Food Sci Biotechnol (2019) 28(5):1401–1408
https://doi.org/10.1007/s10068-019-00589-6

Effects of oleaster flour supplementation in total phenolic contents, antioxidant capacities and their bioaccessibilities of cookies

Yasemin Sahan[1] · Emine Aydin[2] · Ayse Inkaya Dundar[3] · Dilek Dulger Altiner[4] · Guler Celik[5] · Duygu Gocmen[1]

Received: 4 December 2018 / Revised: 12 February 2019 / Accepted: 18 February 2019 / Published online: 16 March 2019

Abstract In presented study total phenolic contents, antioxidant capacities and their bioaccessibilities from cookies supplemented with oleaster flour were investigated. Oleaster flours (OFs) were produced using two different methods (peeled oleaster flour: POF and unpeeled oleaster flour: UPOF) from two different genotypes. OFs were used to replace wheat flour in the cookie formulation (control) at the levels of 5, 10, 15, 20 and 25% (w/w). According to the results, enrichment of OFs clearly increased total phenolic contents, antioxidant capacities and bioaccessibilities of cookies. The highest bioaccessible antioxidant capacities (ABTS, CUPRAC, and FRAP) of the samples were obtained from cookie samples enriched with 25% UPOF-1. In conclusion, the increases in phenolic contents, antioxidant capacities, and bioaccessibilities from cookies supplemented with OFs suggest the potential enhancement of beneficial health effect of cookie due to increased content of bioactive compounds present in oleaster flour.

Keywords Oleaster flour · Cookie · Bakery · Fortification · Antioxidant capacity

Introduction

In recent times, consumers increasingly believe that foods make a significant contribution directly to their health, so requirements in the field of food production have changed in this directions. Therefore, food consumption is not only intended to satisfy hunger and provide the necessary nutrients, but also specifically to prevent diseases associated with nutrition and to improve physical and mental health.

✉ Yasemin Sahan
yasemins@uludag.edu.tr

Emine Aydin
emineaydn@gmail.com

Ayse Inkaya Dundar
neslihanayse@gmail.com

Dilek Dulger Altiner
dilek.dulgeraltiner@gmail.com

Guler Celik
guler.celik@tubitak.gov.tr

Duygu Gocmen
gocmend@gmail.com

[1] Faculty of Agriculture, Department of Food Engineering, Uludag University, Gorukle Campus, 16059 Bursa, Turkey

[2] Faculty of Agriculture and Natural Sciences, Department of Agricultural Biotechnology, Duzce University, Duzce, Turkey

[3] Faculty of Natural Sciences, Architecture and Engineering, Department of Food Engineering, Bursa Technical University, Bursa, Turkey

[4] School of Tourism and Hotel Management, Department of Gastronomy and Culinary Arts, Kocaeli University, Kartepe/Kocaeli, Turkey

[5] The Scientific and Technological Research Council of Turkey, Bursa Test and Analysis Laboratory, (TUBITAK BUTAL), Bursa, Turkey

Oleaster *(Elaeagnus angustifolia* L.) belongs to *Elaeagnus* L. genus and *Elaeagnaceae* family. *Elaeagnus angustifolia* L. grows widely in a broad geographic area such as Asia, Europe, particularly Turkey, the Caucasus and Central Asia (Ayaz and Bertof, 2001). It is usually called a wild olive, silverberry, Russian olive or oleaster (Bailey and Bailey, 1976). Although oleaster (*Elaeagnus angustifolia* L.) grows naturally in most parts of Turkey, its fruits are of limited use in agricultural and food industry.

Oleaster is used as a nutrient or herbal remedy due to its known medicinal properties (Farzaeia et al., 2015). Especially the fruits and flowers of *E. angustifolia* have been used in treating a variety of common illnesses such as nausea, cough, asthma, fever, jaundice, and diarrhea (Hamidpour et al., 2017). In Turkey and Middle Eastern, oleaster fruits are generally used in traditional medicine (Ahmadiani et al., 2000; Ayaz and Bertof, 2001).

In parallel with the increase in demand for healthy foods, functional additives are increasingly being used to improve the functionality of foods and to improve their nutritional properties. Although oleaster fruits have been consumed fresh or dried for decades (Ayaz and Bertof, 2001), there is not much known about their composition. The special taste, the floury structure and the functional content of the flour obtained from the dried oleaster fruits are attracting notice.

It is highly possible that oleaster flour (OF) can be used as an innovative food ingredient. OF can be produced from dried fruits and used as a functional ingredient in a lot of products such as bakery products, yoghurt, ice cream, infant food, chocolate, confectionery etc. thanks to its floury structure, specific taste and functional properties like dietary fiber, mineral content, phenolic compounds and antioxidant activity (Sahan et al., 2013; 2015).

