Chemical Composition and Antioxidant Properties of Some Industrial Tree Bark Extracts

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Wood bark is a residue of forestry production that is used as a fuel source. The chemical composition of tree bark is similar to that of the harvested wood, and it contains a variety of useful compounds. To determine the chemical composition and antioxidant activities of different barks, fir *(Abies nordmanniana)*, beech *(Fagus orientalis)*, pine *(Pinus sylvestris)*, poplar *(Populus alba)*, and oak *(Quercus robur)* barks were selected because they are used for industrial purposes in Turkey. The dried bark powders were extracted using a 65:35 methanol-water mixture (v/v) to determine the total phenolic content, the flavonoid content, and the antioxidant properties (2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), metal chelating, and H_2O_2 scavenging). The flavonoid components were analyzed by high performance liquid chromatography (HPLC) and extracted by hexane to analyze the volatile components by gas chromatography-mass spectrometry (GC-MS). The poplar bark extracts had the highest total phenolic content, highest total flavonoid content, and highest antioxidant content. The poplar bark extracts were rich in myricetin (87.761 mg/L), which is a flavonoid with rich antioxidant properties. The presence of valuable extracts suggests that barks may have uses as valuable raw materials for chemical applications such as cosmetics, perfumes, and food preservatives.

Keywords: Bark; Extractive; Antioxidant; Phenolic components; Volatile components

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INTRODUCTION

Amounts of wood production is roughly 20,000,000 m^3 from Turkey Forest Areas (OGM 2012). According to Miles and Smith (2009), the bark ratio is over than 10% of woods. Approximately 2 million m^3 of barks were considered as a waste material of forest products. In Turkey, softwood barks are usually left as a fertilizer in the harvesting areas, while hardwood barks are debarked in the first stage of the production line. Hardwood barks are usually used as a fuel resource for meeting the requirements of forest products industry, such as fiberboard and particle board industries.

Wood bark is a more expensive raw material than other fuel resources and fertilizer because it has a variety of chemical components (Dönmez and Dönmez 2013). Research on bark was initiated to handle raw material issues, production bottlenecks, and alleviate environmental pollution. There have been many topics of bark utilization research. However, bark research can be divided into two main objectives: utilization of their main components (cellulose, lignin, and hemicellulose) (Fengel and Wegener 1989; Usta 1993; Balaban and Ucar 2001; Odabaş-Serin and Gümüşkaya 2006; Safdari *et al.* 2011; Miranda *et al.* 2012; Akgül *et al.* 2013; Feng *et. al.* 2013; Serin and Güleç 2014; Durmaz *et al.* 2016; Gönültaş and Uçar 2017), and their secondary metabolite qualities (Sjödin *et al.* 1996;

Kuliev *et al.* 1997; Vrkočová *et al.* 2000; Diouf *et al.* 2009; Yesil-Celiktas *et al.* 2009; Duda-Chodak *et al.* 2011; Lee *et al.* 2011; Maimoona *et al.* 2011; Sati *et al.* 2012; Feng *et al.* 2013; Legault *et al.* 2013; Bouras *et al.* 2015; Devappa *et al.* 2015; Hofmann *et al.* 2015; Özgenç *et al.* 2016; Özgenç *et al.* 2017; Dróżdż and Pyrzynska 2018).

Wood bark metabolites are a major part of extracts, which are a soluble material comprised of water and organic solvents. Extracts are a natural chemical mixture, which varies from sample to sample in a species (Fengel and Wegener 1989; Hafızoğlu and Deniz 2011; Belgacem and Pizzi 2016). A majoriy of research has been focused on the antifungal, antibacterial, and antioxidant properties of extracts.

The aim of this study was to characterize the exractives of five different bark species that are grown naturally in Turkey. The bark extracts were investigated with gas chromatography-mass spectrometry (GC-MS), high performance liquid chromatography (HPLC), and ultraviolet visible (UV-Vis) spectrometry. A spectrophotometer was used to investigate the antioxidant properties of the wood barks.

