

Some Physicochemical Characteristics, Bioactive Content and Antioxidant Characteristics of Non-Sprayed Barberry (*Berberis vulgaris* L.) Fruits from Turkey

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Abstract Increasing consumer demands for indigenous, non-sprayed with pesticides and less-known or “forgotten” fruits necessitate knowledge on their breeding, cultivation, biochemical content, harvesting and marketing. Anatolia is rich for wild edible fruit species and barberry is abundant throughout Anatolia. The aim of this study was to deter-

mine some important physicochemical characteristics, bioactive content and antioxidant capacity of fruits from nineteen promising barberry (*Berberis vulgaris* L.) genotypes grown in the Coruh valley, Northeastern Anatolia. The results indicated genotype-specific differences for most of the physicochemical characteristics, antioxidant capacity and the content of some bioactive compounds. Fruit mass ranged from 0.073 (‘Coruh-7’) to 0.267 g (‘Coruh-11’). Total phenolic content ranged from 2532 (‘Coruh-’) to 3719 mg GAE per liter fruit juice (‘Coruh-11’). The genotype ‘Coruh-12’ had the highest total monomeric anthocyanin content (1004 mg per liter fruit juice) as cyanidin-3-glucoside. The highest total antioxidant capacity was observed in fruits of ‘Coruh-8’ and ‘Coruh-9’ genotypes with all three antioxidant-determining methods. We conclude that the barberry fruits represent a good source of bioactive phytochemicals because of their high phenolic and anthocyanin contents.

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Keywords Barberry · Bioactive content · Diversity · Germplasm characterization

Physikalisch-chemische Eigenschaften, bioaktive Inhaltsstoffe und antioxidative Eigenschaften von nicht mit Pflanzenschutzmitteln behandelten Früchten der Berberitze (*Berberis vulgaris* L.) aus der Türkei

Zusammenfassung Der zunehmende Wunsch der Verbraucher nach heimischen, mit Pflanzenschutzmitteln nicht behandelten, wenig bekannten oder „vergessenen“ Fruchtarten erfordert über diese Kenntnisse in Züchtung, Anbau, biochemischen Inhaltsstoffen, Ernte und Vermarktung. Anatolien ist reich an essbaren Wildobstarten und die Berberitze ist in ganz Anatolien häufig vorhanden.

Das Ziel dieser Studie war es, einige wichtige physikalisch-chemischen Eigenschaften, bioaktive Inhaltsstoffe und antioxidative Kapazitäten von Früchten von neunzehn vielversprechenden Berberitzen (*Berberis vulgaris* L.) zu bestimmen, deren Genotypen im Coruh Tal, im Nordosten Anatoliens, gewachsen sind. Die Ergebnisse zeigten, dass es Genotyp-spezifische Unterschiede bei den meisten der physikalisch-chemischen Eigenschaften, der antioxidativen Kapazität und einigen bioaktiven Inhaltsstoffen gibt. Das Fruchtgewicht reichte von 0,073 ('Coruh-7') bis zu 0,267 g ('Coruh-11'). Der Gesamtphenolgehalt lag zwischen 2532 ('Coruh-9') und 3719 mg GAE pro Liter Fruchtsaft ('Coruh-11'). Der Genotyp „Coruh-12“ hatte den höchsten Gehalt an monomerem Anthocyan (1004 mg pro Liter Fruchtsaft) in Form von Cyanidin-3-glucosid. Der höchste Gesamtgehalt an Antioxidantien wurde in den Früchten von 'Coruh-8'- und 'Coruh-9'- Genotypen bei allen drei Analyseverfahren für Antioxidantien beobachtet. Wir schließen daraus, dass die Früchte der Berberitze aufgrund ihrer hohen Phenol- und Anthocyan-Gehalte eine gute Quelle für bioaktive, sekundäre Inhaltsstoffe sind.