Multiple sensorial food properties, such as flavour, astringency, and color are influenced by phenolic compounds. They contribute to aroma and taste of plant origin food products (Rodriguez et al., 2009). In addition, polyphenols in our diet as a source of micronutrients prevent degenerative diseases such as cancer and cardiovascular diseases. The amount and bioaccessibility of polyphenols are also important (Manach et al., 2004). Bioaccessibility, which is the amount of an ingested nutrient that is potentially available for absorption, is dependent only on digestion and release from the food matrix (Etcheverry et al., 2012; Jakobek, 2015). Bioaccessibility measurement informs to choose the appropriate dosage and the source of food matrices to ensure the nutritional efficacy of food products (Fernández-García et al., 2009).

Antioxidants prevent undesirable changes in the flavor and nutritional quality of foods. At the same time, antioxidants have important preventive roles against tissue damage in various human diseases. They prevent degenerative illnesses, such as different types of cancers, cardiovascular and neurological diseases, cataracts and oxidative stress dysfunctions (Sharma et al., 2013).

The current study focused on improving the quality of the cookie via oleaster flour supplementation. Yet no information has been provided in the literature with regard to the utilization of oleaster flours (peeled and unpeeled oleaster flour) in bakery products and its phenolic contents, antioxidant activity and their bioaccessibility. Therefore, this study was designed to investigate the effects of supplementation of oleaster flours and their potential utilization in cookies.

Materials and methods

Materials

Two different genotypes of oleaster fruit were supplied from two different regions GO1 (40°11′19.60″N–26°06′09.16″E) and GO2 (39°34′01.48″N–26°51′02.90″E) of Turkey. The fruits had approximately same maturity (almost reddish) with uniform shape, size and healthy. Mature fruits were harvested and randomly collected. Harvested fruits were dried at 50 °C for 20 h in a hot air oven dryer prior to production of oleaster flour.

Preparation of oleaster flours

OFs were produced by two different methods. In the first method, skin and seeds of dry fruits were removed using a plastic knife, the fruit pulp was ground in a coffee grinder and then sieved through 60 mm sieve to obtain Peeled Oleaster Flour (POF). In the second preparation method, only seeds of dry fruits were removed using a plastic knife, and then the fruit pulp and skin were ground together in a coffee grinder and sieved through 60 mm sieve to obtain Unpeeled Oleaster Flour (UPOF). All flour samples were stored in glass jars and kept in at +4 °C prior to analyses. Due to using two different genotypes, samples are labelled as POF-1 (Genotype 1, Peeled Oleaster Flour), UPOF-1 (Genotype 1, Un-peeled Oleaster Flour), POF-2 (Genotype 2, Peeled Oleaster Flour) and UPOF-2 (Genotype 2, Unpeeled Oleaster Flour).

Production of cookies

Cookies were prepared using the American Association of Cereal Chemists International (AACCI) method 10–54.01 (AACCI, 2000). The dough was formulated in Table 1. Oleaster flours (POFs and UPOFs) were used to replace wheat flour in the formulation at the levels of 5, 10, 15, 20

and 25% (w/w) (Table 1). The levels selected for incorporating OFs were based on pre-treatments. The control sample containing no OFs was also prepared. All-purpose shortening was put into mixing bowl and dry ingredients were added. These ingredients were mixed for 3 min stir speed (Electrolux Ditomix 5, EU), by scraping every minute. High-fructose corn syrup, water, ammonium bicarbonate, and sodium bicarbonate were added into 100 mL beaker and swirled to dissolve. Liquid was added to creamed mass and mixed for 1 min, by scraping every 15 s. Finally, flour was added and mixed for 10 s while tapping the side of bowl, scraped dough from mixer and bowl pins; scraped outer edge and bottom of bowl. The dough was divided into two relatively equal portions and given oblong shape having approximately 5 cm length. Both portions were placed on the ungreased baking sheet. The dough was cut with cookie cutter, the excess dough was discarded and cutter removed. Baking was performed in a convection oven (Inoksan FKE 006, TR) at 175 °C for 10 min. The baked cookies were left to cool for 30 min and then they were wrapped in aluminum foil and stored for 24 h at room temperature prior to analyses. Each batch yielded 4 cookies.

Extraction of extractable, hydrolyzable and bioaccessible phenolics

Extractable, hydrolyzable and bioaccessible phenolics were extracted according to the method improved by Vitali et al. (2009) with slight modifications. Extractions of each type of phenolics were carried out in triplicate samples for each cookie samples.

For extractable phenolics, 2.0 g dw sample was mixed with 20 mL of HClconc/methanol/water (1:80:10, v/v) mixture and shaked with a rotary shaker (JB50-D; China) at 250 rpm for 2 h at 20 °C, and then the mixture was centrifuged at 3500*g* for 10 min at 4 °C in a centrifuge (Sigma 3 K 30). The supernatants were stored at − 20 °C prior to analyses.

