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ORIGINAL ARTICLE

Effect of sonication process of terebinth (*Pistacia terebinthus* L.) fruits on antioxidant activity, phenolic compounds, fatty acids and tocopherol contents

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Abstract The current study investigated the impact of sonication process on antioxidant activity, phenolic compounds, total phenolic, total flavonoid, oil contents, fatty acids profile, and tocopherols of terebinth (*Pistacia terebinthus*) fruits. The highest antioxidant activity (87.32%), total phenolic (251.25 mg/100 g) and flavonoid (3413.72 mg/100 g) contents were observed in terebinth fruits sonicated for 30 min. The oil contents of terebinth increased from 38.93% (control) to 42.60% (sonicated for 15 min) after sonication process. The quercetin and catechin were the chief phenolic compounds in *P. terebinthus* extracts and their values were increased from 129.09 to 467.28 mg/100 g (quercetin) and from 5.58 to 21.33 mg/100 g (catechin) in fruits sonicated for 30 min. The major fatty acids of terebinth fruit oil were oleic (48.02–49.15%), linoleic (22.28–23.48%) and palmitic (22.10–23.67%) and sonication processes did not affect the quantities of these fatty acids. γ-Tocopherol was the most abundant isomer with the value of 63.95–122.03 mg/100 g in terebinth fruit oil. It could be concluded that pre-sonication for 30 min was more suitable for enhancing the antioxidants and phenolic compounds of *P. terebinthus* fruit.

Keywords Turpentine · *P. terebinthus* sonication · Antioxidants · Phenolic compounds · Oil content · Tocopherol

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Introduction

Terebinth (*Pistacia terebinthus*), perennial plant belongs to Anacardiaceae family, is widely grown western and southern areas of Turkey, where it is called “menengiç” in Turkish. The main cultivation areas are Middle East, United States, and Mediterranean countries (Bozorgi et al. 2013). In Turkey, the terebinth tree is usually found growing on the dry rock slopes and hillsides as well as in pine forests of the Taurus Mountains (Baytop 1984). *Pistacia* species have antioxidant activity in addition to antimicrobial, anti-inflammatory and cytotoxic activities because of their high flavonoids and phenolic contents (Topçu et al. 2007). *Pistacia terebinthus* fruits consume as snack food in raw or roasted forms, add to drinks particularly coffee, and are used in bakery products (Ertas et al. 2013). Terebinth fruit extracts have high contents of apigenin, luteolin, luteolin 7-o-glucoside, quercetin and kaempferol (Kavak et al. 2010). In traditional medicine, *P. terebinthus* fruits were used internally or externally to treat several diseases such as gastralgia, stomach ache, diarrheic, throat infections, asthma, cough, rheumatism, and eczema (Matthaus and Özcan 2006). Besides fruits, different parts of *P. terebinthus* are antiseptic for bronchitis and diuretic (Orhan et al. 2012). Terebinth fruits are significant sources of protein, oil, minerals, and fiber. The oil extracted from *P. terebinthus* fruits is an alternative to vegetable oils because it contains high amounts of mono-unsaturated (oleic acid) and omega-3 (linoleic acid) fatty acids, and it has desirable odor and taste (Bozorgi et al. 2013). In a previous study, Özcan (2004) reported the physical and nutritional characteristics of terebinth (*Pistachia terebinthus* L.) fruits from Mersin area, Turkey and concluded that they have significant potential uses. However, research on effect of pretreatment process to enhance the extraction

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of phytochemicals from terebinth fruits is scarce. Therefore, the objective of the study was to investigate the influence of sonication treatment on bioactive properties and phenolic compounds of terebinth as well as fatty acid composition and tocopherol content of terebinth oil.

Materials and methods

Material

The ripe terebinth (*P. terebinthus* L.) fruits were obtained from wildly growing trees in Mersin (Silifke) province in Turkey in 2018. The samples were packed polypropylene bags and then transported to the laboratory under cold conditions. After that, the fruits were subjected to drying at room temperature until reaching constant weight. Then, the dust and dirt were removed from dried fruits by using an air screen cleaner. In addition to that, immature and broken fruits were also discarded. Clean dried fruits were ground using a hummer mill and kept in close container until used for sonication and extraction processes.