EXPERIMENTAL

Fir (*Abies nordmanniana*), beech (*Fagus orientalis*), pine (*Pinus sylvestris*), poplar (*Populus alba*), and oak (*Quercus robur*) barks were taken from harvesting areas in the Kastamonu province in Turkey. The wood barks processed separately were dried at room temperature and milled using a Wiley mill. The main components (Alcohol extractive (TAPPI 1988a), hot and cold water soluble (TAPPI 1993a), 1% NaOH soluble (TAPPI, 1993b), holocellulose content (Wise *et al.* 1946), Alpha cellulose content (TAPPI 1993c), Lignin content (TAPPI 1988b), and ash content (TAPPI 1993d)) of the barks were determined according to standard testing methods (Ateş *et al*. 2016). All chemicals for determining the main components of barks were used as analytical reagent grade and purchased from Sigma-Aldrich (Sigma-Aldrich GmbH, Sternheim, Germany). The bark powders were extracted by using hexane to analyze the volatile components by GC-MS. The phenolic compounds were extracted by a 65:35 methanol-water mixture (v/v) and freeze dried. The total phenolic content and total flavonoid content were determined by using the Folin-Ciocâlteu assay and the colorimetric method, respectively. The flavonoid component analysis was also investigated *via* HPLC. Furthermore, their antioxidant activities were tested with four methods such as 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), metal chelating, and H_2O_2 scavenging.

GC-MS Analyses

The hexane extracts of the bark samples were analyzed by a GC-MS QP 2010 Ultra (Shimadzu, Kyoto, Japan), which was equipped with a Rtx-5MS capillary column (Restek, Bellefonte, PA, USA). The capillary column was 30 m long, 0.25 mm wide, and had a coating thickness of 0.25 μm. For identifying chemical components, Wiley W9N11 library mass spectra was used. The experimental conditions were applied according to the requirements of the W9N11 (Özkinali *et al.* 2017). The experiment was initiated with an initial oven temperature of 40 °C for 3 min. The temperature was then ramped at 4 °C/min until it firstly reached 240 °C, and it was held at 240 °C for 10 min. The temperature was ramped at 4°C/min until it reached 260 °C, and then it was held at 260 °C for 10 min (total run time: 78 min).

HPLC Analyses

The extracts of the bark samples were analyzed using an LC20-A Prominence HPLC system (Shimadzu, Kyoto, Japan), which was equipped with an Inertsil ODS-3 5 µm column (GL Systems, Torrance, CA, USA). The column size was 25 mm × 4.6 mm. For identifying each compound, the combination of spectral matching was used for a certain retention time. The mobile phase consisted of water with 3% glacial acetic acid (Solvent A) and methanol (Solvent B). The gradient is shown in Table 1. The flow rate was 0.6 mL/min, the column temperature was 30 °C, and the monitoring wavelength was 280 nm. The chromatogram of a standard mixture of Eleutheroside, Taxifolin, Naringin, Myricetin, Quercetin, Butein, Luteolin, and Kaempferol (all purchased from Sigma Aldrich HPLC grade) was obtained by the gradient elution according to Table1.

Total Phenolic Content Determination

The total phenol content (TPC) was determined by the Folin-Ciocâlteu assay protocol (Ateş *et al.* 2015). Stock Solutions were prepared with nearly 1000 µg/mL from each type of dried extractives; 500 µL extractive solution were diluted with 7 mL methanol and 500 µL Folin-Ciocâlteu regent was added. Na_2CO_3 solution (2 mL, 20%) was added to mixture after 6 min. The solution was held for 10 min, then centrifuged at 4500 rpm for 10 min. Gallic acid was applied as the standard at 760 nm using a Shimadzu UVmini-1240 spectrophotometer (Kyoto, Japan). The total phenol content was expressed in mg equivalents of gallic acid per g of dry bark extract units (GAE mg/g).

Table 1. Gradient for HPLC Analysis

Time (min)	Solvent A (%)	Solvent B (%)
0 to 20	93	7
20 to 28	72	28
28 to 35	75	25
35 to 60	70	30
60 to 70	58	42
70 to 73	50	50
73 to 75	30	70
75 to 77	20	80
77 to 78.5	15	85
78.5 to 80	10	90
80 to 81.25	8	92
81.25 to 81.5	5	95
81.5 to 91	0	100
91 to 95	93	7

Total Flavonoid Content Determination

The total flavonoid content (TFC) was determined by the colorimetric method (Ateş *et al.* 2015). 500 µL extractive solution were diluted with 1.5 mL methanol. Solutions of $AlCl_3 \cdot 6H_2O$ (0.1 mL, 10%) and potassium acetate (0.1 mL, 1M) were subsequently added. Total volume of solution were adjusted to 5 mL with methanol and were held 0.5 h. Catechin was applied as the standard at 415 nm. The total flavonoid content was expressed in mg equivalents of catechin/g dry bark extract units (CE mg/g).