For hydrolyzable phenolics, after extractable phenolic extraction, the residue which was combined with 20 mL of methanol/H_2SO_4conc (10:1) mixtures was placed in water bath at 85 °C for 20 h and then cooled at room temperature. The mixtures were centrifuged at 3500*g* for 10 min at 4 °C in a centrifuge (Sigma 3 K 30). The supernatants were stored at − 20 °C prior to analyses.

Bioaccessible phenolics were determined using an in vitro digestion enzymatic extraction method that mimics the conditions in the gastrointestinal tract identified beforehand (Vitali et al., 2009) with slight modifications. In conclusion, 10 mL of distilled water and 0.5 mL of pepsin (20 g/L in 0.1 mol/L HCl) were added to 1 g of sample, pH was adjusted to 2 using 5 mol/L HCl. Incubation of the sample at 37 °C in a shaking water bath for 1 h was followed by adjustment of the pH to 7.2 in order to terminate gastric digestion. Following 2.5 h, intestinal digestion was performed at 37 °C in shaking water bath by adding 2.5 mL of bile/pancreatin solution (2 g/L of pancreatin and 12 g/L of bile salt in 0.1 mol/L GO$NaHCO_3$) and 2.5 mL of NaCl/KCl (120 mmol/L NaCl and 5 mmol/L KCl) to the sample. The sample was then centrifuged at 3500*g* for 10 min and the supernatant was used for determination of bioaccessible phenolics.

Determination of phenolic contents

Each extracts of extractable, hydrolysable, and bioaccessible phenolics were determined on the basis of the Folin-Ciocalteu colorimetric method as described by Naczk and Shahidi (2004). Phenolic contents were expressed as gallic acid equivalents (mg of GAE/100 g dw). The total phenolic content was estimated as the sum of extractable and hydrolysable phenolics. Determinations were performed three times for each extract.

Determination of antioxidant capacity

Antioxidant capacities of extractable, hydrolysable, and bioaccessible phenolics were determined using (2,2-azinobis-[3-ethylbenzothiazoline-6-sulphonicacid]) (ABTS) radical cation assay, cupric ion reducing antioxidant activity assay (CUPRAC) Apak et al. (2008) and ferric reducing antioxidant power assay (FRAP) (Benzie and Strain, 2002). The results were expressed as μmol trolox g^{-1} dw. All assays were repeated three times for each extract from each sample.

Table 1 Cookies formulation

Ingredients[a]	Proportion (g)
Wheat flour[b]	100
Sucrose	32
Brownulated granulated sucrose	10
Nonfat dry milk	1.0
Salt	1.25
Sodium bicarbonate	1.0
All-purpose shortening (fat)	40
High-fructose corn syrup	1.5
Ammonium bicarbonate	0.5
Deionized water	Variable

[a]Ingredients at 21 ± 1 °C, [b]14% moisture basis

Statistics

Data are presented as mean values ± standard error of 3 replicates. Statistical analysis was performed by 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.

Results and discussion

Impact of oleaster flour on total phenolic contents and their bioaccessibilities from cookies

Effect of OFs on phenolic contents and their bioaccessibilities are presented in Table 2. The significant increase ($p \leq 0.05$) in phenolic contents in relation to the control sample was also achieved by using OFs in cookie production. The highest content of extractable phenolics was obtained by incorporation of 25% of UPOF-1 to recipe (291.26 mg of GAE/100 g dw). The extractable phenolics of cookies with UPOFs were slightly higher than those of the cookies incorporated with POFs.

It is apparent from the present results that the contents of hydrolysable phenolics of cookies with OFs were significantly ($p \leq 0.05$) higher compared to the control sample. The highest content of hydrolysable phenolics was also obtained in the sample with 25% of UPOF-1 (364.83 mg of GAE/100 g dw). The hydrolysable phenolics of cookies supplemented with UPOFs were slightly higher than those of cookies with POFs.

Significant ($p \leq 0.05$) increases in total phenolic contents with regard to the control sample were achieved in all cookie samples enriched with OFs ranging from 5% to 25%. The total phenolic content of control was 141.07 mg of GAE/100 g dw. Supplementation with OFs increased total phenolic contents of cookies to 656.09 mg GAE/g (Table 2). These results indicate that cookies supplemented with OFs might be considered as a source of phenolic compounds and might significantly contribute to the phenolic intake.

