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Evaluation of Pomological Characteristics and Bioactive Compounds of Wild Sea Buckthorn (*Hippophae Rhamnoides* L.) and Hawthorn (*Crataegus songarica*) from Walnut-Fruit Forest Kyzyl-Unkur, Kyrgyzstan

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ABSTRACT
There are different berries and fruits naturally growing in the walnut-fruit forests of Kyrgyzstan, however, their composition and bioactive compounds have not been studied. This study aims to contribute to the limited literature on dietary fibres, ash, bioactive compounds such as vitamin C, polyphenols, antioxidant activity, and physical parameters of wild sea buckthorn (*Hippophae rhamnoides* L.) and hawthorn (*Crataegus songarica*) from walnut-fruit forests of Kyrgyzstan. The standard food analysis techniques and DPPH assay were used to determine the nutritional composition and antioxidant activity of the samples, respectively. The total amount of polyphenols in the extracts was determined by the Folin-Ciocalteau micro method. The content of vitamin C in fresh sea buckthorn was higher than in hawthorn, but hawthorn has advantages in terms of the amount of phenolic compounds and antioxidant activity. Both studied species have high nutritional values and are recommended to be used in the diet to improve the food security of the local population.

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Kırgızistan Kyzyl-Unkur Ceviz-Meyve Ormanından Yabani İğde (*Hippophae Rhamnoides* L.) ve Alıcın (*Crataegus songarica*) Pomolojik Özelliklerinin ve Biyoaktif Bileşiklerinin Değerlendirilmesi

ÖZET
Kırgızistan'ın ceviz-meyve ormanlarında doğal olarak yetişen farklı meyveler vardır, ancak bunların bileşimi ve biyoaktif bileşenleri araştırılmamıştır. Bu çalışma, ceviz-meyve ormanındaki yabani iğdesi (*Hippophae rhamnoides* L.) ve alıcın (*Crataegus songarica*) C vitamini, polifenoller, antioksidan aktivite gibi biyoaktif bileşenleri, diyet lifleri, kül ve fiziksel parametreleri hakkinda sınırlı literatüre katkıda bulunmayı amaçlamaktadır. Standart gıda analiz yöntemleri yabani bitkilerin bileşimini ve antioksidan aktiviteyi belirlemek için DPPH analizi kullanılmıştır. Ekstraktlardaki toplam polifenol miktarı Folin-Ciocalteau mikro yöntemi ile belirlenmiştir. Taze deniz iğdesindeki C vitamini içeriği alıçtan daha yüksektir, ancak alıç, fenolik bileşik miktarı ve antioksidan aktivite açısından avantajlıdır. İncelenen her iki türün de yerel nüfusun gıda güvenliğini artırmak için beslenmede kullanılması önerilmektedir.

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INTRODUCTION

Wild berries are natural food sources with high nutritional value and can help for enhancing food security (Powell et al., 2015). The natural and climatic conditions of Kyrgyzstan allow the growth of numerous wild fruit trees and shrubs in forests and high mountains.

Sea buckthorn (*Hippophae rhamnoides* L.) is a thorny shrub that grows widely on the sea and river coasts of Kyrgyzstan. All parts of sea buckthorn contain about 200 bioactive components, including flavonoids, phenolic compounds, tocopherols, fatty and organic acids, fats, vitamins (A, E, K, C, B_1, and B_2), amino acids, terpenes, tannins, and microelements (Kumar et al., 2011). Sea buckthorn is recommended for the prevention and treatment of cardiovascular diseases due to its high polyphenol content (Cheng et al., 2003; Skalski et al., 2019). In addition, sea buckthorn seed oil extracts are known to have significant anti-atherogenic and cardioprotective effects, as well as positive effect on atherosclerosis (Basu et al., 2007), acute alcohol intoxication (Wen et al., 2016), burn wound (Ito et al., 2014; Koskovac et al., 2017), depression (Tian et al., 2015) etc. In Kyrgyz folk medicine, sea buckthorn is used to treat diseases of gastrointestinal tract (Pawera et al., 2016). In recent years, in the food industry of Kyrgyzstan, sea buckthorn has been used as a functional ingredient in the production of cereal drink "Bozo" (Smanalieva et al., 2022) and for the production of jams and juices. In addition, dried sea buckthorn berries are used as an additive to tea and cereal products.

Crataegus spp. – is a genus of approximately 300 species of shrubs and trees, and grows easily in shallow, sandy or stony soil. The Asian hawthorn species *Crataegus songarica* grows in the walnut-fruit forests of Kyrgyzstan with yellow, red (Figure 1) and black fruits. The plant is a tree or small shrub with thorns up to 15 mm in length. According to researchers, antioxidant phytochemicals of the genus *Crataegus* are procyanidins, flavonoids, flavonols, glycosylated flavanones, and triterpene pentacyclic acids (Liu et al., 2010; Yang & Liu 2012; Sytařová et al., 2020). Since ancient times, *Crataegus* spp. has traditionally been used in folk medicine to treat heart problems such as hypertension, arrhythmia, and congestive heart failure (Yang & Liu, 2012). In Europe and China, hawthorn fruit is also eaten and used to make commercial products such as wine, jam and candy (Edwards et al., 2012).