Schlüsselwörter Berberitze · *Berberis vulgaris* · Bioaktive Inhaltsstoffe · Biodiversität · Germplasm Charakterisierung

Introduction

Recent studies have shown that a wide range of less-known, forgotten or indigenous-fruit species are abundant in specific rural areas of most parts of the world (Egea et al. 2010; Ercisli 2012a; Jurikova et al. 2012a; Drkenda et al. 2014; Gebauer et al. 2014). Moreover, in the past decades, many reports have been published on the nutritional composition and medicinal value of wild edible fruits growing in different regions of the world. Most of these studies indicate that indigenous fruits have important socio-economic value. Cultivation and consumption of indigenous fruits could reduce malnutrition and poverty in rural peoples worldwide (Jurikova et al. 2012b; Murillo et al. 2012; Oryema et al. 2013).

Most of these fruit species has numerous unnamed genotypes that naturally growing in the diverse agro climatic regions and they do not sprayed with pesticides. Barberry is the one of the most important wild edible fruits grown in the different parts of Anatolia and it is free of pest and diseases and therefore they are not sprayed properly or are left untreated with pesticides. They have been grown over many centuries in the region and traditionally they have been multipurpose using (Gundogdu 2013; Yildiz et al. 2014).

Turkey is rich in wild edible fruits, and these fruits have been an important component in the traditional diets since

the beginning of human occupation of the Anatolia peninsula. The Coruh region, located in Northeastern part of the country, is especial rich in wild edible fruits. The consumption of locally grown wild edible fruits is gaining interest, both in the region and throughout the country. These fruits make an important contribution to local communities' health and welfare (Yildiz et al. 2010; Ercisli et al. 2012b). All these wild edible fruits can be consumed as raw, as well as dried for winter consumption, or processed into some traditional products such as 'pekmez' or 'pestil'. They are also cooked to produce jams and are included in non-alcoholic beverages in the Coruh region (Ercisli and Orhan 2008; Tosun et al. 2009). Most of the wild-harvested edible fruits have been reported to contain higher amounts of nutrient and bioactive compounds compared to cultivated varieties (Barros et al. 2010; Yildiz et al. 2010; Milivojevic et al. 2012).

Overwhelming evidence from *in vitro*, *in vivo*, epidemiological, and clinical trial data, indicates that there are components in a plant-based diet, other than traditional nutrients, that can reduce cancer risk. More than a dozen classes of these biologically active plant chemicals, now known as 'phytochemicals', have been identified. The majority of naturally occurring health-enhancing substances appear to be of plant origin (Bolek and Obuz 2014; Rop et al. 2014; Yildiz 2013; Jurikova et al. 2011; Milivojevic et al. 2011). These health properties are attributed to high level of beneficial phytochemicals and other micro-nutrients in these crops which act as antioxidants by scavenging free radicals. These free radicals damage cellular lipids, proteins and DNA thus initiating many degenerative disorders (Lampe 1999; Boyer and Liu 2004; Veberic et al. 2009).

The genus *Berberis* including about 450–500 species found throughout the temperate and subtropical regions of the world. The most well-known among these species, is the so-called European barberry, *Berberis vulgaris*, which is common in Europe, North Africa, the Middle East, and central Asia (Gundogdu 2013). The genus is characterized by dimorphic shoots with long shoots that form the structure of the plant, and short shoots only 1–2 mm long. *Berberis vulgaris*, is noted for their attractive pink or red autumn colour. The fruit is a small berry 5–15 mm long, ripening to red or dark blue, often with a pink or violet waxy surface bloom; in some species, they may be either long or narrow, but are spherical in other species (Ozgen et al. 2012; Ahmed et al. 2013; Gundogdu 2013).

Previously only few studies, based on a very limited number of genotypes, have been reported on the bioactive content and antioxidant characteristics of barberry fruits (Motalleb et al. 2005; Akbulut et al. 2009; Ozgen et al. 2012; Ahmed et al. 2013; Gundogdu 2013). Thus, more data are needed about the biodiversity of bioactive contents of this fruit to identify the most nutritious varieties. Such data will also assist in the genotype selection for parental

material to breed new cultivars for commercial production to meet increasing market demand. We present here new information on some physicochemical characteristics, bioactive contents and antioxidant capacity of nineteen barberry genotypes from Turkey.

Material and Methods

Plant Material

The research was conducted in 2012 on harvested fruits from nineteen promising barberry genotypes named from Coruh-1 to Coruh-19 grown together in Coruh valley in Northeastern part of Turkey.

