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Chemical and techno-functional properties of flours from peeled and unpeeled oleaster (*Elaeagnus angustifolia* L.)

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Summary

Oleaster flours were produced from two different genotypes (GO1 and GO2) and methods (peeled oleaster flour: POF and unpeeled oleaster flour: UPOF). Oleaster flour samples (OFs) contained high levels of dietary fibers and micro minerals. The contents of Fe, Cu, B, and Cr in flours obtained from oleaster fruits were higher in UPOF than in POF samples. Palmitic acid was the major fatty acid which was followed by oleic acid and lignoceric acid. All samples contained greater amount of saturated fatty acids (SFA) as compared to mono unsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). Among seven different organic acids detected, the level of citric acid was the highest and it was followed by malic, acetic and oxalic acids. High nutritional contents of oleaster flour indicated that it is a good source of dietary fiber, micro minerals, as well as organic and fatty acids.

The water solubilities (WS) and water absorption capacities (WAC) of oleaster flours were adequate for their utilization. They also seem to have an improving effect on emulsion properties of albumin. These results highlighted that it is possible to use the oleaster flour in some processed foods such as bakery goods, dairy products (ice cream and yoghurt), beverages and confectionery. Moreover, the oleaster flour could also be used in the preparation of low-fat, high-fiber dietetic products due to its high dietary fiber content.

Introduction

Oleaster *(Elaeagnus angustifolia* L., Russian olive) belongs to *Elaeagnus* L. genus and *Elaeagnaceae* family. *Elaeagnus angustifolia* L. is a kind of shrub or tree with a height of up to 7 m and a capacity to grow under a wide range of environmental conditions (KLICH, 2000). This species shows a broad geographical range, existing widely in Asia and Europe, particularly in Turkey, Caucasia and Central Asia (AKSOY and SAHIN, 1999). It is widely cultivated for its edible fruits in Middle and East Anatolia. Its fruits are reddish-brown, elliptic, 9-12 mm long and 6-10 mm wide and they ripen in September. They can be consumed either fresh or in dried form. Oleaster fruits are also used as diuretic, tonic, antipyretic, antidiarrheal and as a medicine against kidney disorders (to prevent inflammation or to eliminate kidney stone) in traditional Turkish medicine (AYAZ and BERTOFT, 2001; GURBUZ et al., 2003), against dysentery and diarrhea in The Kingdom of Jordan (LEV and AMAR, 2002) and, owing to their anti-inflammatory, antinociceptive and analgesic effects, in Iranian folk medicine. Medicine obtained by decoction and infusion of its fruits is considered to be a good remedy against fever, jaundice, asthma, tetanus and rheumatoid arthritis (AHMADIANI et al., 2000).

Although this species grows naturally in most parts of Turkey, its fruits are of limited use in agricultural and food industry. In parallel with the increase in demand for healthy foods, functional products have been used increasingly as ingredients to improve functionality of foods by modifying their nutritive composition. CANSEV et al. (2011) suggested that *Elaeagnus angustifolia* L. fruit was a valuable horticultural product thanks to its rich and beneficial nutrient composition. Their study was a preliminary research for investigating the nutritional values and potential use of *Elaeagnus angustifolia* L. species in the food industry. GONCHAROVA et al. (1993) have also reported an abundance of palmitoleic acid (16:1) in fruit skin and linoleic acid (18:0) and palmitic acid (16:0) in seeds as both phospholipids and glycolipids.

Oleaster flour may be obtained from dried fruits and its flour may be used as a functional ingredient in the production of bakery products, yoghurt, ice cream, infant food, chocolate, confectionery etc. thanks to its floury structure, specific taste and functional properties like dietary fibre, mineral content and phenolic compounds.

However, there was no sufficient information regarding the composition of oleaster flour. Therefore, the goal of our research was to examine flour from oleaster fruit and to investigate its functional properties [water absorption capacity (WAC), water solubility (WS), emulsion capacity (EC) and emulsion stability (ES)] and composition of minerals, organic acids and fatty acids.

Material and methods

Materials

Two different genotypes were used as oleaster fruit samples. These genotypes were supplied from two different regions in Turkey: GO1 (40º11´19.60´´N-26º06´09.16´´E) and GO2 (39º34´01.48´´N-26º51´02.90´´E). The fruits had approximately the same maturity (almost reddish) with uniform shape, size and health conditions. Mature fruits were randomly collected. Fruit samples were dried at 50 ºC for 20 hours in a hot air oven dryer. Oleaster flour was produced by two different methods. In the first method; skin and seeds of dry fruit samples were removed using a plastic knife, and then the fruit pulp was ground in a coffee grinder and sieved through a standard sieve (mesh size 60). The product obtained at the end of this process was named peeled oleaster flour (POF). In the second method; only seeds of dry samples were removed using a plastic knife, and then the fruit pulp and skin were ground together in a coffee grinder and sieved through a standard sieve (mesh size 60). This product was named unpeeled oleaster flour (UPOF). Sample codes are GO1-POF (Genotype 1, peeled oleaster flour), GO1-UPOF (Genotype 1, unpeeled oleaster flour), GO2-POF (Genotype 2, peeled oleaster flour) and GO2-UPOF (Genotype 2, unpeeled oleaster flour).