2,2-Diphenyl-1-Picrylhydrazyl (DPPH) Method

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was carried out as described by Özkan *et al.* (2015), with slight modification to solutions at concentrations of 1, 0.5, 0.25, and 0.125 g/L. The solutions were obtained from the extraction samples and 2 mL of each sample was taken in the test tubes for each concentration. In addition, 2 mL of 40 mM DPPH solution was added to each sample. The samples were centrifuged at 4500 rpm for 10 min and the sample absorbance was read at 520 nm after 30 min incubation at room temperature in dark.

Ferric Reducing Antioxidant Power (FRAP) Method

The FRAP processes were carried out as described by Özkan *et al.* (2016) with slight modifications. Solutions having 1, 0.5, 0.25, and 0.125 g/L concentrations were obtained from the extraction samples. A quantity of 0.5 mL of sample was put in the test tubes for each concentration and 4.5 mL of methanol was added to them. After that, 2.5 mL of 1% potassium ferricyanide ($K_3Fe(CN)_6$) was added. This mixture was heated at 50 °C for 20 min in a water bath and 2.5 mL of trichloric acid (TCA) was added to it. The UV absorption at 520 nm was measured at 0 min. The samples were centrifugated at 4500 rpm and were then shifted to another test tube. A quantity of 2.5 mL of alcohol and 0.5 mL 0.1% $FeCl_3$ were added to the tube. Afterwards, the absorption was measured at 700 nm.

H_2O_2 Reduction Activity

The hydrogen peroxide content was determined as described by Güder and Korkmaz (2012). The H_2O_2 solution was prepared using 40 mM phosphate solution according to the final volume, which was nearly 4 mL. A quantity of 170 µL of methanol-water extract was added to the H_2O_2 solution. The absorption at 230 nm was determined by UV-Vis spectrophotometer.

Metal Chelating Activities

The metal chelating activity of the ferrous ions by the extracts and standards was determined as explained by Güder and Korkmaz (2012), with slight modifications. The different extractive concentrations were prepared, and 0.4 mL of extract was added to 50 µL of $FeCl_2$ solution (2 mM). The reaction was initiated when 0.2 mL of ferrozine (5 mM) was added and the mixture was forcefully shaken. Then, the solution was left at room temperature for 10 min. Finally, the UV absorption was measured at 562 nm using a spectrophotometer.

RESULTS AND DISCUSSION

Table 2 compares the chemical composition of the bark samples with those of literature studies. The pine bark extractive content was determined to be 18.3%. This percentage is close to the percentages found in previous literature studies, which reported 18.8% and 20.07%, reported by Miranda *et al.* (2012) and Fengel and Wegener (1989), respectively. The oak bark extractive content was found to be 18.8%, which was higher than the 11.4% reported by Gönültaş and Uçar (2017). The fir bark extractive content was also 11.4%. This content was more than the percentages reported in previous studies (Serin and Güleç 2014; Ozgenç *et al*. 2017). The extractive content of the beech bark was 15.5%, which was higher than the percentage reported by Ozgenç *et al.* (2017).