Unfortunately, the scientific literature lacks information on bioactive compounds and antioxidant activity, and there is very limited old data on the nutritional composition of wild sea buckthorn and hawthorn berries from the walnut-fruit forest of Kyrgyzstan. Therefore, this study aimed to contribute to the limited literature on chemical composition (dry matter, sugars, pH, titratable acidity, ash, fibre, vitamin C) and the radical scavenging activity, total polyphenols of sea buckthorn and hawthorn berries, which are required for documentation in the national food composition database.

MATERIAL and METHODS

Biological Material

Sea buckthorn and hawthorn samples were harvested (2 kg) at full maturity in 2017 and 2018 in the walnut-fruit forests in Kyzyl-Unkur village, Kyrgyzstan (Figure 1). The samples were transported to the laboratory in air-conditioned vehicles in a portable refrigerator at a temperature of 4–6 °C (within 9–12 h). All samples were stored in plastic bags under two different conditions: at 4–6 °C for physical properties analysis and at -23 °C for chemical composition analysis.

Analysis of Nutritional Value and Pomological Characteristics

The AOAC methods were used (AOAC, 1990) to determine moisture content (No. 930.15), titratable acidity (No. 949.08) and ash content (No. 942.05). The concentration of reducing sugars (glucose and fructose) was determined by the iodometric method according to AOAC methods 939.03. Ascorbic acid was determined using the AOAC 967.21 titration method with a solution of 2,6-dichloroindophenol (AOAC, 2019). The crude fibre content was determined by filtre bag technique (No. 962.09). All chemical analyses were performed in triplicate, mean values and standard deviations (SD) were determined.

The physical properties of fruits (fruit weight, size, sphericity, average radius, aspect ratio, volume, fruit and bulk density) included the examination of randomly selected 25 fruits in three replications at a natural moisture content of 66.03% for sea buckthorn and 71.48% for hawthorn by weight basis (w.b.) according to Mohsenin (2019):

The sphericity of fruits φ (–) was defined by formula(1):

$$\varphi = \frac{(D_{max} \cdot D_i \cdot D_{min})^{\frac{1}{3}}}{D_{max}} \quad (1)$$

Sphericity expresses the characteristic shape of a solid object in relation to the shape of a sphere of the same volume.

The surface area A (mm^2) was calculated by the formula (2) of the surface area of a sphere and multiplied by sphericity, where r_a is the average fruit radius (mm):

$$A = (\pi \cdot r_a^2) \cdot \varphi \quad (2)$$

The aspect ratio R_a (–) was calculated by formula (3):

$$R_a = \frac{D_{max}}{D_{min}} \quad (3)$$

Fruit volume V (mm^3) and solid density ρ_s (kg m^{-3}) were determined experimentally from liquid displacement. Briefly, 3 g of fruit samples were placed into a 100 mL beaker filled with 50 mL of distilled water. The volume of water displaced by fruits was calculated as follows (4):

$$V_s = \frac{M_{bws} - M_{bw}}{\rho_w} \quad (4)$$

Where M_{bws} is the weight of the beaker, water and fruits; M_{bw} is the weight of the beaker and water. The measurement was repeated three times.

Figure 1. The appearance of the fresh sea buckthorn and hawthorn
Şekil 1. Taze iğde ve alıç görünümü

The bulk density ρ_b (kg m^{-3}) was determined by dividing the fruit weight M_f by the beaker (1000 mL) volume V_b (5). The procedure was repeated three times:

$$\rho_b = \frac{M_f}{V_b} \quad (5)$$

Total Phenolic Compounds Measurement

Sample extracts for polyphenol analysis were prepared according to Kalt et al. (1999). The total amount of polyphenols in the extracts was determined by the Folin-Ciocalteau micro method using a UV-VIS spectrophotometer (Specord 50, Analytik Jena, Germany) at a wavelength of 765 nm. The total amount of polyphenols was expressed as mg gallic acid equivalents (GAE) per 100 g fresh sample.

Analysis of Total Antioxidant Capacity

Both extracts and analysis of total antioxidants were performed according to Hangun-Balkir & McKenney (2012) using a solution of 80% ethanol. Individual solutions of antioxidants were prepared at five concentrations (1, 2.5, 5, 7.5 and 10 µg mL^{-1}) in 80% ethanol. A radical solution of 0.01% DPPH (2,2 diphenyl-1-picrylhydrazyl) in 80% ethanol solution was used. The absorbance of the control and sample solutions was measured at 517 nm by using a UV-VIS spectrophotometer (Specord 50, Analytik Jena, Germany). Values are expressed as inhibition concentration (IC_{50}), the concentration of the samples that causes 50% scavenging of the DPPH radical.

Statistical Analyses

All chemical analyses were carried out in triplicate and physical properties - in 20 replicates. Results were expressed as mean values with SD calculated using the SPSS software version 13 for statistical evaluation (SPSS Inc., Chicago, IL, USA).