Determination of Physicochemical Characteristics

Barberry fruits were harvested from nineteen genotypes at fully maturates stage. Approximately 0.5 kg fully matured, fresh barberry fruits were hand harvested and transferred to laboratory for analysis. The pomological analysis was conducted from 3 replicates, each having about 50 fruits. Fruit mass each fruit were measured with an electronic balance of 0.01 g sensitivity. Peel colour were determined by using a portable chromometer (Minolta CR-400). Colour measurements were recorded using the CIE L , a , b colour space. The soluble solid content (SSC) was measured in the filtered juice using a digital refractometer. The juice was also analyzed for titratable acidity as malic acid was determined by titration with 0.01 mol/L NaOH using phenolphthalein as indicator and pH of juices was determined following the guidelines of the official AOAC method (AOAC 1995). The intake fruit samples were also used for ash and fruit pulp ratio analysis. Total inorganic matters (ash percentage) were determined by incinerating the sample at 600 °C (AOAC 1995).

Determination of Bioactive Contents

For the total phenolic, total anthocyanin and total antioxidant capacity analyses, harvested fruit samples were frozen and stored at -20 °C until analysis. After thawing to room temperature, triplicate of 100 g lots of barberry fruits from each genotype were homogenized in a blender and they were screened for their total phenolic, total anthocyanin and antioxidant capacity following a single extraction procedure (Singleton and Rossi 1965). For this procedure, 3 g aliquots of each homogenate were transferred to polypropylene tubes and extracted with 20 mL of extraction buffer containing acetone, deionized water, and acetic acid (70:29.5:0.5 v/v), for 1 h. Total phenolic contents were measured according to Singleton and Rossi (1965). To determine the levels

of total phenolics, 1 mL of each extract was combined with Folin-Ciocalteu's phenol reagent and water 1:1:20 (v/v) and incubated for eight minutes, followed by the addition of 10 mL of 7% (w/v) sodium carbonate. After two hours, the absorbance of each was measured at 750 nm. The values of total phenolic were estimated by comparing the absorbance of each with those of a standard response curve generated with gallic acid. The results were expressed as mg gallic acid equivalent in liter of fruit juice.

Total monomeric anthocyanins (TMA) were determined by a pH differential method (Giusti and Wrolstad 2001), using a UV-VIS spectrophotometer. Absorbance was measured at 533 and 700 nm in buffers at pH 1.0 and 4.5 using $A=(A_{533}-A_{700})_{pH\ 1.0}-(A_{533}-A_{700})_{pH\ 4.5}$ with a molar extinction coefficient of 29,600. Results were expressed as mg of cyanidin-3-glucoside equivalents per liter of fruit juice.

Antioxidant capacity were determined with three different method including β carotene bleaching, FRAP (Ferric reducing antioxidant power) and TEAC (Trolox equivalent antioxidant capacity).

β -carotene bleaching method which, described by Kaur and Kapoor (2002). Briefly, 4 ml of β -carotene solution (0.1 mg in 1 ml chloroform), 40 mg of linoleic acid and 400 mg of Tween 40 were transferred to a round-bottom flask. The mixture was then evaporated at 50 °C by means of a rotary evaporator to remove chloroform. Then, 100 ml of oxygenated distilled water were added slowly to the residue and vigorously agitated to give a stable emulsion. Then, 800 μ l of extracts were added to 3 ml aliquots of β -carotene/linoleic acid emulsion. As soon as the emulsion was added to each tube, the zero time absorbance was measured at 470 nm using a spectrophotometer (T60V PG Instruments Ltd). Butylated hydroxyanisole (BHA) was used as a standard. All samples were assayed in triplicate. Degradation rate (DR) was calculated according to first order kinetics, using the following equation based on:

$$\ln\left(\frac{a}{b}\right) \times \frac{1}{t} = DR_{\text{sample}} \text{ or } DR_{\text{standart}}$$