Methods

Chemical analysis

Oleaster flours (OFs) were analyzed for moisture (Metod No: 925.40), ash (Metod No: 950.49) and dietary fiber (Method No: 985.29) (AOAC, 1990). Protein contents of samples were determined by the Kjeldahl method according to AACC Metod No: 46-10.01(AACC 1999) using a Buchi apparatus (Models 430 and 320, Buchi Laboratoriums-Techinic AG, Flawil, Switzerland). Starch contents of oleaster flours were determined with Starch (GO/P) Assay Kit (Sigma-Aldrich Corp.)

Determination of micro minerals

Reagents

All solutions were prepared with analytical reagent grade chemicals and ultra-pure water (with 18 MΩ cm resistivity) generated by purifying distilled water with the TKA Ultra Pacific and Genpura water purification system (Germany). Suprapur HNO_3 (67 % v/v) was purchased from Merck (Darmstadt, Germany). Standard stock solutions containing 1000 mg/L of each element (Zn, Fe, Cu, Mn, B, Cr, Co, Se and Mo) were purchased from Merck (Darmstadt, Germany) and used to prepare appropriate calibration standards. Working standards were prepared daily in 0.3 % (v/v) HNO_3 and used without further purification. Botanical certified reference materials (CRMs), cabbage IAEA – 359 (Austria), tea NCS ZC73014-(GSB-7) (China) and strawberry LGC7162 (England), were analyzed for validation purpose. A 10 µg/L Lithium, Yttrium, Cerium, Thallium, and Cobalt in 2 % HNO_3, Cat No. 5184-3566 (Agilent Technologies) was used to prepare a tuning solution. 1000 mg/L standard stock solutions (Merck, Darmstadt, Germany) were prepared in 0.3 % HNO_3 for internal standard solution. Argon (purity: 99.9995 %, Linde, Turkey) was used as carrier gas.

Sample preparation procedure

Sample digestion was carried out using the Millestone MLS 1200 (Italy) microwave digestion system, equipped with a rotor for 6 type sample vessels (polytetrafluorethylene (PTFE) tubes). Before use, quartz vessels were decontaminated in a bath of 10 % HNO_3 (67 % v/v), then rinsed with ultra pure water, and dried in an oven at 40 °C. The samples were homogenized and subsequently around 0.5 g was weighed directly on PTFE flasks after adding 6 mL of HNO_3 and subjected to a digestion program: 250 W (2 min), 0 W (2 min), 250 W (6 min), 400 W (5 min) and 600 W (5 min). After cooling to room temperature, sample solutions were quantitatively transferred into 50 mL polyethylene flasks. 100 µL of internal standard solution (1 mg/L) was added and then the digested samples were diluted to 25 mL before analysis by using ICP-MS and ICP-OES equipments.

Instrumentation

ICP-MS measurements were performed using an Agillent 7500a Series Shield Torch System ICP-MS (USA). The sample solutions were pumped by a peristaltic pump from tubes arranged on a CETAC ASX 520 auto sampler (CETAC, Omaha, Nebraska, USA). The isotopes ^{53}Cr, ^{95}Mo, ^{82}Se and ^{59}Co were selected as analytical masses in ICP-MS standard mode. The analyses were performed at the following flow rates: (a) plasma gas of 15 L/min, (b) auxiliary gas of 0.9 L/min, and (c) sample of 0.8 mL/min. All chemical analyses were carried out in duplicate on each sample. Multi-element standard solutions were used for external calibration. Eight standards with standard linear regression and internal standardization were prepared at levels ranging from 0 to 200 µg/L. The calibration curve was drawn from six points including the calibration blank (SAHAN et al., 2007).

The Zn, Fe, Cu, Mn and B determination process was performed using an inductively coupled plasma optical emission spectrometer (ICP-OES) model Perkin Elmer 2100 with axial view (USA). The emission intensities were obtained for the most sensitive lines free of spectral interference. The analyses were performed at the following flow rates: (a) plasma gas of 15 L/min, (b) auxiliary gas of 1 L/min, and (c) sample of 0.8 mL/min. The mineral eluates were monitored at different wavelengths: 206.2 nm-Zn, 238.2 nm-Fe, 327.4 nm-Cu and 257.6 nm-Mn. All chemical analyses were carried out in duplicate on each sample.

Determination of fatty acid composition

The fatty acids of oleaster flour were separately extracted with diethyl ether for 6 hr by using Soxhlet Extraction Method. The extract was protected against light. The solvent was evaporated under reduced pressure and temperature and the oil was collected. The analytical methods for determination of fatty acid composition are described in regulation standard method (ISO 5509:2000, 2000). Fatty acids were converted to fatty acid methyl esters before analysis by shaking a solution of 0.6 g of oil and 4 mL of isooctane with 0.2 mL of 2 N methanolic potassium hydroxide. The converted fatty acid methyl esters were analyzed using a Shimadzu (GC-17 A) chromatograph, equipped with a capillary column (DB wax; 30 m × 0.25 mm; 0.25 µm), a split-splitless injector, and a flame ionization detector (FID). The carrier gas was nitrogen and used at a flow rate of 1 mL/min. The temperatures of the injector, detector, and oven were held at 250, 250, and 210 °C, respectively.