Due to the lack of literature data dealing with phenolic contents of cookies supplemented with OFs, the consistency of our results was roughly estimated and confirmed by comparing them with recently published data dealing with phenolic contents of cookies incorporated with similar types of additives, such as dietary fiber (Vitali et al., 2009), black carrot fiber (Turksoy et al., 2011), purple sweet potato powder (Liu et al., 2013), grape pomace and grape seed flours (Acun and Gul, 2014), guava peel flour (Bertagnolli et al., 2014), and peanut skins (De Camargo et al., 2014). Our findings are in agreement with Vitali et al. (2009), who found higher levels of total phenolics in biscuit with apple fiber rather than in the control sample. Previously, Bertagnolli et al. (2014) reported that increased quantities of guava peel flour in the cookies resulted in significant increases in total phenolic compounds. Similar results in total phenolic contents were also identified in cookies enriched with peanut skins (de Camargo et al., 2014). Liu et al. (2013) reported that the contents of total phenolic compounds in cookies with purple sweet potato powder were higher than that of the control sample. According to Turksoy et al. (2011), the black carrot fiber also increased the polyphenol content of the cookies.

Finally, the contents of bioaccessible phenolics of cookie samples with OFs ranged from 100.31 mg of GAE/100 g dw to 458.41 mg of GAE/100 g dw. The levels of bioaccessible phenolics of cookies supplemented with OFs were significantly ($p \leq 0.05$) higher than that of control sample. The highest value (458.41 mg of GAE/100 g dw) of bioaccessible phenolics was also observed in the cookie with UPOF-1. The bioaccessible phenolics of cookies with UPOFs were slightly higher than those of cookies enriched with POFs. Data on the bioaccessibility of polyphenols from cookies are quite limited. A previous study showed that the content of bioaccessible phenolics in biscuit with apple fiber was higher than that in the control sample (Vitali et al., 2009).

Our data showed that the contents of bioaccessible phenolics obtained in physiological extracts were lower compared to those obtained in chemical extracts (extractable, and hydrolysable phenolics). Such difference might be explained by the fact that health effects of polyphenols depend on both their respective intakes and their bioavailability which can vary greatly (Vitali et al., 2009).

In present study, total phenolic content of GO1 flours were higher than GO2 flours for all the extract (Table 2). Variation in the phenolic content within genotypes may be due to growing and climatic condition.

This study showed that OF supplementation enhances the beneficial health effects and nutraceutical properties of cookies due to its bioactive components. Therefore, OF is thought to be an important source of phenolic compounds.

Antioxidant capacities of cookies supplemented with oleaster flours

Results for antioxidant capacities of cookies incorporated OFs are presented in Table 3. The antioxidant evaluations were carried out using the ABTS, CUPRAC, and FRAP methods. Antioxidant capacities demonstrated the same trend with total phenolic contents; cookies with OFs had significantly ($p \leq 0.05$) higher antioxidant capacities compared to control sample. Our data obtained in cookies

Table 2 Extractable, hydrolysable, total and bioaccessible phenolics of cookies supplemented with oleaster flours

Sample	OF level (%)	Extractable phenolics (mg of GAE 100 g^{-1}dw)	Hydrolysable phenolics (mg of GAE 100 g^{-1}dw)	Total phenolicss[a] (mg of GAE 100 g^{-1}dw)	Bioaccessible phenolics (mg of GAE 100 g^{-1} dw)
Control	0	50.21 ± 2.48^{f}	90.86 ± 1.84^{g}	141.07 ± 2.97^{f}	53.46 ± 9.93^{f}
POF-1	5	107.76 ± 4.67^{de}	214.39 ± 6.28^{cd}	322.14 ± 9.72^{d}	139.98 ± 1.19^{d}
	10	170.66 ± 11.57^{c}	233.29 ± 7.04^{c}	403.95 ± 11.38^{cd}	181.53 ± 32.27^{c}
	15	186.54 ± 12.46^{c}	276.67 ± 6.11^{bc}	463.21 ± 7.56^{c}	227.13 ± 34.72^{c}
	20	242.74 ± 8.91^{ab}	312.11 ± 6.35^{b}	554.85 ± 9.33^{b}	306.93 ± 25.16^{b}
	25	275.23 ± 10.26^{a}	338.62 ± 9.12^{a}	613.85 ± 14.21^{a}	403.16 ± 2.37^{a}
UPOF-1	5	168.30 ± 11.17^{c}	229.69 ± 8.69^{c}	397.99 ± 9.49^{cd}	171.05 ± 15.16^{cd}
	10	184.03 ± 7.55^{c}	253.63 ± 8.79^{c}	437.66 ± 8.91^{c}	218.37 ± 3.59^{c}
	15	235.61 ± 4.73^{b}	302.69 ± 6.57^{b}	538.30 ± 10.04^{b}	302.97 ± 32.17^{b}
	20	262.69 ± 7.62^{a}	340.22 ± 9.54^{a}	602.21 ± 11.60^{a}	393.95 ± 16.81^{a}
	25	291.26 ± 9.95^{a}	364.83 ± 7.52^{a}	656,09 ± 11.45^{a}	458.41 ± 5.98^{a}
POF-2	5	85.51 ± 4.13^{e}	148.95 ± 2.23^{f}	234.46 ± 8.41^{e}	100.31 ± 7.11^{e}
	10	112.46 ± 3.08^{de}	177.22 ± 4.10^{e}	289,68 ± 6.57^{de}	118.30 ± 9.70^{de}
	15	147.65 ± 6.65^{cd}	180.02 ± 5.49^{e}	327,67 ± 5.63^{d}	152.27 ± 5.94^{d}
	20	189.64 ± 10.98^{c}	203.87 ± 6.05^{d}	393,51 ± 9.42^{cd}	217.24 ± 1.50^{c}
	25	202.74 ± 4.85^{b}	217.42 ± 5.31^{cd}	420.16 ± 8.91^{bc}	265.33 ± 8.60^{bc}
UPOF-2	5	94.71 ± 11.10^{e}	182.77 ± 11.64^{de}	277.48 ± 11.08^{e}	115.63 ± 4.43^{de}
	10	127.70 ± 2.97^{d}	202.08 ± 9.96^{d}	329.78 ± 7.53^{de}	154.31 ± 7.89^{d}
	15	172.38 ± 13.40^{c}	226.83 ± 8.99^{c}	399.21 ± 10.89^{cd}	224.52 ± 4.91^{c}
	20	198.20 ± 7.93^{b}	284.06 ± 11.82^{b}	482.26 ± 8.23^{bc}	305.26 ± 10.95^{b}
	25	221.40 ± 3.85^{b}	325.16 ± 10.33^{ab}	546.56 ± 12.61^{b}	371.52 ± 8.86^{a}

Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.05$. Data are expressed as means ± standard deviations (n = 3)

[a]Total phenol content was calculated as the sum of extractable, and hydrolysable phenolics

with OFs were comparable to recently published data dealing with antioxidant capacities of cookies containing similar types of additives (Acun and Gul, 2014; de Camargo et al., 2014; Liu et al., 2013; Turksoy et al., 2011; Vitali et al., 2009).

The contents of extractable antioxidant capacities were increased from 4.15 µmol trolox/g dw (control) to 15.37 µmol trolox/g dw (ABTS), from 3.46 µmol trolox/g dw (control) to 23.82 µmol trolox/g dw (CUPRAC), from 2.61 µmol trolox/g dw (control) to 12.43 µmol trolox/g dw (FRAP). Highest increases in extractable antioxidant capacities were observed in ABTS, CUPRAC and FRAP assays of cookie samples enriched with 25% UPOF-1 (15.37, 23.82, 12.43 µmol trolox/g dw, respectively). In addition, the extractable antioxidant capacities of cookies enriched with UPOFs were partially higher than those of cookies with POFs. These data are in accordance with a previous study which reported that DPPH radical scavenging capacities of cookies were increased by up to 250% upon addition of peanut skins (de Camargo et al., 2014). In another study, Liu et al. (2013) reported similar results for cookies with purple sweet potato powder.

The contents of hydrolysable antioxidant capacities were increased from 70.91 µmol trolox/g dw (control) to 273.96 µmol trolox/g dw (ABTS), from 43.30 µmol trolox/g dw (control) to 249.01 µmol trolox g^{-1} dw (CUPRAC), from 68.88 µmol trolox/g dw (control) to 139.53 µmol trolox/g dw (FRAP). The highest hydrolysable antioxidant capacities (ABTS, CUPRAC and FRAP assays) were obtained from cookie samples enriched with 25% UPOF-1 (273.96, 249.01, 139.53 µmol trolox/g dw, respectively). In addition, the extractable antioxidant capacities of cookies with UPOFs were partially higher than those of cookies with POFs. The antioxidant capacities were in line with data previously obtained in similar types of samples. Turksoy et al. (2011) reported that enrichment with 15% black carrot fiber increased the antioxidant activity of cookies by 5 and 5.5 times, respectively. Vitali et al. (2009) reported that best results regarding antioxidant activity were achieved by incorporation of carob and apple fibre into the reference sample. In a previous study by Acun and

Table 3 Extractable, hydrolysable and bioaccessible antioxidant capacities of cookies supplemented with oleaster flours

