ISSN 1644-0692
www.acta.media.pl

ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 14(1) 2015, 83-93*

PHYSICO-CHEMICAL AND BIOLOGICAL ACTIVITY OF HAWTHORN (*Crataegus* spp. L.) FRUITS IN TURKEY

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Abstract. Hawthorn (*Crataegus* spp. L.) is a native fruit of great economic importance in Turkey and has been widely using in folk medicine particularly for the treatment of mild heart diseases for a long time. In the study, 18 previously selected hawthorn genotypes belong to several *Crataegus* species grown in the hawthorn repository collection in Malatya province in Turkey were evaluated. Fruit mass and soluble solid content of selected genotypes ranged from 0.76 to 4.27 g and 6.71 to 15.83%, respectively. The genotype 44MA12 belongs to *C. monogyna* subsp. *azarella* had distinct and the highest anthocyanin (516 mg per 100 g fresh fruit) content and the strongest 1,1-diphenyl-2-picrylhydrazyl radical scavenging capacity (2.91 $\mu g \cdot g^{-1}$). The genotype 44MA11 belongs to *C. meyeri* had the highest phenolic content (3460 mg per 100 g gallic acid equivalent in fresh fruits). All hawthorn genotypes displayed high antioxidant activity. The results suggest that hawthorn fruits including significant human health benefit substances and may be used for developing functional foods because of its high phenolic, anthocyanin content and antioxidant properties.

Key words: Hawthorn, *Crataegus* spp., biochemical diversity, genotypic variation, fruit mass, anthocyanin

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INTRODUCTION

In last decade, a lot of scientific studies indicated that consumption of horticultural crops including fruits, vegetables and grapes plays a vital role in the prevention and treatment of various diseases due to their rich polyphenol content [Khan and Mukhtar 2007, Naruszewicz et al. 2007, Scalbert et al. 2005, Voca et al. 2010].

Throughout history, wellness enthusiasts have celebrated the medicinal potential of plants, looking to these botanical allies to promote vitality and restore good health. Modern science has borne out these theories, showing that in particular horticulture plants are to be valued not only for their high vitamin and fiber content but also for their rich store of polyphenols-antioxidant compounds that give plants some of their color, flavor, and healing qualities [Voca et al. 2009, Ercisli et al. 2012, Kostic et al. 2013a].

In the last decade, there has been much interest in the potential health benefits of dietary plant polyphenols as antioxidant [Voca et al. 2008, Hegedus et al. 2011, Kostic et al. 2013b]. Epidemiological studies and associated meta-analyses strongly suggest that long term consumption of diets rich in plant polyphenols offer protection against development of cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases [Pandey and Rizvi 2009].

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. These fruits have the potential to provide nutrients, in particular, to rural households, that may help to meet their nutritional needs [Egea et al. 2010, Ercisli et al. 2012]. Cultivation and consumption of indigenous fruits could reduce malnutrition and poverty in rural peoples worldwide.

Turkey is rich in a variety of wild edible fruits including hawthorn and these fruits have been an important component in the traditional diets since the beginning of human occupation of the Anatolia peninsula. The Malatya province, located in east part of the country, is especial rich in hawthorn species. Hawthorn fruits make an important contribution to local communities' health and welfare in Malatya [Ercisli 2004].

The hawthorn (*Crataegus* spp.) is represented by 150–120 species in the world It is usually multi-branched ranged from shrubs to small trees even normal size trees can reach a height of up to 10 m. The number of *Crataegus* species in Turkey is estimated 19 [Christensen 1992]. It is one of the native plants of Turkey's flora and prefers the forest margins of lower and warmer areas.