Determination of organic acids

Seven organic acids (oxalic, tartaric, malic, L-ascorbic, acetic, citric, and fumaric acid) were analyzed by Dionex ICS 3000 ion chromatography device (CA, USA) which consists of a separation Acclaim 4 x 250 mm column, a gradient pump, and ICS –VWD UV detector set at 210 nm with a flow-rate of 0.6 mL/min maintaining the column temperature at 30 ºC. In the mobile phase, 100 mM Na_2SO_4 (pH 2.65) was used. Organic acids quantification was achieved by the absorbance value recorded in the chromatograms based on the external standards in the standards solution and the peaks were integrated using a default baseline construction technique. The chemicals for the organic acid standard solutions were purchased from Supelco (USA). The measurement process repeated five times and average values were calculated based on the external standards (1-200 mg/L). For the preparation of tested samples, approximately 2 g ground flour of oleaster was weighed into a 250 mL Erlenmeyer flask, and 100 mL of an 5 mM H_2SO_4 added. After adding a stirring bar, the flask was placed on a VWR ADV 3500 stirrer at 175 rps for 3 hr. The extract was filtered through 0.45 µm PVDF filter (QUI and JIN, 2002).

Determination of functional properties

Water solubility (WS) and water absorption capacity (WAC)

Water solubility and absorption capacity of samples were determined according to SINGH and SINGH (2003) with slight modifications. A 0.5 g flour sample was dispersed in 5 mL of distilled water and vortexed for 15 s in every 5 min. After 40 min it was centrifuged (Cencom II, Selecta) at 2100 g for 10 min. Supernatant was dried at 100 ºC and solubility was calculated as follows:

$$\textit{Water Solubility (WS) (\%)} = W_1 / W_2 * 100$$

Where W_1 is the weight of dried supernatant, W_2 is the weight of sample.

Precipitate was weighed and then dried at 100 ºC. Water absorption capacity was calculated as follows:

Water absorption Capacity (WAC) (%) = $(W_1 - W_2) / W_3 * 100$

Where W_1 is the weight of wet precipitate, W_2 is the weight of dried precipitate, W_3 is the weight of sample.

Emulsion capacity (EC) and emulsion stability (ES)

Emulsion capacity and emulsion stability values were determined according AHMEDNA et al. (1999) as modified by BILGI and CELIK (2004) with some modifications. Five mL of 7 % dispersion of the oleaster flour sample (prepared with 0.05 % albumin solution) was mixed with 5 mL of corn oil and homogenized at 23 500 rpm for 1 min. Then it was centrifuged at 2100 g for 30 min (Cencom II, Selecta). The ratio of the height of the emulsified phase to the height of total liquid was named as emulsion capacity (%).

In order to determine the value of emulsion stability, homogenized sample was incubated at 45 ºC for 30 min. After that, it was allowed to stand for 10 min at room temperature. Then it was centrifuged at 2100 g for 20 min (Cencom II, Selecta). The ratio of the height of the emulsified phase to the height of total liquid was named as emulsion stability (%). Experiments were conducted in triplicate.

Statistics

Data are presented as mean values +/- standard error of 3 replicates. Statistical analysis was performed by one-way analysis of variance (ANOVA) on SPSS version 17.0 software for Windows (USA). When significant differences were found ($p \leq 0{,}05$), the least significant difference (LSD) test was used to determine the differences among mean values. Paired t-test was carried out to compare the properties of GO1-POF, GO1-UPOF, GO2-POF and GO2-UPOF.

Result and discussion

Chemical Compositions

Chemical compositions of oleaster flour (OF) samples are presented in Tab. 1. The moisture contents of the OF samples in the present study varied between 18.43 and 20.20 %. The protein contents of the OFs ranged from 3.74 to 4.65 %. The highest (4.65 %) protein level was observed in GO2-UPOF, followed by GO1-UPOF (4.49 %), GO2-POF (4.51 %) and GO1-POF (3.74 %). Protein content of UPOF samples was higher than those of the POF samples. The starch contents of the OFs obtained in this study were found to be between 13.80-43.18 %. The starch contents of the peeled oleaster flours (POFs) samples were significantly ($p \leq 0.05$) higher than those of the unpeeled oleaster flours (UPOFs). It can be attributed to the presence of higher amount of starch in pulp than in peel.

Tab. 1: Chemical compositions of oleaster flours[a]*.

Samples	Moisture* (g/100 g)	Protein* (g/100 g, db)	Starch (mg/100 g, db)	Total Dietary Fiber (g/100 g, db)
GO1-POF	18.99 ±1.05[a]	3.74±0.26[c]	43.18±2.26[b]	23.55±0.07[c]
GO1-UPOF	18.43±1.13[a]	4.49±0.17[b]	17.73±2.38[cd]	30.65±0.16[a]
GO2-POF	19.78±1.11[a]	4.51±0.24[b]	36.86±4.89[b]	20.67±0.21[d]
GO2-UPOF	20.20±0.96[a]	4.65±0.19[b]	13.80±2.13[cd]	25.44±0.44[b]

[a] Means with different superscripts in columns indicate significant difference ($p \leq < 0.05$).

*Data are expressed as means ± standard deviations.

The total dietary fibre (TDF) content of the OFs ranged from 20.67 % to 30.65 %. Total dietary fiber (TDF) levels of the samples. These results were lower than pumpkin flour samples (32.15 % to 36.73 %) found by AYDIN and GOCMEN (2015). The highest TDF content was found in GO1-UPOF (30.65 %) followed by GO2-UPOF (25.44 %). The dietary fiber values of UPOFs were significantly ($p \leq 0.05$) higher than those of POFs. The higher TDF levels observed in UPOF samples are possibly related to pericarp contents. Epidemiological studies suggest that dietary fibre consumption helps to reduce obesity, some kinds of cancer, cardiovascular diseases and gastrointestinal diseases. Although numerous health organizations indicate the necessity of increasing fibre consumption of up to 20-35 g per day, most people are unaware of the recommended dose (GOMEZ et al., 2010). Oleaster flour is a good source in TDF, it might be important from the nutrition point of view.

