaster peel and pulp as 74.71 and 53.76%, respectively. Another study reported about AA by DPPH method as 86.95 and 91.78%, respectively (Faramarz et al., 2015). On the other hand, in the present study, the AA values based on FRAP assay were not significantly different for the extract of crust from oleaster fruits of different places. The AA values changed between 4.44 ± 0.35 and 6.65 ± 0.55 µmol TE/g DM for the extract of oleaster crust. Previous studies reported AA values measured by FRAP assay as the range of 86–164.67 mg/100 g fresh weight for the oleaster pulp and 0.246 and 0.548 mM/mg for the oleaster peel and pulp, respectively (Faramarz et al., 2015; Hassanzadeh and Hassanpour, 2018).

### Texture Profile Analysis

The hardness values of the crust and crumb of oleaster fruits were presented in Figure 1. The hardness values of crust of oleaster fruits from different locations varied between 30.36 and 39.01 N. There was no significant difference among the crust or crumb of oleaster fruits from different locations (P>0.05). The hardness values for the crumb ranged from 24.50 and 37.43 N. The hardness of the crumb of oleaster fruits was lower compared to that of crust.

### Conclusion

This study clearly showed that the physical and bioactive properties of oleaster fruits can change significantly due to the geographical location. The genotype, climate and environmental conditions greatly influence the fruit composition. In this study, there were significant differences among total phenolic and flavonoid content, total tannin content and antioxidant activities of fruits from different locations. Also, this study demonstrated that the cultivated region of oleaster fruit did not affect the hardness of oleaster fruit. In addition, this study evaluated the crust and crumb of the oleaster fruit individually which would present the detailed information to researchers and food industry. As a result, the oleaster fruit has a potential to incorporate into foods due to its high bioactive content.

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