Where \ln is natural log, a is the initial absorbance (470 nm) at time 0, b is the absorbance (470 nm) at 100 min and t is time. Antioxidant activity (AA) was expressed as percent of inhibition relative to the control, using the following formula:

$$AA = \left(DR_{\text{control}} - DR_{\text{sample}} \text{ or } \frac{\text{standart}}{DR_{\text{control}}} \right)$$

In FRAP (Ferric reducing ability of plasma) assay, 2.95 mL aliquot of a FRAP reagent, a mixture of 0.1 mol/L acetate buffer, 10 mmol/L TPTZ (2,4,6-tris(2-pyridyl)-1,3,5-triazine),

and 20 mmol/L ferric chloride (10:1:1 v/v/v), were combined with 50 μ L of acetone fruit extract. These solutions were prepared and stored in the dark under refrigeration. Stock solutions were combined (10:1:1 v/v/v) to form the FRAP reagent just prior to analysis. For each assay laboratory duplicate, 2.98 mL of FRAP reagent and 20 μ L of sample extract were mixed. After 10 min, the absorbance of the reaction mixture was determined at 593 nm in a spectrophotometer. The antioxidant capacity values were expressed as mmol trolox equivalent per liter of fruit juice (Benzie and Strain 1996).

For the standard trolox equivalent antioxidant capacity (TEAC) assay, ABTS was dissolved in acetate buffer and prepared with potassium persulfate, as described by Ozgen et al. (2006). The mixture was diluted in acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm for longer stability (Ozgen et al. 2006). For the spectrophotometric assay, 2.98 mL of the ABTS solution and 20 μ L of fruit extract were mixed and incubated for 10 min and the absorbance was determined at 734 nm. The antioxidant capacity values were expressed as mmol trolox equivalent per liter of fruit juice.

Statistical Analysis

All data were analyzed using SPSS software and procedures. Analysis of variance tables were constructed using the Least Significant Difference (LSD) method at $p < 0.01$.

Results and Discussion

Physicochemical Characteristics

The results indicated that there were significant differences among barberry genotypes for most of fruit physicochemical characteristics (Table 1 and 2). Peel color indices of the barberry genotypes are presented in Table 1. The lightness (L), the greenness (a) and the yellowness (b) for peel varied from 9.70 ('Coruh-3') to 14.10 ('Coruh-1'), 3.14 ('Coruh-4') to 6.15 ('Coruh-14') and 1.85 ('Coruh-13') to 4.41 ('Coruh-14') among genotypes, respectively. L value of the barberry genotypes for fruit peel were found to be different from each other at $p < 0.01$, while a and b values of genotypes were found not to be different from each other at $p < 0.01$ (Table 1).

Previously Ozgen et al. (2012) showed genotype dependent peel color in fruits of barberry genotypes (*Berberis vulgaris* L.) grown in middle parts of Turkey ranged from 10.36–12.27 for L value, 3.28 to 4.94 for a value and 2.37 to 2.63 for b value and Ahmed et al. (2013) reported a wide variation on exterior color of barberry fruits belongs to *Berberis vulgaris* L. Akbulut et al. (2009) also reported average fruit color indices 17.05% for L value, 2.06 for a value and -0.20 for b value. Fruit skin color is also an effective indi-

Table 1 Plant growth habit, fruit shape and fruit skin colour indices of the tested barberry (*Berberis vulgaris* L.) genotypes

Genotypes	Plant growth habit	Fruit shape	L	a	b
Coruh-1	Upright	Ovate	14.10a	4.15 ^{NS}	1.87 ^{NS}
Coruh-2	Upright	Oblong	11.40ab	4.82	3.15
Coruh-3	Broad-spreading	Ovate	9.70b	5.05	2.45
Coruh-4	Upright	Ovate	12.15ab	3.14	2.67
Coruh-5	Pyramidal	Oblong	11.40ab	3.41	3.05
Coruh-6	Upright	Ovate	12.05ab	3.76	2.44
Coruh-7	Broad-spreading	Ovate	10.05ab	4.85	2.66
Coruh-8	Upright	Oblong	9.85b	6.12	3.40
Coruh-9	Upright	Ovate	9.90b	5.47	2.28
Coruh-10	Upright	Ovate	11.10ab	5.15	3.40
Coruh-11	Upright	Ovate	11.70ab	4.80	2.66
Coruh-12	Pyramidal	Oblong	10.80ab	3.45	2.18
Coruh-13	Upright	Ovate	10.40ab	3.80	1.85
Coruh-14	Broad-spreading	Ovate	11.65ab	6.15	4.41
Coruh-15	Upright	Ovate	1.85ab	4.33	3.10
Coruh-16	Pyramidal	Ovate	10.02ab	3.45	3.70
Coruh-17	Upright	Oblong	9.80b	5.67	3.05
Coruh-18	Upright	Ovate	11.12ab	4.85	2.76
Coruh-19	Upright	Ovate	11.19ab	3.96	2.84