Hawthorn fruit refers to the bright colored fruits of *Crataegus* species and are a rich source of flavonoids, vitamin C, glycoside, anthocyanin's, saponin and tannin [Ljubuncic et al. 2005, Kostic et al. 2012]. Fruits are usually eaten fresh. All *Crataegus* species found in Turkey have long been used in folk medicine to treat human some diseases [Ercisli 2004]. Many species are used as ornamentals. In arid regions the trees are planted in forest belts and windbreaks. The trees are suitable as frost-resistant rootstocks for pear and quinces. Fruits ripen in late summer and are highly attractive to birds, which consume the fruit and disperse the seeds. There is a great variation in terms of fruit color of *Crataegus* species distributed in Turkey. For instance, *C. pentagyna* has black or blackish-purple fruit, *C. tanacetifolia* yellow, sometimes suffused with red, *C. orientalis* reddish-orange, *C. pontica* yellow to orange, *C. atrosanguinea* deep red,

C. curvisepala dark purple, *C. stevenii* red, *C. monogyna* red or brownish-red and *C. microphylla* bright red [Browicz 1972].

Previously limited number and randomly sampled hawthorn genotypes from different locations that strongly open environmental effect in Turkey have been used to determine bioactive content and antioxidant activity. However, in this study, we used previously selected a large number of hawthorn genotypes (cultivar candidates) and all cultivar candidates were grown in a single collection parcel in Malatya with environment free conditions.

MATERIAL AND METHODS

Plant material. A total of 18 hawthorn genotypes were used in this study (tab. 1). These genotypes previously selected from a wide natural growing area in Malatya region of Turkey by Malatya Fruit Research Station according to selection criteria such as high yield, attractive fruits and free of pest and disease characteristics. According to long-term data, Malatya region has 12.6ºC annual average temperature, and 495 mm annual precipitation. Fruits were sampled from hawthorn genotypes in 2012 year. The hawthorn species identified by senior taxonomist Tuncer Taskin from Celal Bayar University in Turkey.

Table 1. Plant form, thorn, fruit skin color and fruit shape index of the tested hawthorn (*Crataegus spp.*) genotypes

Genotypes	Species	Plant form	Thorn	Fruit color	Fruit shape index
44MA1	*C. tanacetifolia*	tree	medium	yellow	oblate
44MA2	*C. azarolus* var. *dentata*	tree	thornless	red	oblate
44MA3	*C. azarolus* var. *aronia*	tree	dense	orange	oblate
44MA4	*C. pontica*	tree	medium	orange	oblate
44MA5	*C. azarolus* var. *aronia*	tree	medium	orange	oblate
44MA6	*C. pontica*	tree	thornless	orange	oblate
44MA7	*C. meyeri*	tree	medium	red	oblate
44MA8	*C. azarolus* var. *dentata*	tree	thornless	red	oblate
44MA9	*C* × *bornmuelleri*	tree	few	red	oblong
44MA10	*C. pontica*	tree	thornless	light orange	oblate
44MA11	*C. meyeri*	tree	dense	red	oblate
44MA12	*C. monogyna* subsp. *azorella*	shrub	few	dark red	oblong
44MA13	*C. pontica*	tree	thornless	yellow	oblate
44MA14	*C* × *bornmuelleri*	tree	medium	yellow	oblate
44MA15	*C. pseudoheterophylla*	shrub	few	dark red	oblong
44MA16	*C* × *bornmuelleri*	tree	few	red	oblate
44MA17	*C. curvisepala*	tree	medium	dark pink	round
44MA18	*C. azarolus* var. *aronia*	tree	medium	yellow	oblate

Determination of physico-chemical characteristics. Hawthorn fruits were harvested from eighteen genotypes at fully maturates stage from hawthorn repository collection in Malatya. Approximately 1 kg fully matured, fresh hawthorn fruits were hand harvested and transferred to laboratory for analysis. For fruit mass, dimensions, flesh/seed ratio and color measurements, a total 60 fruits (3 replicates) were used. Fruit mass each fruit were measured with an electronic balance of 0.01 g sensitivity. Fruit external color was determined by visible means. To determine flesh/seed ratio, first the fruits are cut and flesh separated from seeds. Both parts weighted separately then divide each component to determine the ratio of flesh/seed ratio. Fruit shape index was calculated by the average length/width ratio on 60 fully ripe hawthorn fruits for each genotype. About 300 g of fruit samples for each genotype were frozen at -20ºC. At the time of analysis, fruits were thawed and homogenized in a standard food blender. Slurries were used to determine bioactive content, soluble solid content (SSC) determined by refractometer (Model RA-250HE, Kyoto Electronics Manufacturing Co. Ltd., Japan) and for levels of pH using standard methodology [AOAC 2005]. Some plant characteristics such as plant form and thorn situation were also determined to compare genotypes each other.