Micro minerals

The micro minerals of flour samples obtained from *Elaeagnus angustifolia* L. are presented in Fig. 1. Determined detection and quantification limits of elements are shown in Tab. 2. According to averages level of micro minerals in all samples, Fe was found to be highest (10.72 mg/kg) and it was followed by B (7.79 mg/kg) and Zn (4.08 mg/kg).

With regard to genotypes, generally Zn, Cu, Mn contents of GO1 samples were higher than those of GO2 samples ($p \leq 0.05$). These differences between genotypes may be due to growth conditions, genetic factors, soil properties and geographical variations. On the

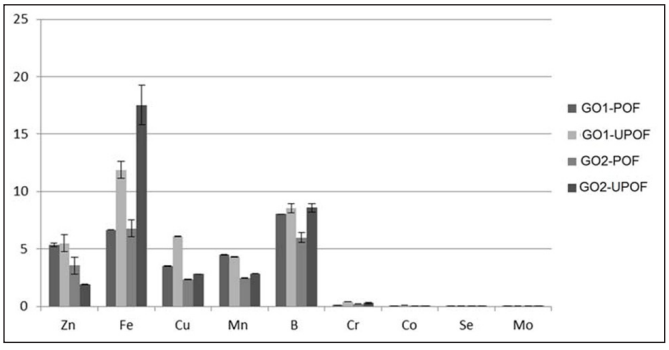

Fig. 1: The micro minerals of peeled (POF) and unpeeled (UPOF) oleaster flours from two genotypes (GO1 and GO2). Data show mean values of three replicates +/- standard error.

Tab. 2: Performance characteristic of mineral determination methods.

ICP-MS İsotope	Recovery (%)	LOD mg kg^{-1}	LOQ mg kg^{-1}
^{53}Cr	90.6	0.009	0.030
^{59}Co	90.1	0.006	0.020
^{82}Se	49.3	0.012	0.039
^{95}Mo	71.3	0.016	0.055
ICP-OES Line			
Zn (206.200 nm)	93.8	0.3	0.8
Fe (238.204 nm)	87.3	0.3	1.0
Cu (327.393 nm)	100.1	0.2	0.7
Mn (257.610 nm)	89.5	0.1	0.4
B (249.677 nm)	92.8	0.4	1.3

other hand, no correlation could be found between other micro minerals and genotypes. Regarding to the flour obtained from oleaster fruits, Fe, Cu, B, and Cr contents were higher in UPOF than in POF samples ($p \leq 0.05$). Especially Fe content of UPOF samples showed significant increase ($p \leq 0.05$). Our data showed that Fe, Cu, B, and Cr accumulations were higher in fruit skin than in pulp tissues. In peel of fruit the measured concentrations of elements were higher compared to corresponding pulp and juice samples, which is in accordance with previously published results (Henriquez et al., 2010 and Savikin et al., 2014).

Conversely, no significant differences regarding Co, Se and Mo contents were determined in all samples ($p \geq 0.05$) (Fig. 1).

The highest content of Zn was determined in GO1-UPOF sample (5.50 mg/kg) while the lowest content of Zn was determined in GO2-UPOF (1.90 mg/kg). Our results were compatible with those obtained by Dolezal et al. (2001) and Akbolat et al. (2008) (2.32 mg/kg).

Fe content was the highest (17.53 mg/kg) in GO2-UPOF and the lowest (6.66 mg/kg) in GO1-POF. Our results revealed that the oleaster fruit is a good natural source of iron. Dolezal et al. (2001), reported lower (5.77 mg/kg) Fe content in oleaster fruit suggesting that the oleaster fruits in Turkey contain greater amount of Fe.

The levels of Cu in OFs were within the range of 2.37-6.11 mg/kg (Fig. 1). Our results were higher than those reported by Dolezal et al. (2001), (1.73 mg/kg). We found greater Cu content compared with those reported in previous studies.

The boron content varied beetween 5.99 mg/kg (GO2-POF) and 8.58 mg/kg (GO2-UPOF). Sungur and Okur (2009) determined boron concentrations of 32 species of vegetable and 17 species of fruit in Hatay, Turkey. High concentrations of boron were found in thyme (10.44 mg/kg), mint (6.96 mg/kg), red cabbage (6.45 mg/kg), broad-bean (6.28 mg/kg), quince (5.41 mg/kg), pomegranate (5.27 mg/kg) and orange (4.08 mg/kg) while low concentrations of boron were found in pumpkin (0.76 mg/kg), white radish (0.97 mg/kg), plum (1.16 mg/kg) and cucumber (1.17 mg/kg). Most foods had boron concentrations in the range of 1.48-3.60 mg/kg. According to our results, oleaster fruits are good natural sources of boron. Hence, our findings make a significant contrubition to the limited information available in the literature.

Mn contents of all samples varied between 2.46 mg/kg and 4.51 mg/kg. Mn concentrations in oleaster fruit were reported as 10.15 mg/kg by Dolezal et al. (2001) and 47.10-49.76 mg/kg by Akbolat et al. (2008). We found lower Mn content compared with those reported in previous studies.