Table 2. The Main Components' Ratios of Barks

	Extractives (%)	Ash (%)	Holo-Cellulose (%)	Alfa Cellulose (%)	Lignin (%)	Solubility (%)		
						1% NaOH	Hot Water	Cold Water
Pine (Determined)	18.33	2.40	49.60	32.58	27.28	38.26	18.72	14.87
Pine (Usta 1993)	9.34	-	43.70	-	49.20	45.20	10.82	
Pine (Miranda *et al.* 2012)	18.8	4.6	37.6	-	32.9	-	9.2	-
Oak (Determined)	18.75	1.73	45.91	20.79	32.67	34.45	25.52	12.11
Oak (Balaban and Ucar 2001)	-	13.5	50.59	-	30.82	37.47	-	-
Oak (Gönültaş and Ucar 2017)	11.4	10.2	44.79	41.59	33.57	47.67	18.39	-
Fir (Determined)	19.10	2.2	52.00	25.80	24.72	27.43	17.93	16.77
Fir (Serin and Güleç 2014)	7.53	1.84	62.72	32.72	29.44	33.54	10.32	10.62
Fir (Durmaz *et al.* 2016)	16.44	3.69	44.60	32.86	34.54	25.00	14.40	11.06
Fir (Ozgenç *et al*. 2017)	17.01	-	50.13	-	28.05	25.54	-	-
Beech (Determined)	15.50	1.95	50.07	32.30	24.63	37.35	18.65	17.28
Beech (Ozgenç *et al.* 2017)	5.50		63.52	-	32.87	26.93	-	-
Poplar (Determined)	19.43	1.60	54.93	35.58	28.17	34.82	22.81	16.92
Poplar (Safdari *et al. 2011*)	13	12.22	-	-	33	-	-	-
Poplar (Akgül *et al.* 2013)	10.85	5.80	56.65	31.33	36.04	40.62	14.02	12.85

The poplar bark extractive content was found to be 19.4%. Determined extractive contents of bark samples were found similar. The samples in this research had the same moisture content and were dried under the same conditions. Therefore, some compounds could not be dissolved by the solvent.

The chemical components of extractives were investigated with a UV-Vis spectrophotometer to determine the amount of total phenolic components. According to results in Table 3, the phenolic components of the bark sample extractives made up nearly 5 to 10% of their total weight. The oak bark extractive phenolic content was 48 mg/g. This result is lower than the results of literature studies (Duda-Chodak *et al.* 2011; Dróżdż *et al.* 2018). All of the bark samples, except for fir and beech, had lower phenolic content than the percentages reported in previous studies (Diouf *et al.* 2009; Yesil-Celiktas *et al.* 2009; Maimoona *et al.* 2011; Legault *et al.* 2013; Hofmann *et al.* 2015). This can be attributed to environmental factors such as growing conditions or processing errors. On the other hand, chemical composition of extractives show an alteration with changing extractive parameters, such as changing the solvent (Maimoona *et al.* 2011).

Table 3. Total Phenolic Content of Bark Extracts (GAE mg/g)

	Poplar	Beech	Pine	Fir	Oak
Total Phenolic Content (mg GAE/g)	100	42.04	88	73	48
Duda-Chodak *et al*. 2011	-	-	-	-	74.2
Dróżdż *et al.* 2018 (Ethanol and Water Extract)	-	-	-	-	71 to 79
Dróżdż *et al.* 2018 (Water Extract)	-	-	-	-	55.4 to 60.4
Legault *et al.* 2013 (*Picea glauca* bark)	-	-	-	36 to 55	-
Celiktas *et al.* 2009	-	-	42	-	-
Maimoona *et al*. 2011 (*Pinus roxburghii* Bark)	-	-	89.1	-	-
Hofmann *et al*. 2015 (quercetin equivalent)	-	49.9	-	-	-
Lajnef *et al.* 2018 (Hot Water Extract)		30			
Diouf *et al.* 2009 (Hot Water Extract)	113.5	-	-	-	-

The total flavonoid contents of the bark extracts were determined (Table 4). There are very limited data that in the literature about the TFC of beech and fir bark extracts (Hofmann *et al*. 2015).

Table 4. Total Flavonoid Content of Bark Extracts (CE mg/g)

	Poplar	Beech	Pine	Fir	Oak
Total Flavonoid Content (CE mg/g)	54.1	31	22	38	32
Dróżdż *et al.* 2018 (Ethanol and Water Extract)	-	-	-	-	72 to 73.4
Dróżdż *et al*. 2018 (Water Extract)	-	-	-	-	35.1 to 38
Diouf *et al.* 2009 (Hot Water Extract)	11.5	-	-	-	-
Maimoona *et al.* 2011 (*Pinus roxburghii* bark)	-	-	33.4	-	-

Table 5. Main Components of Hexane Extractives of Barks by GC-MS (≥ 3%)