Determination of bioactive compounds and biological activity. For the extraction and determination of total phenolic content, a single extraction procedure was designed to assay phenols [Bartolome et al. 1995]. For each replicate, a 3 g aliquot of slurry was transferred to polypropylene tubes and extracted with 20 mL of extraction buffer containing acetone, water, and acetic acid (70:29.5:0.5, v/v) for 2 h. After filtration, acetone was removed by rotary evaporation, after which the concentrated samples were brought to a final volume of 20 mL with deionised water. Next, Folin-Ciocalteu's phenol reagent and water were incubated for 8 min, followed by the addition of 7% sodium carbonate. After 2 h, the absorbance was measured by an automated UV–VIS spectrophotometer at 750 nm. Gallic acid was used as standard. The results were expressed as µg gallic acid equivalents on per g fresh mass (mg GAE·100 g^{-1} FW).

Total antioxidant activity was estimated by two standard procedures: β-carotene bleaching and DPPH assays.

β-carotene bleaching assay was described by Kaur and Kapoor [2002]. Briefly, 4 ml of β-carotene solution (0.1 mg in 1ml 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 µl 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. 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:

$$\ln (a/b) \times 1/t = DR_{sample} \text{ or } Dr_{standard}$$

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:

$$AA = (DR_{control} - DR_{sample \text{ or } standard}/DR_{control}) \times 100.$$

Free radical scavenging activity was determined according to the method of Suja et al. [2005] with slight modifications. Fruit extract (1 mL) was added to 2 mL DPPH solution (2 mL of 0.02 $g \cdot L^{-1}$ DPPH) in ethanol. The reduction of DPPH was measured at 517 nm against a blank assay for 30 min. The percentage of the remaining radical in medium is calculated as the absorbance of the sample divided by that of DPPH control at the same time multiplied by 100. The amount of sample needed to decrease the initial DPPH concentration by 50%, EC_{50}, was calculated graphically. The results were expressed as μmol on g fresh weight.

Total monomeric anthocyanins (TMA) were determined by the pH differential method [Giusti and Wrolstad 2001] using a UV-VIS spectrophotometer. Absorbance was measured at 533 nm and 700 nm in buffers at pH 1.0 and 4.5 using A = (A533–A700) pH 1.0 – (A533–A700) pH 4.5 with a molar extinction coefficient of 29,600. Total anthocyanin content was expressed as mg cyanidin-3-glucoside equivalent in 100 g FW.

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

Physico-chemical characteristics. Table 1 indicates plant form, thorn, fruit skin color and fruit shape index of the tested hawthorn (*Crataegus* spp.) genotypes. As shown in Table 1, 18 hawthorn genotypes were belongs to 7 *Crataegus* species (*C. tanacetifolia*, *C. curvisephala*, *C. azarolus* var. *aronaria*, *C. azarolus* var. dentata, *C. pontica*, *C. meyeri*, *C. monogyna* subsp. *azorella*, *C* × *bornmuelleri*, and *C. pseudoheterophylla*) and this result imply the importance of Malatya region for *Crataegus* diversity. Previously Turkoglu et al. [2005] reported *C. orientalis*, *C. curvisephala*, *C. monogyna* subsp. *monogyna*, *C. monogyna* subsp. *azorella* and *C. pentagyna* in Van region of eastern Turkey. Fruit species diversity is a popular and hot topic in fruit breeding research because they are ready material for breeding and they have also benefits for ecosystem function. Among the species, *C. monogyna* subsp. *azorella* and *C. pseudoheterophylla* had shrub plant form distinguished from the rest of the tree formed species by its multiple stems and shorter height, usually less than 6 m tall. There were differences among genotypes on external fruit color as well which were light yellow, yellow, light orange, orange, dark pink, red and dark red (tab. 1). The yellow fruit skin colour is not favourable by consumers. The plants of genotypes 44MA2, 44MA6, 44MA8, 44MA10 and 44MA13 did not have thorn while the genotypes 44MA3 and 44MA13 had dense thorn on plants. The rest of genotypes showed intermediate (few or medium