In the present study, Se contents ranged from 0.025 mg/kg and 0.04 mg/kg. Se levels of all samples are relatively higher than those of different fruits investigated in another study by Ventura et al. (2009). Additionally, we provide information with regard to levels of essential nutrients Cr, Co and Mo in oleaster fruit for the first time in the literature. The chromium value of oleaster ranged between 0.11-0.38 mg/kg. The Co content of oleaster fruits averaged 0.06 mg/kg; this value is smaller than the average Co content of the fruits, including apples (35.24-39.9 μg/g), plums (45.32 μg/g), cornelians (32.45-41.03 μg/g), (Hamurcu et al., 2010), red guava (3.17 μg/g), yellow guava (0.31 μg/g), and guobiroba (0.62 μg/g) (Pereira et al., 2014). The mean Mo levels of oleaster fruit varied between 0.03 and 0.05 mg/kg. No data have been reported on Mo content in dried fruits.

Fatty Acids

Nine different fatty acids were detected in POF and UPOF samples of two genotypes and their percentages are presented in Fig. 2. The major fatty acid in all samples according to average values was palmitic acid (C16:0) (34.31 %), and it was followed by oleic acid (C18:1) (26.23 %) and lignoceric acid (C24:0) (17.47 %). Linoleic acid was detected only in GO2 samples (2.20 %). All samples were characterized by high amounts of saturated fatty acids (SFA) as compared to mono unsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). Limited information is available in the literature regarding the fatty acid composition of *Elaeagnus angustifolia*. Goncharova et al. (1993) reported an abundance of palmitoleic acid (16:1) in fruit skin and linoleic acid (18:0) and palmitic acid (16:0) in seeds. These differences might be explained by differences in gentypes, climatic condition and soil composition.

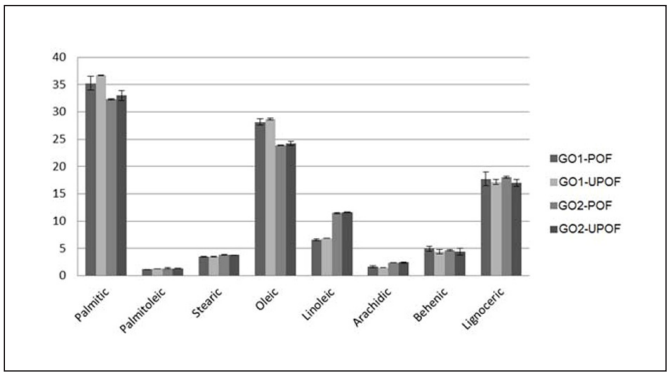

Fig. 2: The fatty acids of peeled (POF) and unpeeled (UPOF) oleaster flours from two genotypes (GO1 and GO2). Data show mean values of three replicates +/- standard error.

Significant differences were observed for each individual fatty acid of POF and UPOF samples between genotypes. Palmitic and oleic acid concentrations were significantly higher in GO1 samples than in GO2 samples ($p \leq 0.05$). Conversely, palmitoleic, stearic, linoleic, arachidic acid levels in GO2 samples were higher than those in GO1 ($p \leq 0.05$). On the other hand, palmitoleic, behenic and lignoceric acid contents were similar in all samples. In addition, levels of all fatty acids in POF samples were similar with those of UPOF samples in both genotypes (Fig. 2.).

Among the POF and UPOF samples, GO1-UPOF had the highest palmitic and oleic acid contents in all fatty acids (36.69 %, 28.69 %), respectively. The highest lignoceric acid level (18.02 %) was detected in GO2-POF samples compared to the other samples. GO2-UPOF samples had the highest linoleic acid content (11.59 %) among all samples (Fig. 2.). Oleic acid and linoleic acid were predominant unsaturated fatty acids in all samples.

Organic Acids

Organic acids may have a protective role against various diseases due to their antioxidant activity (Silva et al., 2004). In this study, the organic acid composition of POF and UPOF samples were determined by ion chromatography. The performance characteristics of organic acids are shown in Tab. 3. Seven different organic acids were detected and their percentages were presented in Fig. 3.

According to the average values of POF and UPOF samples, the highest levels were obtained in citric acid (16.94 mg/g) content which was followed by malic acid (15.07 mg/g), acetic acid (6.97 mg/g), oxalic acid (4.72 mg/g), tartaric acid (3.67 mg/g), fumaric acid (0.82 mg/g), and trace amounts of ascorbic acid (0.035 mg/g) (Fig. 3). To the best of our knowledge, only few studies were conducted exploring the organic acid composition of oleaster (*Elaeagnus angustifolia* L.).

In the literature, citric and malic (both aliphatic) acids are the most abundant acids in fruits and vegetables (Bae et al., 2014; Gundogdu et al., 2014; Oliveira et al., 2014; Ma et al., 2015). In this study, the levels of citric acid in OFs were within the range of 13.00-26.69 mg/g (Fig. 3). Levels of organic acids showed significant variations ($p \leq 0.05$) in two genotypes as a function of the growth con-

Tab. 3: Performance characteristics of the determination of organic acid method.