Poplar			Beech			Pine			Fir			Oak		
%	Time min	Compound	%	Time min	Compound	%	Time min	Compound	%	Time min	Compound	%	Time min	Compound
13.95	70.665	Lupenone	23.89	32.916	Diethyl Phthalate	41.43	9.133	Alpha Pinene	36.27	9.132	Alpha Pinene	16.71	32.922	Diethyl Phthalate
10.54	72.436	Lupeol	8.23	66.329	Squalene	6.88	10.783	Beta Pinene	9.34	32.920	Diethyl Phthalate	12.99	9.131	Alpha Pinene
6.89	7.559	Alpha Pinene	7.96	67.103	n.d.*	6.56	32.919	Diethyl Phthalate	6.23	53.133	Methyl Abietate	12.53	10.781	Betapinene
6.66	9.120	Alpha Pinene	6.18	67.055	n.d	6.26	48.008	Cembrene	5.12	67.107	Prostasal	7.21	12.895	D-Limonene
6.19	32.904	Diethyl Phthalate	5.51	35.281	Coniferol	4.83	19.300	Terpineol <alpha->	4.01	19.943	Verbenone	5.42	67.099	Prostasal
5.59	9.627	Beta Pinene	3.12	42.962	Dibutyl Phthalate	4.51	12.899	D-Limonene	3.79	51.202	Cycloisolongifolene, 9,10-dehydro-	4.44	11.466	Myrcene
5.49	10.771	Beta Pinene				3.2	11.468	Myrcene	3.04	47.581	(12Z)-Abienol	4.33	67.140	n.d.
4.96	68.643	1-Heptacosanol				3.18	49.970	Kaur-16-en-19-ol				4.16	66.339	Squalene
3.87	66.644	Octadecanal												
3.65	76.618	1-Heptacosanol												
3.44	12.165	D-Limonene												
3.43	12.888	D-Limonene												

* Non-defined compounds from the data library

The oak extractive TFC was very close to the literature value obtained *via* water extraction (Dróżdż *et al.* 2018). The TFC of the poplar extract was higher than reported values. This is likely because methanol, which was used in this study, has more flavonoids than water, which was used in the cited study (Devappa 2015).

The chemical compositions of the hexane extractives were analyzed *via* GC-MS, and the essential oil constituents were identified by comparing with the help of W9N11. Table 5 indicates the constituents, which were observed in quantities higher than 3% and were accepted as the main components. The pine bark hexane extract was very rich in secondary metabolites. Özgenç *et al.* (2017) reported that pine bark extract is abundant with monoterpene hydrocarbons (α-pinene and δ-3-carene). Previous research indicates that alpha pinene, camphene, beta pinene, sabinene, limonene, and 3-carene are found in branch phloem and pine bark (Sjödin *et al.* 1996).

The main component of the fir bark extractive volatile compound was alpha-pinene, which had a concentration of 36.3%. Generally, alpha pinene is a dominant component found in fir barks. Alpha pinene is a volatile compound according to some previous studies (Hafizoglu *et al.* 1994; Ramdani *et al.* 2014; Özgenç *et al.* 2017). The pine and fir extracts had the highest alpha pinene content, which is widely used in flavors, fragrances, medicines, and fine chemicals (Yang *et al.* 2013).

The hexane extract of oak barks can be defined as a mixture of invaluable hydrocarbons. Vrkočová *et al.* (2000) reported that the main component of oak bark volatile oil is (E)-2-hexenal, while monoterpene and sesquiterpene were found among the minor components. Another study about *Quercus leucotrichophora* showed that the major components were 1.8-cineol (40.4%), followed by γ-terpinene (16.4%), β-pinene (11.1%), p-cymene (6.2%), α-pinene (5.3%), 4-terpineol (3.7%), aromadendrene (1.8%), p-menth-1-en-8-ol (1.6%), and β-eudesmol (1.0%) (Sati *et al*. 2012).

Özgenç *et al.* (2017) reported that the major components of beech barks include hexanoic acid ethyl ester (32.4%), allo-aromadendrene (13.8%), octanoic acid ethyl ester (12.5%), 2-amylfuran (8.1%), and hexanal (5.8%). It was determined that diethyl phthalate was the main component of the hexane extract of beech bark samples. In this study, hexanal was a small component (2.6%) of the hexane extract. There were a couple of major components in the extracts, which could not be identified because they were not found in the data library.

According to the GC-MS results of the poplar extracts, the main components were lupenone (14.0%), lupeol (10.5%), alpha pinene (6.9% and 6.7%), diethyl phthalate (6.2%), beta pinene (5.6% and 5.5%), 1-heptacosanol (5.0%), octadecanal (3.9%), 1-heptacosanol (3.4%), and D-limonene (3.44% and 3.43%).