Antıoxıdant Actıvıty (µmol trolox g^{-1} dw)										
OF	OF Level (%)	ABTS			CUPRAC			FRAP		
		Extractable	Hyrolysable	Bioaccessible	Extractable	Hydrolysable	Bioaccessible	Extractable	Hydrolysable	Bioaccessible
Control	0	4.15 ± 0.49^{d}	70.91 ± 5.84 ^{g}	1.86 ± 0.17^{f}	3.46 ± 0.21^{f}	43.30 ± 2.58 ^{g}	3.74 ± 0.47^{f}	2.61 ± 1.11^{d}	68.88 ± 1.58^{e}	7.06 ± 0.88^{e}
POF-1	5	9.68 ± 0.50^{c}	157.71 ± 9.62^{f}	12.02 ± 0.36^{de}	7.81 ± 0.20^{e}	98.91 ± 2.16^{d}	11.84 ± 1.29^{e}	5.36 ± 1.39^{c}	82.78 ± 3.85^{d}	10.06 ± 0.14^{d}
	10	10.27 ± 0.65^{cb}	180.36 ± 6.03e	13.24 ± 0.54^{d}	13.54 ± 0.21^{c}	124.88 ± 2.01^{c}	19.35 ± 2.80^{d}	6.65 ± 0.45^{c}	94.41 ± 1.07^{cd}	13.98 ± 0.24^{cd}
	15	11.58 ± 0.65^{b}	196.49 ± 14.64^{de}	25.16 ± 0.58^{cb}	16.24 ± 0.28^{b}	163.05 ± 2.51^{b}	30.18 ± 4.18^{c}	10.23 ± 4.20^{b}	102.51 ± 5.06^{c}	18.81 ± 0.90^{c}
	20	13.06 ± 0.11^{ab}	217.32 ± 10.15^{cd}	36.38 ± 0.11^{b}	17.33 ± 0.85^{b}	189.83 ± 2.21^{b}	41.01 ± 4.78^{b}	11.08 ± 1.81^{ab}	116.67 ± 4.49^{bc}	22.63 ± 0.36^{b}
	25	14.91 ± 0.28^{a}	220.13 ± 3.11^{b}	43.24 ± 0.40^{ab}	20.02 ± 0.65^{ab}	213.34 ± 6.38^{ab}	55.53 ± 2.21^{a}	11.23 ± ..85^{ab}	130.66 ± 8.93^{b}	26.95 ± 0.77^{ab}
UPOF-1	5	10.01 ± 0.07^{c}	164.91 ± 7.34^{e}	11.22 ± 0.14^{de}	10.65 ± 0.18^{d}	100.80 ± 5.01^{d}	12.95 ± 1.94^{e}	5.71 ± 0.72^{c}	87.18 ± 1.41^{d}	11.15 ± 0.33^{d}
	10	11.09 ± 0.16^{cb}	198.26 ± 9.78^{de}	19.36 ± 0.10^{c}	14.59 ± 0.25^{bc}	147.87 ± 3.11^{bc}	27.14 ± 1.49^{cd}	8.15 ± 3.28^{bc}	100.08 ± 2.71^{cd}	16.15 ± 0.56^{c}
	15	13.93 ± 0.10^{ab}	215.57 ± 8.18^{cd}	27.37 ± 0.19^{c}	17.17 ± 0.28^{b}	169.44 ± 4.05^{b}	35.45 ± 1.04^{c}	10.94 ± 1.66^{b}	119.35 ± 1.19^{bc}	20.20 ± 0.19^{bc}
	20	14.40 ± 0.29^{a}	255.60 ± 5.27^{a}	48.95 ± 0.20^{b}	20.29 ± 0.84^{ab}	198.06 ± 7.07^{ab}	49.25 ± 3.78^{b}	11.42 ± 0.31^{ab}	128.08 ± 5.47^{b}	24.04 ± 0.47^{b}
	25	15.37 ± 0.25^{a}	273.96 ± 6.05^{a}	54.09 ± 0.12^{a}	23.82 ± 0.17^{a}	249.01 ± 6.73^{a}	60.73 ± 2.76^{a}	12.43 ± 0.62^{a}	139.53 ± 2.32^{a}	31.88 ± 0.70^{a}
POF-2	5	9.33 ± 0.12^{c}	148.95 ± 5.23^{f}	8.91 ± 0.18^{e}	6.23 ± 0.57^{e}	60.43 ± 1.98^{f}	9.41 ± 0.95^{e}	5.16 ± 0.58^{c}	78.55 ± 2.16^{d}	9.48 ± 0.54^{d}
	10	9.91 ± 0.96^{c}	177.22 ± 4.10^{e}	9.54 ± 0.34^{e}	11.55 ± 0.18^{cd}	83.99 ± 3.18^{e}	13.50 ± 1.39^{e}	6.28 ± 0.19^{c}	83.69 ± 1.69^{d}	12.71 ± 0.52^{cd}
	15	10.12 ± 0.50^{cb}	180.02 ± 6.49^{e}	22.30 ± 0.21^{c}	13.75 ± 0.31^{c}	108.08 ± 4.51^{d}	21.45 ± 1.62^{d}	9.16 ± 0.20^{b}	92.50 ± 1.55^{cd}	15.37 ± 0.16^{c}
	20	11.62 ± 0.16^{b}	203.87 ± 4.05^{d}	35.08 ± 0.75^{b}	15.19 ± 0.11^{bc}	136.70 ± 3.34^{c}	29.49 ± 2.99^{c}	10.31 ± 0.21^{b}	108.49 ± 1.08^{c}	19.17 ± 0.50^{bc}
	25	12.07 ± 0.54^{b}	217.42 ± 3.31^{cd}	41.98 ± 0.02^{ab}	17.39 ± 0.25^{b}	198.46 ± 3.82^{ab}	49.25 ± 3.43^{a}	10.98 ± 0.57^{b}	120.16 ± 1.93^{b}	23.12 ± 0.88^{b}
UPOF-2	5	9.84 ± 0.23^{c}	156.34 ± 7.27^{f}	10.05 ± 0.77^{e}	10.26 ± 0.16^{d}	71.38 ± 1.71^{e}	10.41 ± 3.40^{e}	5.41 ± 0.44^{c}	85.30 ± 2.30^{d}	10.46 ± 0.37^{d}
	10	10.35 ± 0.46^{cb}	188.17 ± 7.94^{e}	17.09 ± 0.16^{cd}	12.42 ± 0.18^{c}	103.63 ± 2.31^{d}	18.99 ± 1.54^{d}	7.76 ± 0.21^{bc}	91.20 ± 1.50^{cd}	14.69 ± 0.27^{cd}
	15	10.58 ± 0.29^{cb}	208.12 ± 5.28^{d}	25.79 ± 0.14^{cb}	16.03 ± 0.30^{b}	125.36 ± 4.34^{c}	25.34 ± 5.34^{cd}	10.75 ± 0.42^{b}	109.01 ± 5.92^{c}	19.89 ± 0.25^{bc}
	20	12.97 ± 0.54^{b}	231.61 ± 3.40^{b}	40.47 ± 0.17^{b}	18.37 ± 0.32^{b}	160.96 ± 4.96^{b}	36.10 ± 2.08^{c}	11.18 ± 0.21^{ab}	117.30 ± 4.33^{bc}	23.97 ± 0.95^{ba}
	25	15.03 ± 0.31^{a}	240.71 ± 6.27^{ab}	49.92 ± 0.59^{a}	20.59 ± 0.41^{ab}	220.66 ± 5.42^{a}	57.25 ± 3.45^{a}	12.01 ± 1.89^{a}	130.06 ± 4.58^{b}	28.87 ± 0.26^{a}

Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.05$. Data are expressed as means ± standard deviations (n = 3)

Gul (2014), antioxidant activity of cookie containing 10% grape seed flour was found to be higher (153.10 g/kg GAE and 5.61 mg/ml, respectively) than control.

Antioxidant capacities of physiological extracts are correlated with bioaccessible phenolics (Vitali et al., 2009). Bioaccessible antioxidants of cookies with OFs were also significantly ($p \leq 0.05$) higher than control sample. The most efficient increases of bioaccessible ABTS, CUPRAC and FRAP values of the samples were achieved by supplementation with 25% UPOF-1 (54.09, 60.73, and 31.88 μmol trolox/g dw, respectively). In addition, the bioaccessible antioxidants from cookies with UPOFs were partially higher than those of cookies with POFs. Antioxidant capacities of digestive extracts from cookies were lower compared to those of hydrolysable extracts. It could be explained by lower bioavailability of phenolic compounds and release or degradation of these phenolics were not complete after the gastric digestion. This was emphasized also in earlier studies indicating lower concentrations of polyphenols present compared to chemical extraction (Bouayed et al., 2011).

According to all assays (ABTS, CUPRAC, and FRAP), antioxidant capacities of POF-1 and UPOF-1 were slightly higher than those of POF-2 and UPOF-2 for enriched cookies. These differences between genotypes may be due to growth conditions, genetic factors, soil properties and geographical variations.

As a result, the increase in antioxidant capacities of cookies supplemented with OFs demonstrates the potential enhancement of beneficial health effect of OFs due to increase in the content of bioactives present.

Cookie is one of the most consumed baked products in the world since it is a cheap, fulfilling and ready-to-eat food product with a high nutritional level. Demand has increased on natural food additive in recent years leading to increased functional food consumption. Oleaster flour was included as an additive in the cookie since it is a highly preferable snack for consumers. The cookie supplemented with oleaster has a functional food feature which could become a new dietary product by increasing its nutritive value and sensory properties. In this study, it was determined that cookies supplemented with oleaster flour had functional advantages such as increased amounts of phenolic content, improved antioxidant activity and bioavailability.

Acknowledgements The authors would like to thank The Scientific and Technological Research Council of Turkey (TUBITAK) for their financial support to this research project (Project No: TOVAG 110 O 060).