thorns on plant). The genotypes are also differed each other for fruit shape index. The majority of genotypes had oblate fruit shape index (14 genotypes) and 3 genotypes were found in oblong shape index and only one genotype was round shape (tab. 1). Fruit shape is one of the most important physical properties and quality parameters of horticultural crops. To determine fruit shape is also important for discriminate cultivars each other easily if they grown same ecological conditions. Fruit shape also affects consumer behavior.

Table 2 indicates fruit mass, flesh/seed ratio, soluble solid content (SSC) and pH of 18 hawthorn cultivar candidates. The results indicated that there were significant differences among hawthorn genotypes for all fruit physicochemical characteristics (tab. 2). Fruit mass of all hawthorn genotypes tested in this study ranged from 0.76 g (44MA15) to 4.27 g (44MA14), respectively. Previously, Balta et al. [2006] reported fruit mass between 1.36 g (*C. meyeri*) and 4.99 g (*C. tanacetifolia*). The authors also found average fruit mass in the other *Crataegus* species as; *C. orientalis* (3.48 g), *C. pontica* (3.31 g) and *C. aronia* (2.63 g), respectively. The findings of the present study are consistent with those of Balta et al. [2006].

Table 2. Fruit mass, flesh/seed ratio, soluble solid content (SSC) and pH of the tested hawthorn (*Crataegus* spp.) genotypes

Genotypes	Species	Fruit mass (g)	Flesh/seed ratio (%)	SSC (%)	pH
44MA1	*C. tanacetifolia*	3.21de	4.18bc	6.71cd	2.94ab
44MA2	*C. azarolus* var. *dentata*	2.31h	4.34bc	15.83a	2.88b
44MA3	*C. azarolus* var. *aronia*	2.51g	4.47bc	7.41c	3.07ab
44MA4	*C. pontica*	3.78c	3.61bc	9.49bc	3.31ab
44MA5	*C. azarolus* var. *aronia*	4.09b	4.75bc	8.56bc	3.02ab
44MA6	*C. pontica*	2.80f	6.38b	8.11bc	3.07ab
44MA7	*C. meyeri*	1.81jk	5.03bc	8.04bc	3.65ab
44MA8	*C. azarolus* var. *dentata*	1.65k	5.60bc	7.83c	3.31ab
44MA9	*C* × *bornmuelleri*	1.24m	5.83bc	7.71c	3.40ab
44MA10	*C. pontica*	3.03e	3.71bc	9.67bc	3.10ab
44MA11	*C. meyeri*	1.56k	3.65bc	11.95b	3.22ab
44MA12	*C. monogyna* subsp. *azorella*	1.02n	9.14a	8.27bc	3.60a
44MA13	*C. pontica*	2.91ef	3.31c	8.94bc	3.28ab
44MA14	*C* × *bornmuelleri*	4.27a	4.40bc	8.51bc	3.35ab
44MA15	*C. pseudoheterophylla*	0.76o	5.33bc	9.64bc	3.51ab
44MA16	*C* × *bornmuelleri*	1.45lm	4.65bc	8.65bc	3.06ab
44MA17	*C. curvisephala*	3.98bc	4.38bc	8.05bc	3.02ab
44MA18	*C. azarolus* var. *aronia*	2.11i	4.46bc	14.85ab	2.95b

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

For the fresh fruit market flavor and appearance are still basic determinants for the acceptance of the fruit and the popularity of the cultivars. In addition, the importance of fruit size as a parameter of quality has increased markedly in recent times. This is reflected in the changes in the legal regulations that have risen recently in minimum diameter to accept a fruit as marketable in the European markets. Further, the consumer's preference for big fruit determines huge differences in market price to a point that the income from the smaller, albeit marketable, fruit is often lower than the actual costs of production and commercialization. Fruit size has become as important as total yield in the determination of the profitability of the hawthorn.