Methods

Sonication process

Powdered samples (5 g) were mixed with 25 mL of methanol (for bioactive compounds) or petroleum benzene (for oil content) in Erlenmeyer flask. The flasks were sonicated separately for 15, 30, and 45 min in ultrasonic bath. Thereafter, the control (untreated) and sonicated samples were analysed.

Sample extraction

Extraction process was performed as described previously (Jakopic et al. 2011) with minor changes. The untreated and sonicated samples (5 g/25 mL methanol) were subjected to 10 min centrifugation at 6000×*g*. After filtration of the supernatant with a 0.45 µm membrane filter, the filtrate was mixed with 10 ml of *n*-hexane, poured in separation funnel and shaken to separate the methanol and hexane layers. After two times repeating of this step, the methanol layers were collected, combined, evaporated to dryness at 50 °C using rotary evaporator. Before analysis, the dried extracts were re-suspended in 25 ml of methanol.

Total phenolic content

Folin-Ciocalteu (FC) method (Yoo et al. 2004) was applied for the quantification of total phenolic contents of terebinth fruit extracts. Gallic acid at the concentration range of 0.0–200 mg/mL was used to construct the standard curve. The absorbances of the sample extracts and standard were measured at 750 nm and the results were defined as mg gallic acid equivalent (GAE)/100 grams of fresh weight. Triplicate analysis was performed.

Antioxidant activity

The DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging method was used for the determination of the free radical scavenging activity of untreated and sonicated terebinth fruits as described elsewhere (Lee et al. 1998). In brief, 2 mL of terebinth extracts was mixed with equal volume of DPPH in methanol, mixed throughly, and kept for 30 min at room temperature. After that, the absorbance of the mixture was measured at 517 nm and the percentage of DPPH inhibition was calculated using the following equation:

$$\text{DPPH activity } (\%) = \frac{\text{Absorbance of blank} - \text{Absorbance of extracts}}{\text{Absorbance of blank}} \times 100$$

Total flavonoid content

The colorimetric method described by Hogan et al. (2009) was used for the determination of total flavonoid contents of terebinth fruit samples. After mixing the extracts (1 mL) with $NaNO_2$ (0.3 mL), $AlCl_3$ (0.3 ml) and NaOH (2 ml), the absorbance of the mixture was measured at 510 nm with a spectrophotometer and the results were presented as mg catechin (CA)/100 g of fresh weight for triplicate samples.

Determination of phenolic compounds

The phenolic compounds of untreated and sonicated terebinth fruit samples were separated using Inertsil ODS-3 (5 µm; 4.6 × 250 mm) column attached to a Shimadzu-HPLC system. A mixture of 0.05% acetic acid (A) and acetonitrile (B) was used as a mobile phase buffer. Twenty microliter sample was injected and the system was run at a flow rate of 1 mL/min at 30 °C and the peaks were detected on a PDA detector at 280 and 330 nm. A gradient program of 8% buffer B for 0–0.1 min, 10% buffer B for 0.1–2.0 min, 30% buffer B for 2.0–27.0 min, 56% buffer B for 27.0–37.0 min, 8% buffer B for 37.0–37.10 min, and maintained at 8% buffer B for 37.10–45.0 min reaching the total of 60 min running time of each sample.

Oil content

The standard official method was used for determination of oil content of untreated and sonicated terebinth fruits (AOAC 1990). Prior to the determination of total oil content, the oil was subjected to 5 h extraction using Soxhlet and petroleum benzene. After removing of the solvent at 50 °C using rotary vacuum evaporator, the remaining oil was weighed, quantified and then kept for analysis of fatty acid profile and tocopherol composition.

Fatty acid profile

Prior to the analysis the fatty acids of oil extracted from untreated and sonicated terebinth fruits were subjected to esterification following the ISO-5509 (ISO 1978) method with slight alterations. Thereafter, the fatty acids methyl esters of samples and authentic standards of fatty acids methyl esters (Sigma Chemical Co.) were separated and analyzed using a Tecnocroma TR-CN100 (60 m × 0.25 mm, 0.20 μm) capillary column fitted to a Shimadzu GC-2010 gas chromatography system and peaks were detected using flame-ionization detector (FID). Nitrogen was used as carrier gas at a flow rate of 1.51 mL/min. Injector and detector temperature was set as 260 °C. The column temperature was programmed as 120 °C for 5 min, which increased to 240 °C at 4 °C/min, and held 25 min at 240 °C. An 80 ml/min total flow rate and 1/40 split ratio was performed.