References

AACCI. Official methods of American Association of Cereal Chemists International, MN, USA (2000)

Acun S, Gul H. Effects of grape pomace and grape seed flours on cookie quality. Qual. Assur. Saf. Crop. 6: 81–88 (2014)

Ahmadiani A, Hosseiny J, Semnanian S, Javan M, Saeedi F, Kamalinejad M. Antinociceptive and anti-inflammatory effects of *Elaeagnus angustifolia* fruit extract. J. Ethnopharmacol. 72: 287–292 (2000)

Apak R, Guclu K, Ozyurek M, Celik SE. Mechanism of antioxidant capacity assays and the CUPRAC (cupric ion reducing antioxidant capacity) assay. Microchim Acta 160: 413–419 (2008)

Ayaz FA, Bertof E. Sugar and phenolic acid composition of stored commercial oleaster fruits. J. Food Compost. Anal. 14: 505–511 (2001)

Bailey LH, Bailey EZ, Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada, Macmillan, New York (1976)

Benzie IFF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of antioxidant power: The FRAP Assay. Anal. Biochem. 239: 70–76 (2002)

Bertagnolli SMM, Silveira MLR, Fogaça AO, Umann L, Penna ND. Bioactive compounds and acceptance of cookies made with guava peel flour. Food Sci. Technol. (Campinas) 34: 303–308 (2014)

Bouayed J, Hoffmann L, Bohn T. Total phenolics, flavonoids, anthocyanins and antioxidant activity following simulated gastro-intestinal digestion and dialysis of apple varieties: Bioaccessibility and potential uptake. Food Chem. 128: 14–21 (2011)

De Camargo AC, Vidal CMM, Canniatti-Brazaca SG, Shahidi F. Fortification of Cookies with Peanut Skins: Effects on the Composition, Polyphenols, Antioxidant Properties, and Sensory Quality. J. Agric. Food Chem. 62: 11228–11235 (2014)

Etcheverry P, Grusak MA, Fleige LE. Application of in vitro bioaccessibility and bioavailability methods for calcium, carotenoids, folate, iron, magnesium, polyphenols, zinc, and vitamins B6, B12, D, and E. Front. Physiol. 3: 1–22 (2012)

Farzaeia MH, Bahramsoltanic R, Abbasabadia Z, Rahi R. A comprehensive review on phytochemical and pharmacological aspects of *Elaeagnus angustifolia* L. J. Pharm Pharmacol. 67: 1467–1480 (2015)

Fernández-García E, Carvajal-Lérida I, Pérez-Gálvez A. In vitro bioaccessibility assessment as a prediction tool of nutritional efficiency. Nutr. Res. 29: 751–760 (2009)

Hamidpour R, Hamidpour S, Hamidpour M, Shahlari M, Sohraby M, Shahlari N, Hamidpour R. Russian olive (*Elaeagnus angustifolia* L): From a variety of traditional medicinal applications to its novel roles as active antioxidant, anti-inflammatory, anti-mutagenic and analgesic agent. J. Tradit. Complement. Med. 7: 24–29 (2017)

Jakobek L. Interactions of polyphenols with carbohydrates, lipids and proteins. Food Chem. 175: 556–567 (2015)

Liu YN, Jeong DH, Jung JH, Kim HS. Quality characteristics and antioxidant activities of cookies added with purple sweet potato powder. Korean J. Food Cook. Sci. 29: 275–281 (2013)

Manach C, Scalbert A, Morand C, Remesy C, Jimenez L. Polyphenols: Food sources and bioavailability. Am. J. Clin. Nutr. 79: 727–747 (2004)

Naczk M, Shahidi F. Extraction and analysis of phenolics in food. J. Chromatogr. A, 1054: 95–111 (2004)

Rodriguez H, Curiel JA, Landete JM, Rivas BI, Felipe FL, Cordoves CG, Mancheno JM, Munoz R. Food Phenolics and lactic acid bacteria. Int. J. Food Microbiol. 132: 79–90 (2009)

Sahan Y, Dundar AN, Aydin E, Kilci A, Dulger D, Kaplan FB, Gocmen D, Celik G. Characteristics of cookies supplemented with oleaster (*Elaeagnus angustifolia* L.) Flour. I physicochemical, sensorial and textural properties. J. Agric. Sci. 5: 160–168 (2013)

Sahan Y, Gocmen D, Cansev A, Celik G, Aydin E, Dundar AN, Dulger D, Kaplan HB, Kilci A, Gucer S. Chemical and technofunctional properties of flours from peeled and unpeeled oleaster (*Elaeagnus angustifolia* L.). J. Appl. Bot. Food Qual. 88: 34–41 (2015)

Sharma SK, Singh L, Singh S. A review on medicinal plants having antioxidant potential. Indian J. Res. Pharm. Biotechnol. 1: 395–404 (2013)

Turksoy S, Keskin S, Ozkay B, Ozkaya H. Effect of black carrot (*Daucus carota* L. ssp sativus var. atrorubens Alef.) fiber addition on the composition and quality characteristics of cookies. J. Food Agric. Environ. 9: 57–60 (2011)

Vitali D, Dragojevic IV, Sebecic B. Effects of incorporation of integral raw materials and dietary fibre on the selected nutritional and functional properties of biscuits. Food Chem. 114: 1462-1469 (2009)