Soluble solid content and pH of 18 hawthorn genotypes were found between 6.71 (44MA1) to 14.85% (44MA2) and 2.88 (44MA2) and 3.60 (44MA12), respectively (tab 2). Most of the hawthorn genotypes had SSC content between approximately 7.00 to 9.00% (tab. 2). In some studies conducted in different region of Turkey, total soluble solids and pH values of hawthorn genotypes were ranged from 11.66–24.00% and 3.12–4.09, respectively [Ozcan et al. 2005, Turkoglu et al. 2005, Balta et al. 2006]. The difference among studies could be effects of environmental conditions, plant species etc.. However in our study was conducted in common environment conditions, therefore the difference among genotypes is natural results of genotypic effect.

Flesh/seed ratio in 18 hawthorn genotypes is shown in Table 2. For the 18 hawthorn genotypes, flesh/seed ratio ranged from 3.31 (44MA13, belongs to *C* × *bornmuelleri*) to 9.14 (44MA12, belongs to *C. monogyna* subsp. *azorella*). This is not surprising because *C. monogyna* subsp. *azorella* has only a single seed in its fruits that explain high flesh/seed ratio. Turkoglu et al. [2005] reported flesh/seed ratio among hawthorn genotypes were between 4.82 and 9.69 which in agreement with our current results. Higher fruit weight along with higher flesh ratio is the most important desirable fruit characteristics in hawthorn breeding programmes [Ercisli 2004].

Biological activity. The bioactive contents of the analyzed hawthorn genotypes are presented in Table 3. As shown in Table 3, statistically significant differences in the level of total phenolic, total monomeric anthocyanin and antioxidant activity (in both assays) among genotypes were recovered ($p < 0.01$).

We examined the total phenolic content of 18 hawthorn genotypes and the total phenolic content of all hawthorn genotypes tested in this study ranged from 660 (44MA5, *C. azarolus* var. *aronia*) to 3460 mg (44MA11, *C. meyeri*) gallic acid equivalent per 100 g fresh fruits. In general genotypes that has dark red and red fruit color had higher phenol content. It is clear that the genotypes, in particular species, strongly influenced the extent of total phenolic accumulation in hawthorn fruits in the study. Kostic et al. [2012] used methanol extract and reported average 1831 mg GAE per 100 g total phenolic content in fresh fruit of *Crataegus oxyacantha* grown in Serbia. Bahri-Sahloul et al. [2009] used 14 hawthorn genotypes belong to *C. azarolus* and *C. oxyacantha* and they found that the concentration of phenols showed great variation ranged from 499–1477 mg per 100 g fresh fruit. They also found that red fruits had higher phenol content than yellow fruits. Bignami et al. [2003] also reported phenol content in *C. azaroles* genotypes between 400–600 mg per 100 g fresh weight basis. Our results were close these ranges and it can be concluded that besides other small fruits, hawthorn also a good source of total phenolics. Phenolic compounds are considered major con-

tributors to the antioxidant activity of edible fruits. The various factors such as species, genotype, agronomic practices, maturity level at harvest, postharvest storage, climatic and geographical locations affect the total phenolic content of horticultural plants [Hegedus 2008, Kostic et al. 2013b].