Tocopherol content

Tocopherol content of oil extracted from untreated and sonicated terebinth fruits was determined as described previously (Spika et al. 2015). Briefly, oil samples (0.1 g) were dissolved in 10 ml of *n*-hexane and then the mixture was subjected to filtration on a 0.45 μm nylon filter. After that, 20 μL samples and authentic standards (α, β, γ and δ-tocopherol, 0-100 mg/L) were separated and analyzed using LiChroCART Silica 60 (4.6 × 250 mm, 5μ; Merck, Darmstadt, Germany) column attached to a Shimadzu-HPLC apparatus equipped with PDA detector. The mobile phase of 0.7% propan-2-ol in *n*-hexane was run at a flow rate of 0.9 ml/min and peaks were detected at 295 and 330 nm. The total running time per sample was 30 min and triplicate samples of each treatment were analyzed.

Statistical analyses

Triplicate analysis was done for all samples and the results were averaged and analyzed using ANOVA (JMP version 9.0, SAS Inst. Inc., Cary, NC, USA) and the results were presented as mean ± standard deviation (MSTAT C) of sonication times (Püskülcü and İkiz 1989).

Results and discussion

The antioxidant activity, total phenolic, total flavonoid, and oil contents of untreated and sonicated *P. terebinthus* fruit powders are presented in Table 1. Antioxidant activity, total phenolic, and total flavonoid contents of samples were ranged from 84.01 to 87.32%, 80.10–251.25 mg/100 g, 393.35–3413.72 mg/100 g, respectively. Among the sonicated samples, the highest antioxidant activity (87.32%), total phenolic (251.25 mg/100 g) and total flavonoid (3413.72 mg/100 g) contents were found in samples sonicated for 30 min. However, the increase of sonication time from 30 to 45 min caused declines to 86.56% in antioxidant activity, 240.83 mg/100 g in total phenolic content, and 3187.80 mg/100 g in total flavonoids ($P < 0.05$). Results showed that the contents of bioactive compounds and antioxidant activity were affected ($P < 0.05$) by sonication process. Sonication processes promoted the migration of antioxidants and phenolic compounds to the extract. Additionally, the most convenient sonication time for terebinth fruits was determined as 30 min. Similarly, Annegowda et al. (2012) sonication treatment for 30 min significantly enhanced the extractability of antioxidants in methanolic extracts of starfruits. The improvement of antioxidant activity, total phenolic and total flavonoid contents following sonication treatment of terebinth fruit could be attributed to enhance extraction efficiency of sonication due to disruption of cell wall and release of phenolic compounds by this treatment (Abid et al. 2013). Hacıbekiroğlu et al. (2015) reported that the total phenolic

Table 1 Bioactive compounds and oil contents of untreated and pre-sonicated *P. terebinthus*

Pre-ultrasonic time	Antioxidant activity (%)	Total phenolic content (mg/100 g)	Total flavonoid content (mg/100 g)	Oil content (%)
Control	84.01 ± 0.03*d	80.10 ± 0.02d	393.35 ± 0.01d	38.93 ± 0.05c
15 min	86.70 ± 0.02b**	213.47 ± 0.03c	3371.13 ± 0.04b	42.60 ± 0.03a
30 min	87.32 ± 0.01a	251.25 ± 0.01a	3413.72 ± 0.04a	40.43 ± 0.05b
45 min	86.56 ± 0.01c	240.83 ± 0.02b	3187.80 ± 0.06c	40.80 ± 0.04b

*Mean ± standard deviation; **Values within each row followed by different letters are significantly different ($p < 0.05$)

contents of terebinth extracts were lower than their flavonoid amounts. According to Topçu et al. (2007), total phenolic and flavonoid contents in methanol extracts of the *P. terebinthus* were found as 122.78 µg pyrocatechol equivalents/mg and 22.60 µg quercetin equivalents/mg, respectively. Orhan et al. (2012) reported that total phenolic and flavonoid contents of terebinth fruit were 241.07 mg GAE/g and 47.03 mg quercetin/g, respectively. Oil contents of untreated and sonicated samples varied from 38.93 to 42.60%. The maximum oil content (42.60%) was determined when samples were sonicated for 15 min. The ultrasonic extraction, especially the initial 15 min, increased significantly the oil content of *P. terebinthus*. After 15 min, the oil content decreased to 40.43% with sonication for 30 min, and to 40.80% with sonication for 45 min. Matthaus and Özcan (2006) stated that oil content of *P. terebinthus* averaged at 41.2 g/100 g and the range was between 38.4 and 45.1 g/100 g. Total oil amount of kernel and skin oils of terebinth fruit varied from 52.4 to 54.0% and from 42.3 to 48.1%, respectively (Ertas et al. 2013).