Means within a column followed by the same letter are not significantly different at $p < 0.01$

NS Not Significant

cator of appearance, external quality and maturity in barberry fruits.

The average fruit mass values of barberry genotypes were determined between 0.087 g ('Coruh-4') and 0.361 g ('Coruh-8'). Previous studies conducted in Iran and Pakistan showed that average fruit mass of barberry (*Berberis vulgaris*) genotypes were 0.051–0.348 (Ardestani et al. 2013) and 0.115–0.122 g (Ahmed et al. 2013), respectively. Akbulut et al. (2009) reported average fruit mass in barberry as 0.070 g from Turkey. All those studies indicating that barberry genotypes grown different parts of the world differs each other in terms of fruit mass. This variability may be due to different growing conditions, genetic background, climate, geography, cultural applications and maturation stage.

The results showed significant differences ($p < 0.01$) among the barberry genotypes in terms of ash, acidity, pulp ratio, SSC and pH (Table 2). Ash content varied from 0.65 ('Coruh-5') to 0.93 ('Coruh-11'), acidity varied from 2.44% ('Coruh-4') to 3.11% ('Coruh-6'), pulp ratio varied from 65.4% ('Coruh-9') to 76.6% ('Coruh-6'), SSC varied from 17.40% ('Coruh-5') to 21.10% ('Coruh-6') and pH varied from 2.68 ('Coruh-12') to 3.26 ('Coruh-6'), respectively (Table 2).

Ardestani et al. (2013) reported average ash, acidity, SSC and pH values of barberry genotypes as 0.73%, 2.63%, 17.33% and 3.06, respectively which in agreement with our present results. Akbulut et al. (2009) reported average

Table 2 Physicochemical parameters of the tested barberry (*Berberis vulgaris* L.) genotypes

Genotypes	Fruit weight (g)	Ash (%)	Acidity (%)	Pulp ratio (%)	SSC (%)	pH
Coruh-1	0.172bc	0.68b	2.74ab	71.22ab	19.15bc	3.15a
Coruh-2	0.091d	0.81ab	3.01a	68.45ab	18.55de	3.22a
Coruh-3	0.160bc	0.88ab	2.66b	73.22ab	18.90cd	2.89b
Coruh-4	0.087d	0.79ab	2.44c	68.18ab	18.70d	2.80bc
Coruh-5	0.211bc	0.65b	3.07a	66.25ab	17.40e	3.20a
Coruh-6	0.112cd	0.91ab	3.11a	76.69a	21.10a	3.26a
Coruh-7	0.250b	0.88ab	2.68b	71.49ab	19.10c	2.90b
Coruh-8	0.361a	0.85ab	2.91ab	68.10ab	18.65de	2.85bc
Coruh-9	0.169c	0.70ab	2.70b	65.40b	20.00b	2.70bc
Coruh-10	0.181bc	0.79ab	3.00a	66.73ab	18.60de	3.08ab
Coruh-11	0.305ab	0.93a	2.85ab	71.36ab	20.40ab	2.90b
Coruh-12	0.105cd	0.90ab	2.79ab	70.88ab	20.05ab	2.68c
Coruh-13	0.097d	0.81ab	2.68b	68.39ab	19.10c	2.70bc
Coruh-14	0.218bc	0.85ab	2.91ab	68.78ab	19.05c	2.81bc
Coruh-15	0.205bc	0.80ab	2.86ab	71.10ab	18.60de	3.12a
Coruh-16	0.188bc	0.83ab	2.77ab	68.33ab	17.45e	3.18a
Coruh-17	0.180bc	0.88ab	2.69b	65.53b	18.85cd	2.93b
Coruh-18	0.110cd	0.90ab	2.88ab	68.74ab	18.50de	2.73bd
Coruh-19	0.093d	0.87ab	2.81ab	72.10ab	19.00bc	2.80bc