Organic acid (mg/100g)	LOD (mg/kg)	LOQ (mg/kg)	Recovery (%)
Oxalic acid	0.24	0.8	85.5
Malic acid	2.02	6.7	79.6
L-Ascorbic acid	0.23	0.8	73.2
Acetic acid	1.56	5.2	78.0
Citric acid	1.76	5.9	83.8
Tartaric acid	1.55	5.2	77.5
Fumaric acid	0.15	0.5	77.0

LOD: Limit of dedection LOQ: Limit of Quantification

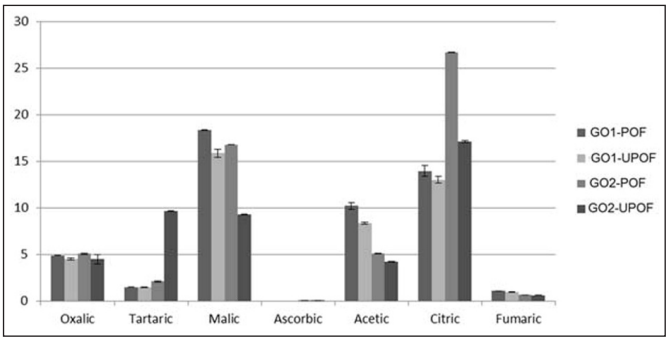

Fig. 3: The organic acids of peeled (POF) and unpeeled (UPOF) oleaster flours from two genotypes (GO1 and GO2). Data show mean values of three replicates +/- standard error.

ditions of the fruits. Citric acid was the major organic acid in GO2 samples and citric acid concentrations were significantly higher in GO2 samples than in GO1 samples ($p \leq 0.05$). Citric acid concentration of GO2-POF sample (26.69 mg/g) was 2 times that of GO1-POF sample (13.0 mg/g). Additionally, its level in GO2-UPOF was 1.3 times higher than that in GO1- UPOF sample. Although citric acid contents were similar in GO1-POF and UPOF samples, they were significantly different between GO2-POF and UPOF samples ($p \leq 0.05$). Similar levels of citric acid have been reported in oleaster fruit (Dolezal et al., 2001).

Malic acid was the predominant organic acid in GO1 samples. The highest malic acid concentration (18.36 mg/g) was detected in GO1-POF samples while the lowest (9.29 mg/g) malic acid concentration was detected in GO2-UPOF samples. Significant differences were determined for citric acid level between genotypes ($p \leq 0.05$). Additionally, malic acid concentrations were significantly higher in POF samples than in UPOF samples ($p \leq 0.05$). This could be explained by the high malic acid level of pulp in oleaster fruits (Fig. 3). Wang and Fordham (2007) indicated that malic, quinic and citric acid were found in *Elaeagnus umbellata* Thunb. fruit and malic acid (range between 2.02 to 6.88 mg/100g of fresh mass) was the primary organic acid.

Among all samples, GO1-POF had the highest acetic acid content (10.21 mg/g), while GO2-UPOF had the lowest acetic acid level (4.23 mg/g). Acetic acid concentrations of GO1 samples were significantly higher than those of GO2 samples ($p \leq 0.05$). In POF samples acetic acid contents were significantly higher than in UPOF samples ($p \leq 0.05$).

Oxalic acid is the simplest dicarboxylic acid and its most striking chemical impact is its strong chelating ability for multivalent cations (Seabra et al., 2006). Oxalic acid is usually found in green leaves. We also measured oxalic acid levels of oleaster flour (both POF and UPOF) The present shows that oxalic acid contents range between 4.47 mg/g and 5.06 mg/g (Fig. 3). These results are much higher than in other fruits, such as fig (0.18 mg/g), cranberry (0.17 mg g^{-1}), and blueberry (0.25 mg/g) (Pande and Akoh, 2010).

Tartaric acids are commonly found in fruits and berries (Valentão et al., 2005). The highest tartaric acid level (9.67 mg/g) was detected in GO2-UPOF samples while the lowest (1.46 mg/g) tartaric acid concentration was found in GO1-UPOF samples. Although citric acid contents were similar in GO1-POF and UPOF samples, they were significantly different in GO2-POF and UPOF samples ($p \leq 0.05$). In addition, significant differences were observed for tartaric acid levels between the two genotypes ($p \leq 0.05$). Soyer et al. (2003) determined that tartaric acid level in Turkish white grapes ranged between 4.98 and 7.48 g/L. These data indicate that the oleaster fruits are very rich in tartaric acid content.

The levels of fumaric acid in OFs were within the range of 0.62-1.06 mg/g (Fig. 3.). Fumaric acid concentrations of GO1 samples were significantly higher than those of GO2 samples ($p \leq 0.05$). In GO1 samples, acetic acid content of POF was higher than that of UPOF samples ($p \leq 0.05$). Usenik et al. (2008) measured lower values for 13 sweet cherry cultivars (0.97-7.56 mg/kg). In support of the findings from previous studies, our results suggest that oleaster flour contains moderate levels of fumaric acid.

Ascorbic acid (vitamin C) is the most widely distributed water-soluble antioxidant in fruits and vegetables (Seabra et al., 2006). Although ascorbic acid was not detected in GO1 samples, extremely low levels of it were detected in GO2-POF and UPOF samples (0.01 mg/g, 0.06 mg/g, respectively). Ascorbic acid levels in oleaster olives were slightly higher than those obtained in Czech Republic (132.5 mg/kg) (Dolezal et al., 2001). Similar levels of ascorbic acid have been reported in various fruits (Pande and Akoh, 2010).