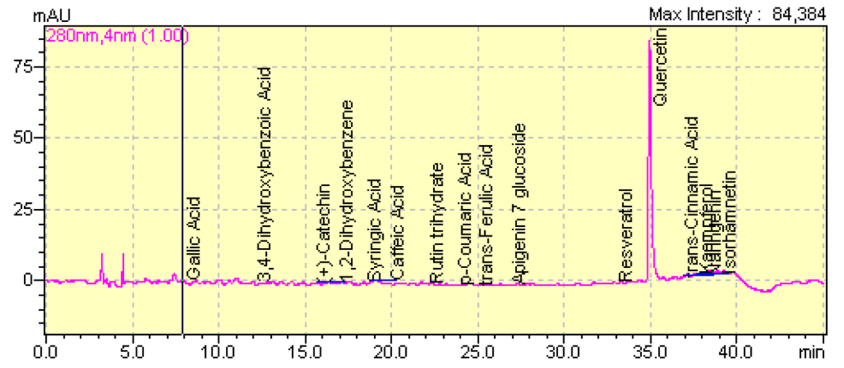
Phenolic compounds of unsonicated and sonicated *P. terebinthus* fruits are presented in Table 2 and Fig. 1. The main phenolic compounds of control sample were quercetin (129.09 mg/100 g), (+)-catechin (5.58 mg/100 g), and gallic acid (4.27 mg/100 g). *P. terebinthus* was a significant ($P < 0.05$) source of quercetin, which varied from 129.09 to 467.78 mg/100 g. Generally, ultrasonic extraction enhanced ($P < 0.05$) the amounts of phenolic compounds in terebinth fruit extracts. The highest amounts of protocatechuic acid, (+)-catechin, 1,2-dihydroxybenzene, caffeic acid, and quercetin were observed in sample sonicated for 30 min ($P < 0.05$). The results demonstrated that the optimum sonication time was 30 min to extract most of the phenolic compounds in high quantities from terebinth fruits. The increased quantities phenolic compounds in sonicated terebinth fruit samples over control could be due to the disruption of cell wall by sonication treatment that lead to liberation of more phenolic compounds (Abid et al. 2013). In agreement with these findings, Abid et al. (2014) reported that 30 min sonication improved the quantities of several phenolic compounds compared to control and those sonicated from 60 min. In addition, Ma et al. (2009) reported that ultrasonic treatments significantly enhanced the extraction of numerous phenolic compounds from citrus peels.

Fatty acid composition and tocopherol contents of untreated and sonicated *P. terebinthus* fruits are given in Table 3 and Fig. 2. The oleic acid (48.02–49.15%) was the main fatty acid of *P. terebinthus* fruits, followed by linoleic (22.28–23.48%) and palmitic (22.10–23.67%) acids. Generally, sonication process did not have significant effects on fatty acid profiles of samples. A minor increase was observed in oleic acid contents after sonication process, especially oleic acid content of sample sonicated 45 min increased from 48.02 to 49.15%. The sample sonicated 45 min had the lowest palmitic acid content (22.10%). In the study reported by Orhan et al. (2012), the amounts of oleic, palmitic, linoleic and stearic acids in terebinth fruits were 53.60, 25.62, 19.08 and 1.70%, respectively. The

Table 2 Phenolic compounds of untreated and pre-sonicated *P. terebinthus* fruits