Means within a column followed by the same letter are not significantly different at $p < 0.01$

ash, pulp ratio, pH and acidity in barberry genotype grown in Turkey as 1.12%, 75.59%, 3.35 and 3.10, respectively. Ahmed et al. (2013) reported average pH, acidity and SSC in barberry genotypes between 3.13–4.43, 0.42–1.27% and 23.60–27.63%, respectively. Ozgen et al. (2012) reported SSC between 19.27–21.80% among 6 barberry genotypes. Genotypic effects might explain the significant differences in our study because all genotypes were grown in a single location and similar cultural and technical practices were applied.

Bioactive Content

The bioactive contents of the analyzed barberry genotypes are presented in Table 3. We found statistically significant differences in the level of total phenolic, total monomeric anthocyanin and antioxidant activity (in all three different methods) among the assayed genotypes ($p < 0.01$) (Table 3).

Total phenolic contents of barberry genotypes ranged from 2532 mg ('Coruh-9') to 3719 mg GAE per liter of fruit juice ('Coruh-11') (Table 3). It is clear that the genotypes strongly influenced the extent of total phenolic accumulation in barberry fruits in the study. Total phenolic content of barberry fruits were reported previously between 2565–3629 mg GAE per L among five barberry genotypes grown in middle part of Turkey (Ozgen et al. 2012). Motalleb et al. (2005) reported 3450 mg GAE per 100 g total phenolic content in barberry fruits. Our results were within these ranges and it can be concluded that besides other fruits,

Table 3 Bioactive content and antioxidant activity of the tested barberry (*Berberis vulgaris* L.) genotypes

Genotypes	Total phenolics (mg GAE per L)	Total anthocyanin (Cy-3-glu, mg per L)	Antioxidant activity		
			β -carotene (%)	TEAC (TE mmol per L)	FRAP (TE mmol per L)
Coruh-1	3392ab	418hij	85.18c	51.10ab	59.30ab
Coruh-2	2884cd	275k	77.88cde	40.80bc	57.40ab
Coruh-3	3431ab	430hi	86.55bc	54.20ab	66.28a
Coruh-4	3391ab	435hi	85.30c	50.18ab	55.40ab
Coruh-5	3590a	522fg	83.44cd	43.10bc	42.85bc
Coruh-6	3337b	782c	82.70cd	49.29ab	50.24b
Coruh-7	2883cd	706d	88.87bc	52.20ab	58.45ab
Coruh-8	3467ab	662e	89.89bc	55.02ab	66.45a
Coruh-9	2532d	969b	90.12b	56.10a	64.28ab
Coruh-10	2771cd	599f	83.67cd	48.50ab	49.76abc
Coruh-11	3719a	533fg	75.01e	39.40bc	38.76c
Coruh-12	3015bc	1004a	90.64b	44.41bc	43.20bc
Coruh-13	3058bc	709d	83.63cd	47.62b	51.10ab
Coruh-14	3035bc	271k	81.26cd	39.05c	42.10bc
Coruh-15	3487ab	427hij	88.41bc	53.20ab	62.43ab
Coruh-16	2782cd	445h	85.80c	52.40ab	56.15ab
Coruh-17	2911c	542g	84.37cd	43.10bc	42.85bc
Coruh-18	2841cd	351j	80.99d	41.15bc	39.62c
Coruh-19	3280bc	543g	78.44cde	43.18bc	46.47bc
BHA			94.10a		

Means within a column followed by the same letter are not significantly different at $p < 0.01$

barberry might be also a good source of total phenolics. The various factors such as genotype, agronomic practices, maturity level at harvest, postharvest storage, climatic and geographical locations affect the total phenolic content of horticultural plants (Rop et al. 2014; Milivojevic et al. 2012; Kunyanga et al. 2012).