Functional Properties

The use of flours as ingredients in food processing is dependent on its functional properties (Hung et al., 1990). The functional properties directly or indirectly affect the processing applications, food quality and ultimately their acceptance and utilisation in food and food formulations (Mahajan and Dua, 2002). Emulsification, solubility and water absorption capacity are these functional properties (Adebowale and Lawal, 2004).

Water solubility (WS)

Water solubility (WS) values of the OFs are given in Tab. 4. The WS values of the samples varied from 90.33 to 96.01 %. The highest value (96.01 %) of solubility was observed in GO2-UPOF, followed by GO1-UPOF (94.79 %), GO2-POF (93.28 %) and GO1-POF (90.33 %). The solubility of oleaster flours differed significantly ($p \leq 0.05$) with respect to the being peeled or unpeeled. The results indicated higher solubility values in the unpeeled oleaster flours (94.79, 96.01 %) than in the peeled oleaster flours (90.33, 93.28 %). The solubility was lower in peeled oleaster flour possibly due to higher starch levels (Tab. 1), as cited by some authors in the case of the mango peel and kernel powders (Sogi et al., 2003). On the other hand, differences in the water solubility of oleaster flours can be attributed to the dietary fiber content of unpeeled oleaster flours were higher than peeled oleaster flours (Tab. 1). The water solubility levels of unpeeled oleaster flours having higher dietary fiber in our study are in accordance with those published by Adrade-Mahecha (2012), who also reported that the high solubility values achieved for the achira flour may be due to the presence of soluble fibers. They suggested that the solubility values for achira flour may also be influenced by the presence of some soluble components such as sugars and soluble fibers.

Tab. 4: Techno-functional properties of oleaster flour samples.[a*]

Samples	Water Solubility (%)	Water Absorption Capacity (%)	Emulsion Capacity (%)	Emulsion Stability (%)
Soy Protein	----	-----	20.96±0.16^{c}	16.28±0.09^{e}
GO1-POF	90.33 ± 0.29^{c}	372.74 ± 0.63^{d}	54.46± 0.03^{a}	26.77± 0.08^{d}
GO1-UPOF	94.79 ± 0.42^{ab}	411.18 ± 0.23^{b}	46.00± 0.53^{b}	28.47± 0.11^{c}
GO2-POF	93.28 ± 0.66^{b}	395.13 ± 0.78^{c}	54.89± 0.14^{a}	29.63± 0.42^{b}
GO2-UPOF	96.01 ± 0.60^{a}	430.33 ± 0.32^{a}	46.87± 0.23^{b}	40.35± 0.37^{a}

[a] Means with different superscripts in columns indicate significant difference ($p \leq < 0.05$).
*Data are expressed as means ± standard deviations.

Water absorption capacity (WAC)
Water absorption capacity (WAC) values of the OFs are given in Tab. 4. The WAC values of the samples were ranging between 372.74 to 430.33 %. The highest WAC value (430.33 %) was obtained in GO2-UPOF samples like water solubility. Results showed that water absorption capacities of the oleaster flours were high and adequate. The WAC values of UPOF samples were significantly ($p \leq 0.05$) higher than those of the POF samples. This might be attributed to higher dietary fiber contents of unpeeled oleaster flour than those of peeled oleaster flours (Tab. 1). These results are similar with those reported by Sogi et al. (2013) who reported water absorption index (WAI) to be higher in mango peel powder compared to mango kernel powder. Koubala et al. (2013) also suggested that mango peel fibre with high hydration capacities has potential in dietary fibre-rich foods preparation. The fibers contribute markedly to the hydration properties, which is attributed to the hydroxyl groups in the fiber structure allowing more water interactions through hydrogen bonding (Rosell et al., 2009). In general, soluble fibers had a high hydration ability to form a viscous solution (Saura-Calixto and Goni, 2006). Lawal et al. (2007) also reported that the higher water absorption capacity of the Brazilian flour may be due to the high hydrophilicity of the cellulose present in the fibers. The main chemical compounds that enhance the water absorption capacity of Brazilian flours are proteins and fibers, since these constituents contain hydrophilic parts, such as polar or charged side chains. Wani et al. (2013 a, b) reported that the major chemical compositions that enhance the WAC of flours are proteins and carbohydrates, since these constituents contain hydrophilic parts, such as polar or charged side chains. They suggested that the functional properties of legume flours mainly depend on proteins, carbohydrates and other components. According to Kaushal et al. (2012), the high WAC of taro flour can be attributed to the presence of high amount of carbohydrates. They indicated that the flours with high water absorption may have more hydrophilic constituents, such as polysaccharides. Hodge and Osman (1976) reported that flour samples with high WAC values contain more hydrophilic constituents.
The water holding capacity of flours is a very important functional property in many different food applications (Ma et al., 2011). Food materials having higher WAC values can act as functional ingredients. Modification of viscosity and texture in formulated food can be achieved by adding ingredients with high WAC, and the resulting changes are attributed to the gelling, bulking, and thickening effects arising from the WAC of the ingredients (Safo-Kantanka and Acquistucci, 1996; De Escalada Pla et al., 2007). Water absorption capacity of thickening or functional agent used in food systems such as in bakery products is important for certain product characteristics, such as the moistness of the product, starch retrogradation, and the subsequent product staling. These agents with high water absorption capacities help reduce staling and thus increase food stability in bakery products (Aziah Abdul Aziz et al., 2012; Wani et al., 2013 a, b). Wolf (1970) also indicated that flours with high water holding capacity could be good ingredients in bakery applications (e.g.,bread formulation), since a higher water holding capacity enables bakers to add more water to the dough, thus improving the handling characteristics and maintaining freshness in bread.
In present study, results showed that the water solubilities (WS) and water absorption capacities (WAC) of the oleaster flours were adequate for their utilization. Thus oleaster flour with high WS and WAC could be useful as a thickening or functional agent for food systems such as baked goods, beverages, ice cream and yoghurt.