Phenolic compounds (mg/100 g)	Control	15 min	30 min	45 min
Gallic acid	4.27 ± 0.21*d	14.70 ± 0.79a	7.87 ± 1.05c	11.05 ± 0.23b
Protocatechuic acid	3.86 ± 0.26d**	8.84 ± 0.81b	9.25 ± 0.85a	7.99 ± 0.95c
(+)-Catechin	5.58 ± 0.89d	15.05 ± 0.90c	21.33 ± 0.46a	19.62 ± 0.79b
1,2-Dihydroxybenzene	3.81 ± 1.11d	7.73 ± 0.33bc	11.75 ± 0.31a	4.14 ± 0.32
Syringic acid	0.95 ± 0.39d	1.32 ± 0.24c	3.05 ± 1.61b	5.33 ± 0.04a
Caffeic acid	0.48 ± 0.09d	3.83 ± 1.78c	13.66 ± 0.28a	12.94 ± 1.23b
Rutin trihydrate	0.51 ± 0.14d	7.23 ± 0.23a	1.93 ± 0.76c	3.13 ± 0.28b
p-Coumaric acid	0.08 ± 0.04d	0.22 ± 0.13c	0.45 ± 0.22b	0.56 ± 0.13a
trans-Ferulic acid	0.24 ± 0.14d	1.65 ± 0.74c	3.40 ± 0.82b	4.74 ± 0.03a
Apigenin 7 glucoside	0.46 ± 0.11d	1.54 ± 1.32c	3.22 ± 0.88a	2.71 ± 0.02b
Resveratrol	0.36 ± 0.17c	0.56 ± 0.18b	0.98 ± 0.45a	0.99 ± 0.49a
Quercetin	129.09 ± 0.84d	330.94 ± 0.46c	467.78 ± 0.79a	457.51 ± 0.24b
trans-Cinnamic acid	0.15 ± 0.04c	0.37 ± 0.08a	0.15 ± 0.05c	0.23 ± 0.03b
Naringenin	0.87 ± 0.27d	3.80 ± 0.24b	3.75 ± 0.35c	4.08 ± 0.23a
Kaempferol	2.50 ± 0.04d	2.69 ± 0.64c	2.92 ± 0.48b	4.17 ± 0.42a
Isorhamnetin	1.75 ± 0.45c	1.95 ± 0.41b	2.26 ± 0.33a	1.58 ± 0.54d

*Mean ± standard deviation; **Values within each row followed by different letters are significantly different ($p < 0.05$)



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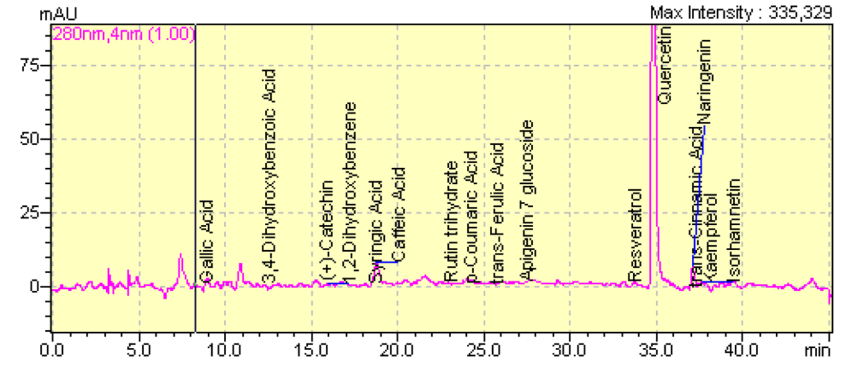
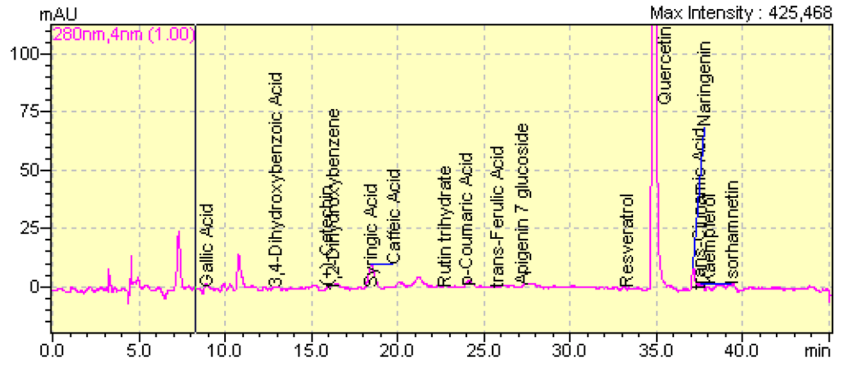
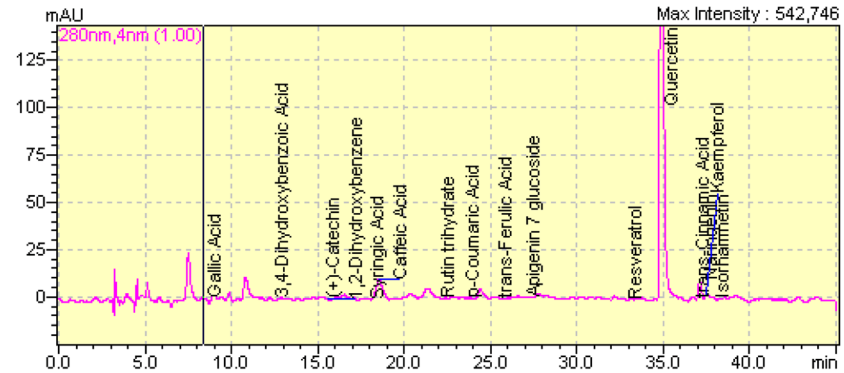