Results of the HPLC analysis at 280 nm and chromatograms are shown in Table 6 and Fig. 1, respectively. Although there are lots of flavonoids, as seen in Fig. 1, we detected in total eight different flavonoid content of bark extractives. Hofmann *et al.* (2014) reported that poplar bark had high antioxidant activity and a high overall phenolic content. The poplar barks had the highest myricetin content (87.8 mg/L), which demonstrates strong antioxidant activity (Gordon and Roedig-Penman 1998; Chobot and Hadacek 2011; Barzegar 2016). Myricetin was a large component of all the bark species other than beech bark, which had a modest myricetin concentration. The beech bark extracts had the lowest flavonoid content among the bark species tested. Other studies have reported that pine and fir bark extracts have a wide variety of flavonoids, such as taxifolin, catechin, and several procyanidins (Karonen *et. al.* 2004; Cretu *et al.* 2013; Amalinei *et al.* 2014; Benković *et al.* 2014; Iravani *et al.* 2014, Ostroukhov *et al.* 2018).

Table 6. HPLC Analyses Results of Bark Sample Extractives at 280 nm (mg/L).

	Poplar	Beech	Pine	Fir	Oak
Eleutheroside	14.266	2.896	9.448	0.432	0.678
Taxifolin	4.141	1.167	1.869	4.254	1.386
Naringin	2.258	0.483	0.38	0.566	0.354
Myricetin	87.761	2.541	20.801	10.833	7.979
Quercetin	13.335	1.302	3.982	3.223	1.966
Butein	1.147	0.082	1.073	1.784	0.335
Luteolin	0.754	0.232	0.099	0.34	0.472
Kaempferol	1.92	0.5	0.805	0.771	0.701