In this experiment, the total monomeric anthocyanin contents were greatly differed among the barberry genotypes and varied from 271 mg to 1004 mg per liter of fruit juice as cyanidin 3-glycoside (Table 3). Results obtained for barberry genotypes indicate that barberry fruits are also a good source of anthocyanin, not only phenolic. Akbulut et al. (2009), Ardestani et al. (2013) and Motalleb et al. (2005) revealed that barberry fruits are rich source of anthocyanin. Ozgen et al. (2012) also reported total monomeric anthocyanin content between 506–803 mg per L as cyanidin 3-glycoside among five barberry genotypes sampled middle part of Turkey. Our data are in agreement with the reported anthocyanin content. The major anthocyanins found in fruits are cyanidin, peonidin, petunidin, malvidin, delphinidin and pelargonidin. Anthocyanins are not only known as non-toxic and non-mutagenic, but they have positive therapeutic properties such as antioxidant, anti-inflammatory, anticarcinogenic, antiviral, and antibacterial effects (Tall et al. 2004).

Total antioxidant activity of the nineteen barberry fruit extracts determined by three methods is shown in Table 3. The antioxidant capacity was highly differed among barberry genotypes in all three antioxidant-determining methods (Table 3).

In β -carotene bleaching method, BHA that used as the standard, had a higher antioxidant activity (94.10%) than all barberry fruit extracts. However most of the barberry genotypes had also relatively high antioxidant activity in this method compared to BHA. Total antioxidant activity of barberry genotypes ranged from 75.01% ('Coruh-11') to 90.64% ('Coruh-12'). As shown in Table 3, there were significant differences ($p < 0.01$) among the genotypes. Total antioxidant activity for genotype 'Coruh-12', 'Coruh-9', 'Coruh-8', 'Coruh-7' and 'Coruh-15' had 90.64%, 90.12, 89.89, 88.87 and 88.41%, respectively. Motalleb et al. (2005) found that total antioxidant activity of barberry fruits determined by β -carotene bleaching method ranged from 73.62 to 82.52%, which indicate close similarity with our study.

The total antioxidant capacity of barberry fruit extracts was quantified by two methods (FRAP and TEAC) and we found significant differences among genotypes by using both methods ($P < 0.01$). The genotype 'Coruh-9', 'Coruh-8' and 'Coruh-3' and 'Coruh-15' showed the higher total antioxidant capacity in both TEAC and FRAP methods. 'Coruh-9', 'Coruh-8' and 'Coruh-3' and 'Coruh-15' genotypes had 56.10, 55.02, 54.20 and 53.20 expressed as Trolox equivalent mmol per liter fruit juice in TEAC method and these values were 66.45, 66.28, 64.28 and 62.43 for 'Coruh-8', 'Coruh-3' and 'Coruh-9' and 'Coruh-15' genotypes expressed as Trolox equivalent mmol per liter fruit juice in FRAP method (Table 3). Our total antioxidant capacity results were similar to the data reported by Ozgen et al. (2012).

The antioxidant effect of fruits is mainly due to phenolic compounds and anthocyanins. Many of these phytochemicals have significant antioxidant activities that may be associated with lower incidence and lower mortality rates of cancer in human. The antioxidant activity of phenolic compounds is due to their redox properties. These components can play an important role in absorbing and neutralizing free radicals, quenching singlet and triplet oxygen, or decomposing peroxides. Antioxidant compounds can delay or inhibit the oxidation of lipids or other molecules by inhibiting the initiation or propagation of oxidative chain reactions (Javanmardi et al. 2003).

Conclusion

The study highlighted the composition of bioactive compounds varied among barberry fruit extracts analyzed which influenced their antioxidant activity. This study showed that phenolics and anthocyanins were the most abundant com-

pounds present in the barberry fruit peel. Present study also showed that *Berberis vulgaris* fruits had the most promising antioxidant agent as potent as the synthetic antioxidants BHA. Thus, results of the present study supported the antioxidant and nutraceutical potential of this plant species. However, further studies of the antioxidative components of barberry fruits are required, especially identification and quantification of individual phenolic compounds.

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