15 min sonication



30 min sonication



45 min sonication

Fig. 1 Phenolic compounds chromatograms

Table 3 Fatty acid compositions and tocopherol contents of oils of untreated and pre-sonicated *P. terebinthus* fruits (%)

Fatty acids	Control	15 min	30 min	45 min
Palmitic	23.40 ± 0.67*a	22.89 ± 0.40b	23.67 ± 0.33a	22.10 ± 0.17b
Stearic	2.19 ± 0.03a**	2.13 ± 0.00c	2.07 ± 0.02d	2.16 ± 0.01b
Oleic	48.02 ± 0.40b	48.09 ± 0.30b	48.63 ± 0.20b	49.15 ± 0.12a
Linoleic	23.03 ± 0.20a	23.48 ± 0.12a	22.28 ± 0.10b	23.06 ± 0.01a
Arachidic	0.16 ± 0.01b	0.17 ± 0.00a	0.16 ± 0.00b	0.17 ± 0.01a
Linolenic	0.71 ± 0.01b	0.79 ± 0.00a	0.69 ± 0.01c	0.68 ± 0.00d
Arachidonic	–***	–	–	0.21 ± 0.01
Tocopherols (mg/100 g)				
α-Tocopherol	44.43 ± 0.22*a	32.29 ± 0.28c	32.41 ± 0.03c	39.22 ± 0.38b
β-Tocopherol	8.38 ± 0.13a**	6.80 ± 0.04c	8.25 ± 0.05a	7.57 ± 0.09b
γ-Tocopherol	102.96 ± 0.06b	63.95 ± 0.01d	122.03 ± 0.02a	80.09 ± 0.04c
δ-Tocopherol	2.15 ± 0.01a	1.76 ± 0.04b	2.10 ± 0.01a	1.67 ± 0.00b

*Mean ± standard deviation; **Values within each row followed by different letters are significantly different ($p < 0.05$);***nonidentified

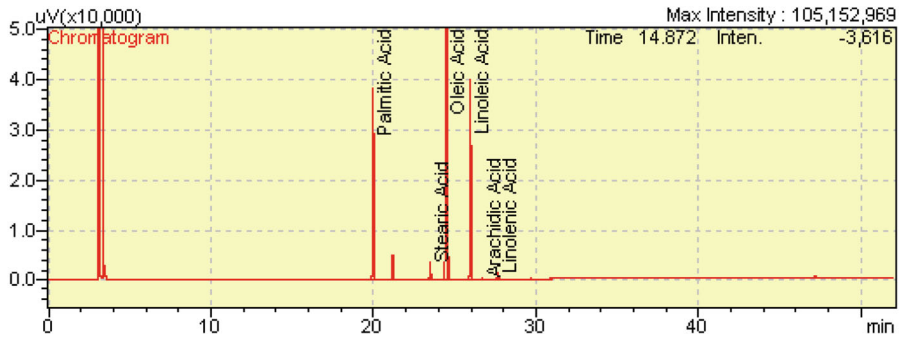
concentrations of the dominant fatty acids varied from 43.8 to 51.3% for oleic acid, from 19.3 to 23.5% for palmitic acid, from 19.0 to 25.9% for linoleic acid (Matthaus and Özcan 2006). In another study, the major fatty acids in oil of *P. terebinthus* fruits were determined to be oleic (52.52%), palmitic (21.65%) and linoleic (19.18%) (Hacıbekiroğlu et al. 2015). The oleic, linoleic and palmitic acid contents in oils of terebinth fruit were 55.6–67.5 g/100 g, 18.7–31.6 g/100 g, 7.7–8.9 g/100 g for kernel; 51.2–56.4 g/100 g, 11.5–12.0 g/100 g, 24.6–25.8 g/100 g for skin, respectively (Ertas et al. 2013).