Emulsion capacity (EC)
In many foods, the interaction between protein and lipids adjust their ability to form stable emulsions. Proteins can stabilize emulsions because of their amphiphilic nature. The emulsion properties of a protein depend on the rate at which it diffuses into the interface, on its adsorbability at the interface, and on the deformability of its conformation under the influence of interfacial tension (Belitz and Grosch, 1999). Proteins are commonly used as emulsion forming and stabilizing agents. On the other hand, starch can not produce emulsion by itself, but might effect emulsion properties (Koksel et al., 2007). Therefore, in present study, effects of oleaster flours on the emulsifying properties of albumin solutions were investigated. Emulsion capacity (EC) values of the OFs are given in Tab. 4.
Emulsion capacity value of albumin solution (0.05 %) was found to be 20.96 %. Emulsion capacity values of albumin solution supplemented with OFs were significantly ($p \leq 0.05$) higher (46.00-54.89 %) than those of the albumin solution on its own. The results indicated that the oleaster flour samples positively affected the emulsion properties of the albumin. The highest EC (54.89 %) value was detected in GO2-POF samples compared to the others. Emulsion capacity of albumin solution supplemented with the peeled oleaster flour samples (POFs) were significantly ($p \leq 0.05$) higher than those of the unpeeled oleaster flour samples (UPOFs). This result was due to having lower protein contents of POFs than those of UPOFs (Tab. 1). Similarly Du et al. (2014) reported that the chickpea flour with lower protein level than the other kinds of legume flour has relatively poor emulsion activity. Besides protein content, starch amount of oleaster flours affected to EC values. The higher EC values of POFs can be attributed to the higher starch content of POFs than those of UPOFs (Tab. 1). The results obtained from oleaster flour in present study corroborated well with those reported by James and Norman (1979), who indicated that the differences among the emulsion activities are related to the protein contents (soluble and insoluble) and other components, such as starch, fat, and sterol contents, of the legume flours. Du et al. (2014) also reported that the protein content of lentil flour was the highest among the legume flours but its emulsion activity was poor, such variation may be related to the other components in the flours.
In present study, the oleaster flours seem to have an improving effect on emulsion properties of albumin.

Emulsion stability (ES)
Emulsion stability and capacity are very important properties that proteins and other amphoteric molecules contribute to the development of traditional or novel foods (Ma et al., 2011). Emulsion stability (ES) values of the samples are given in Tab. 4. ES values of albumin solution (0.05 %) were found to be 16.28 %. ES of albumin solutions supplemented with UPOFs and POFs were within the range of 26.77-40.35 %. ES values of albumin solution supplemented with OFs were significantly ($p \leq 0.05$) higher than those of the albumin solution on its own. The results indicated that OFs did

not have a deteriorating effect on the emulsion stability values of the albumin solution.

The ES values of the GO2 samples were significantly ($p \leq 0.05$) higher than those of GO1 samples. This could be due to growth conditions, genetic factors, soil properties and geographical variations. The highest ES (40.35 %) value was detected in GO2-UPOF samples compared to the others. ES values of UPOFs were significantly ($p \leq 0.05$) higher than those of POF samples. The increase in ES values is probably due to the presence of higher dietary fiber levels in unpeeled oleaster flours than those of peeled ones (Tab. 1). These results were consistent with the findings of AZIAH ABDUL AZIZ et al. (2012), who found that the emulsifying and stabilizing agents present in mango pulp and peel are carbohydrate polymers (such as pectin), which might have increased the viscosity of the aqueous phase and reduced the tendency of the dispersed oil globules to migrate and coalesce. SHARMA et al. (1998) also reported that carbohydrate polymers can also stabilize emulsions by absorption at the interface and forming a coating around the dispersed particles. Carbohydrates such as starch and fiber may also enhance emulsion stability by acting as bulky barriers between the oil droplets, preventing or slowing down the rate of oil droplet coalescence, as reported by ALUKO et al. (2009). DICKINSON (1994) also indicated that some types of polysaccharides can help stabilise the emulsion by increasing the viscosity of the system.

The oleaster flours seem to have an improving effect on emulsion properties of albumin. These results highlight the possibility of using oleaster flour in some processed foods such as bakery products, beverages, ice cream and yoghurt.

Conclusion

Although the oleaster grows spontaneously in many regions of Turkey, consumption of its fruit is limited and it is not yet used as an ingredient in food industry. The results of this study showed that oleaster flour has high nutritional contents and appropriate techno-functional properties. Oleaster flours showed high levels of dietary fibers and minerals, as well as high water solubility and water absorption capacity. OFs also caused an improving effect on the emulsion stability and capacity of albumin solution. Many kinds of organic and fatty acids were determined in oleaster flours. The oleaster flours obtained in the present study seem to be suitable for food products such as bakery goods, dairy products (ice cream and yoghurt), beverages, confectionary, etc. It can also be used as an alternative functional ingredient in food products which require relatively low fat and high dietary fiber content. Further studies are needed to produce bakery products supplemented with oleaster flour with improved functional properties.

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