Table 3. Total phenolic, total monomeric anthocyanin and antioxidant activity of the tested hawthorn (*Crataegus* spp.) genotypes

Genotypes	Species	Total phenolic content (mg GAE ·100 g^{-1} FW)	Total anthocyanin (mg cya-3-glu. equiv. in 100 g FW)	β-carotene bleaching assay (%)	DPPH (µmol·g^{-1} FW)
44MA1	*C. tanacetifolia*	2130e	113d	80.38d	14.23de
44MA2	*C. azarolus* var. *dentata*	1870f	2f	74.80efg	56.96ab
44MA3	*C. azarolus* var. *aronia*	3270b	14f	85.10c	32.68c
44MA4	*C. pontica*	1390g	5f	79.05de	46.60b
44MA5	*C. azarolus* var. *aronia*	660h	1f	58.10f	55.02ab
44MA6	*C. pontica*	2150e	11f	78.01de	49.19ab
44MA7	*C. meyeri*	2750cd	108de	77.40de	23.62d
44MA8	*C. azarolus* var. *dentata*	2300de	1f	79.10de	47.47bc
44MA9	*C* × *bornmuelleri*	3160bc	266b	75.30e	40.12bc
44MA10	*C. pontica*	2560d	8f	73.40de	6.15ef
44MA11	*C. meyeri*	3460a	103e	80.10d	13.26e
44MA12	*C. monogyna* subsp. *azorella*	2810c	516a	78.80def	2.91f
44MA13	*C. pontica*	1910f	5f	84.27bc	28.15cd
44MA14	*C* × *bornmuelleri*	2150e	8f	77.90de	57.61a
44MA15	*C. pseudoheterophylla*	3350ab	223c	90.83b	7.12ef
44MA16	*C* × *bornmuelleri*	1580fg	1f	85.10c	42.71bc
44MA17	*C. curvisephala*	3250b	12f	81.87bcd	28.80cd
44MA18	*C. azarolus* var. *aronia*	3250b	4f	78.08de	43.61bc
BHA	*C. tanacetifolia*			97.40a	

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

In this experiment, the total monomeric anthocyanin contents were greatly differed among the hawthorn genotypes and varied from 1 mg to 516 mg per 100 g of fruit juice as cyanidin-3-glycoside (tab. 3). Results obtained for hawthorn genotypes indicate that anthocyanin content greatly varied among hawthorn species. For example the genotype 44MA12 belongs to *C. monogyna* subsp. *azorella* had dark red color not only on peel but also in pulp. The distinctive dark flesh color of this species is due to the presence of anthocyanins in inside cells. The other red fruit bearing species had red color only in peel. Kostic et al. [2012] reported 3 mg anthocyanin in 100 g *C. oxyacantha* fruits in Serbia. Bahri-Sahloul et al. [2009] reported that yellow *C. azarolus* did not include anthocynins and they also implied that *C. monogyna* is rich in terms of anthocyanins. They also used *C. oxyacantha* and found that the concentration of phenols showed great variation ranged from 499–1477 mg per 100 g fresh fruit among genotypes of this species. They also found that red fruits had higher phenol content than yellow fruits. Froehlicher et al. [2009] also reported high anthocyanin content in *C. monogyna* fresh fruits.

Total antioxidant activity of the hawthorn genotypes determined by β-carotene bleaching and DPPH assays are shown in Table 3. The antioxidant capacity was highly differed among hawthorn genotypes in both antioxidant-determining methods (tab. 3).

In β-carotene bleaching method, BHA that used as the standard, had a higher antioxidant activity (97.40%) than all hawthorn fruit extracts. However most of the hawthorn genotypes had also relatively high antioxidant activity in this method compared to BHA. Total antioxidant activity of hawthorn genotypes ranged from 68.10% (44MA5) to 90.83% (44MA15). Bahri-Sahloul et al. [2009] found that total antioxidant activity of red colored *Crataegus* fruits determined by β-carotene bleaching method was 82.73%, which indicate close similarity with our study. Kostic et al. [2012] also reported that *C. oxyacantha* has strong antioxidant activity due to its high bioactive content.