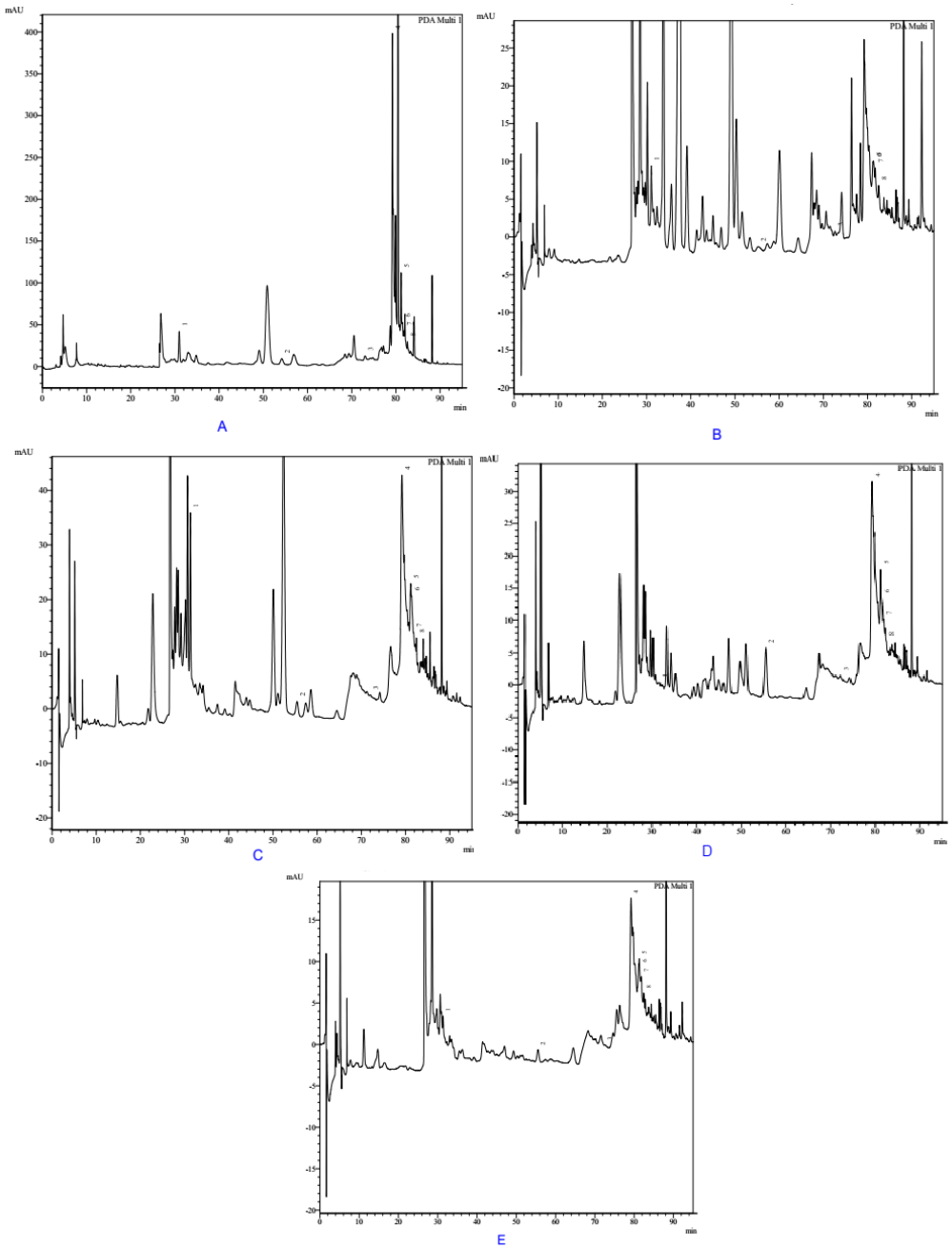

Fig. 1. HPLC spectrograms of Bark extracts A. Poplar; B. Beech; C. Pine; D. Fir; E. Oak

In this study, the oak bark extractive contents were reported as derivatives of catechin and proanthocyanidins. The naringin is a common component between this study and the previous studies (Kuliev *et al.* 1997; Lee *et al.* 2011; Bouras *et al.* 2015). Only a few studies are available on the determination of beech bark extraction by HPLC. Hofmann *et al.* (2015) reported that beech extracts include catechin, epicatechin, quercetin-O-hexoside, and taxifolin-O-hexoside. Another study determined that vanillic acid and eleuthroside B (syringin) were found in beech extractives (Tănase *et al.* 2018).

The bark extractives had modest antioxidant activities compared with butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). The poplar extracts were found to have the highest antioxidant activity. The high flavonoid content and the high myricetin content in poplar bark was determined by HPLC analysis. The antioxidant activity of the pine bark extractives was lower than the findings of Yesil-Celiktas *et al.* (2009), who applied the DPPH method. The pine bark extractives can be oxidized by conditioning in ambient air, which is a common method used by the pulping industry to solve problems related to extractives (Kirci 2000). The antioxidant activities of the oak bark extractives ranged from 36.6% to 48.3%, which was the lowest antioxidant activity among the sampled species. The low antioxidant activity is due to the extraction method used, which was unsuitable for antioxidant chemicals. For this reason, further research is needed in order to optimize the oak bark extraction methods. The study conducted by Bouras *et al.* (2015) demonstrated a good method for antioxidant extraction. The beech bark extractives also yielded low antioxidant activities due to the extraction method used. A previous study on the antioxidant activity of beech bark extracts yielded higher results using a different method and different solvents (Hofmann *et al.* 2015).

Table 7. TPC, TFC, and Antioxidant Activities of Barks

Method (%)	BHA	BHT	Poplar	Beech	Pine	Fir	Oak
DPPH	-	93	60.3	41.1	57.7	52.3	43.8
FRAP	87	90	69.2	37.05	45.8	57.6	36.6
Metal Chelating	91	86	65.1	45.1	54	48	38
H_2O_2	-	89	64.5	46.4	57.8	56.5	48.3

CONCLUSIONS

1. Trees harvested for industrial purposes in Turkey provide wood bark as a byproduct, which has use as a biomass.
2. Wood bark extractives have a significant phenolic and flavonoid content, which can be used for pharmaceutical manufacturing.
3. Hexane extractives of pine and fir barks can be suitable for isolating alfa-pinene, which is used in flavors, fragrances, and medicines.
4. The methanol-water extractives of poplar bark had high quantities of myricetin and natural antioxidant materials.
5. Harvested wood bark can be used as biomass, which is a valuable source of renewable energy.

6. Other parts of the extracted barks, such as cellulose, hemicellulose, and lignin, can be evaluated for industrial applications.

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