Tocopherol contents of untreated and sonicated *P. terebinthus* fruits are shown in Table 3. The tocopherol content of untreated *P. terebinthus* fruits were ranged from 2.15 to 102.96 mg/100 g. The major isomer was γ-tocopherol (63.95–122.03 mg/100 g), followed by α-tocopherol (32.29–44.43 mg/100 g). In general, the sonication process caused a reduction ($P < 0.05$) in tocopherol contents of samples. The minimum α, β and γ tocopherol amounts were determined in sample sonicated for 15 min with the values of 32.29, 6.80 and 63.95 mg/100 g, respectively. However, γ-tocopherol content of the *P. terebinthus* sonicated for 30 min increased from 102.96 to 122.03 mg/100 g. Additionally, the tocopherol results after sonication process for 45 min were closed to untreated (control) samples. Matthaus and Özcan (2006) reported that the major tocopherols in seed oil of *P. terebinthus* were α- and γ- tocopherol, which were determined between 116.4 and 150.7 mg/kg, 113.3 and 155.1 mg/kg, respectively. According to the study of Ertas et al. (2013), α- and γ- tocopherol contents in kernel oil of terebinth fruit ranged from 28.0 to 43.4 mg/kg and from 361.1 to 437.2 mg/kg, while α- and γ- tocopherol amounts of skin oil were varied from 305.4 to 348.7 mg/kg and from 0.0 to 11.3 mg/kg.

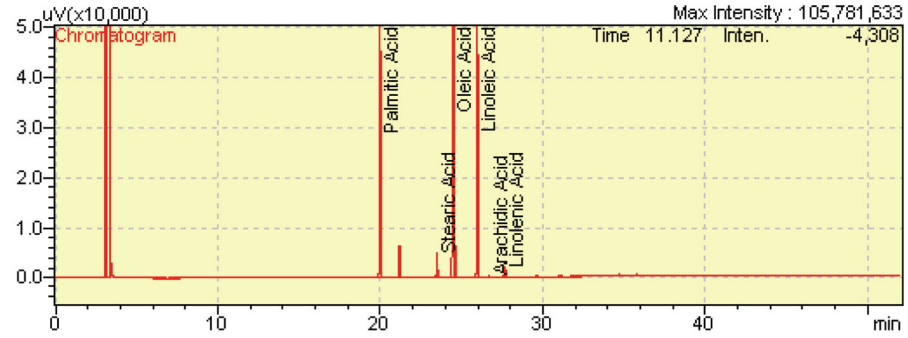
Correlation

Correlation analysis indicated positive correlations between antioxidant activity, total phenolic, total flavonoids, and individual phenolic compounds (Table 4). Total phenolic ($r^2 = 0.981$) and total flavonoid ($r^2 = 0.984$) contents positively ($P < 0.05$) correlated with antioxidant activity. Interestingly, the correlation between antioxidant and protocatechuic acid was highly positive ($r^2 = 0.993$, $P < 0.01$) suggesting the contribution of this phenolic compound to the antioxidant activity of terebinth fruits as reported previously that protocatechuic acid is strong DPPH scavenger compound (Li et al. 2011). Positive correlations ($P < 0.05$) were also observed between total phenolic contents and total flavonoids, protocatechuic acid, catechin, quercetin, and naringenin. In addition, strong positive ($P < 0.01$) correlations of total flavonoids with protocatechuic acid ($r^2 = 0.989$) and naringenin ($r^2 = 0.987$) were observed indicating that the contribution of these phenolic compounds to total phenolic and flavonoid contents in terebinth fruits. There are also several positive correlations among phenolic compounds. Of them, catechin positively correlated with apigenin ($r^2 = 0.976$, $P < 0.05$) and extremely correlated with quercetin ($r^2 = 0.997$, $P < 0.001$). Moreover, caffeic acid showed positive correlations ($P < 0.05$) with rutin ($r^2 = 0.966$) and apigenin ($r^2 = 0.979$) and it showed extreme positive ($P < 0.001$) correlation with resveratrol ($r^2 = 0.997$). Resveratrol also showed positive ($P < 0.05$) correlations with *p*-coumaric acid, trans-ferulic acid and apigenin. In addition, positive correlations ($P < 0.05$) were observed between rutin and trans-cinnamic acid ($r^2 = 0.979$), isorhamnetin and 1,2-dihydrobenzne ($r^2 = 0.962$), kaempferol and syringic acid ($r^2 = 0.965$), and apigenin and quercetin ($r^2 = 0.974$). Furthermore, extreme positive