In DPPH assay, the genotype 44MA12 belongs to *C. monogyna* subsp. *azarella* had distinct and the strongest 1,1-diphenyl-2-picrylhydrazyl radical scavenging capacity (2.91 $\mu g \cdot g^{-1}$). The genotype 44MA10 belongs to *C. pontica* and 44MA15 belongs to *C. pseudoheterophylla* also had strong 1,1-diphenyl-2-picrylhydrazyl radical scavenging capacity (6.15 and 7.12 $\mu g \cdot g^{-1}$, respectively). The antioxidant activity studies on *Crataegus* species have exhibited that these species possess considerable antioxidant potential due to their polyphenolic compounds such as flavonoids [Ljubuncic et al. 2005, Kostic et al. 2012] also found that extracts of *Crataegus aronia syn. azarolus*, the indigenous hawthorn used in Arabic traditional medicine, possesses considerable antioxidant potential and is not cytotoxic. They also proposed the therapeutic benefit of extracts prepared from the indigenous *Crataegus aronia* species is linked to effective inhibition of oxidative processes, efficient scavenging of O_2^- and possible increase in the biosynthesis of the intracellular antioxidant glutathione.

CONCLUSIONS

Our results indicate that the physico-chemical properties, total phenol and total anthocyanin content and antioxidant activity of hawthorn genotypes belongs to different species were very variable. Statistically significant differences are recovered all searched parameters. The genotypes 44MA4, 44MA5, 44MA14 and 44MA17 had bigger fruits. 44MA12 had distinct higher flesh/seed ratio and genotypes 44MA2 and 44MA18 had high SSC content. 44MA11, 44MA12 and 44MA15 were found to be high total phenolic content, total anthocyanin and antioxidant activity, respectively. To our knowledge, this is the first comprehensive study investigated for biological activity of enough number of hawthorn genotypes. This activity appears to underlie the potential utility of hawthorn as an edible fruit and offers remarkable prospects for the prevention of oxidative stress and suggesting that it might be developed into functional foods in the future.

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FIZYKOCHEMICZNA I BIOLOGICZNA AKTYWNOŚĆ OWOCÓW GŁOGU (*Crataegus* spp. L.) W TURCJI

Streszczenie. Głóg (*Crataegus* spp. L.) jest w Turcji rodzimym gatunkiem owocodajnym o dużym znaczeniu gospodarczym, który od dawna jest szeroko stosowany w medycynie ludowej, zwłaszcza w leczeniu łagodnych chorób serca. Niniejsze badanie oceniało 18 wcześniej wyselekcjonowanych genotypów głogu należących do kilku gatunków *Crataegus* i rosnących w kolekcji repozytorim głogu w prowincji Malatya w Turcji. Masa owoców i zawartość rozpuszczalnych substancji stałych wahała się odpowiednio od 0,76 do 4,27 g oraz od 6,71 do 15,83%. Genotyp 44MA12 należący do *C. monogyna* subsp. *Azarella* miał wyraźną i największą zawartość antocyjan (516 mg na 100 g świeżych owoców) oraz najsilniejszą (1,1-difenyl-2-pikrylhydrazyl) zdolność pochłaniania rodników (2,91 $\mu g \cdot g^{-1}$). Należący do *C. meyeri* Genotyp 44MA11 miał największą zawartość fenoli (3460 mg na 100 g ekwiwalentu kwasu galusowego w świeżych owocach). Wszystkie rośliny głogu wykazywały wysokie działanie antyoksydacyjne. Na podstawie wyników można wywnioskować, że owoce głogu zwierają istotne substancje korzystne dla ludzkiego zdrowia i mogą być stosowane do wytwarzania żywności funkcjonalnej z powodu wysokiej zawartości fenoli i antocyjan oraz właściwości antyoksydacyjnych.

Słowa kluczowe: głóg, *Crataegus* spp., różnorodność biochemiczna, zróżnicowanie genetyczne, masa owoców, antocyjany

Accepted for print: 4.11.2014

For citation: Ercisli, S., Yanar, M., Sengul, M., Yildiz, H., Topdas, E.F., Taskin, T., Zengin, Y., Yilmaz, K.U. (2015). Physico-chemical and biological activity of hawthorn (*Crataegus* spp. L.) fruits in Turkey. Acta Sci. Pol., Hortorum Cultus, 14(1), 83–93.