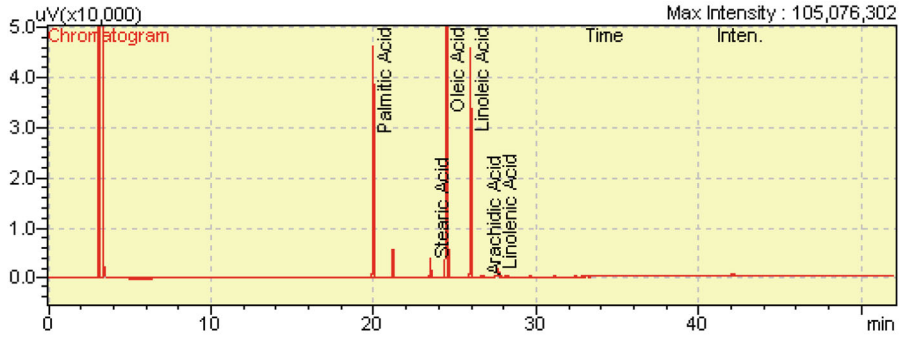
Fig. 2 Fatty acids chromatograms



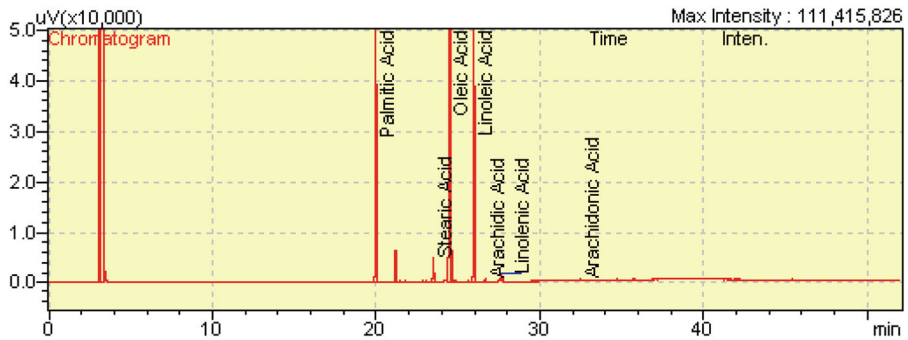
Control



15 min sonication



30 min sonication



45 min sonication

Table 4 Correlation of antioxidant activity (DPPH), total phenolic and flavonoid contents, and phenolic compounds of terebinth fruits

	Antioxidant activity	Total phenolics	Total flavonoids	Catechin	Dihydrobenze	Syringic	Caffeic	Rutin	p-coumaric	trans-Ferulic	Apigenin
Total phenolics	0.981*										
Total flavonoids	0.984*	0.976*									
Gallic											
Protocatechuic	0.993**	0.960*	0.989**								
Catechin		0.983*									
Rutin											
p-coumaric							0.966*				
trans-ferulic									0.997***		
Apigenin				0.976*			0.979*				
Resveratrol							0.997***		0.981*	0.963*	0.978*
Quercetin		0.978*		0.997***							0.974*
Trans-cinnamic								0.979*			
Naringenin		0.977*	0.987**								
Kaempferol						0.965*					
Isorhamnetin					0.962*						

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

($P < 0.001$) correlation was observed between trans-ferulic and *p*-coumaric acids ($r^2 = 0.997$).

Conclusion

This study investigated the effect of sonication treatment on the extraction of oil contents, bioactive properties, phenolic compounds of terebinth fruits. The results demonstrated that 30 min sonication treatment of terebinth fruits significantly enhanced the extraction of antioxidant activity, total phenolic and flavonoid contents, and phenolic compounds. However, this treatment did not affect the oil content and composition of terebinth fruits. Sonication treatment for 30 min greatly improved protocatechuic acid that strongly associated with the antioxidant activity in terebinth fruits. Overall, 30 min sonication treatment might be applied to enhance the antioxidant potentials of terebinth fruits.

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