RESULTS and DISCUSSION

Evaluation of Physical Attributes of Sea Buckthorn and Hawthorn

Measuring the physical attributes of agricultural products is an important tool in the design of sorting, grading, conveying, processing, and packaging equipment (Sahin & Sumnu, 2006). This is also important for the determination of pomological characteristics. Table 1 compares the physical parameters of sea buckthorn (*Hippophae salicifolia)* from the trans-Himalayan region (Yadav et al., 2006; Jaiswal et al., 2017) and Turkey (Sezen et al., 2015). Sea buckthorn from the walnut-fruit forests of Kyrgyzstan has close physical parameters with the genotypes of sea buckthorn from the Himalayas. Fresh sea buckthorn fruits have an average length (D_{max}) of 6.36 mm, an average width (D_{in}) of 4.7 mm, and a thickness (D_{min}) of 4.6 mm. The calculated sphericity was 0.81, which corresponds to an oval shape (ovoid). The fruit surface area was 17.33 mm^2. The solid density (ρ_s) and bulk density (ρ_b) of the fresh samples were 1.05 and 0.53 g cm^{-3}, respectively. The weight of 100 berries was 10.44 g, which is significantly lower than the results of Jaiswal et al. (2017) 36.27 ÷ 91.2 g.

The investigated physical attributes of hawthorn (*Crataegus songarica)* at a natural moisture content of 71.48% by fresh weight basis are given in Table 1. Hawthorn fruits are purple-red in colour with 2-4 seeds, 9-11 mm in diameter, and with a sphericity of 0.89 (Figure 1). According to Turkish authors, D_{max} and D_i were found to be 19.34 mm, and 14.39 mm for *Crataegus* spp. (Özcan et al., 2005), 12.25 mm and 11.37 mm for *Crataegus Monogyna* Jacq. var. *Monogyna* (Yalçın-Dokumacı et al., 2021), and within the range of 2.21 ÷ 17.68 mm, and 1.67 ÷ 15.72 mm for 11 hawthorn species (Gundogdu et al., 2014), respectively. The sphericity of hawthorn berries from Turkey was high at 0.95 ÷ 1.22 (Özcan et al., 2005; Yalçın-Dokumacı et al., 2021). It should be noted that sphericity values around 1 indicate that the fruit is round, while values above 1 indicate an oval shape. The aspect ratio and surface area of the studied hawthorn were determined to be 1.22 and 68.05 mm^2, respectively. The solid and bulk densities of the fruits were 0.88 g cm^{-3} and 591.67 kg m^{-3}, respectively. The average weight of hawthorn berries was 0.49 g per berry and the volume of one hawthorn fruit was 0.56 cm^3. This is significantly lower compared to reports from Turkey, for example, Yalçın-Dokumacı et al. (2021) have measured the average weight of one hawthorn as 0.93 g, Özcan et al. (2005) - 3.03 g, and Gundogdu et al. (2014) - 0.58 ÷ 3.48 g per one berry. The volume of the fruit studied by Özcan et al. (2005) was also significantly higher and equaled 3.08 cm^3. In terms of weight, volume, surface area and length of hawthorn berries harvested in the walnut-fruit forests of Kyrgyzstan are much smaller than berries grown in Turkey. This can be explained by the huge difference in hawthorn cultivars (Gundogdu et al., 2014) and climatic conditions of the locations. Meisen et al. (2020) stated higher variability in the physical properties of walnuts between walnut trees within the same site than between different sites.

Evaluation of Nutritional Composition of Sea Buckthorn and Hawthorn

The moisture content, inverted sugars, organic acid, fibre, and ash content of sea buckthorn and hawthorn are given in Table 2. Fresh sea buckthorn features 66.03 g per 100 g of moisture content, 1.00 ÷ 1.13 g per 100 g of inverted sugars, 1.78 ÷ 2.12 g per 100 g of organic acids, 6.13 g per 100 g of fibres, and 1.75 g per 100 g of ash content. The moisture content of the investigated sea buckthorn was close to fresh berries of *H. tibetana* and *H. rhamnoides* from the Himalayas (67.2 ÷ 76.9%) (Ranjith et al., 2006). Compared to berries from the Czech Republic, the moisture content (84.2 ÷ 87.4%) is significantly lower than reported by Sytařová et al. (2020). According to Bal et al. (2001), the differences in moisture content are associated with differences in origin and climate. Other values of sea buckthorn are consistent with sea buckthorn data from other countries (Ranjith et al., 2006; Ercisli et al., 2007; Bal et al., 2011). For comparison, sea buckthorn grown in Poland contained similar value of sugars 1.34 ÷ 2.87 g per 100 g and organic acids from 2.48 to 2.79 g per 100 g fresh weight (Tkacz et al., 2019). The crude fibre content was 6.13 g per 100 g, which is significantly higher than indicated by Jaroszewska & Biel (2017). In our study, the ash content was determined with seeds, therefore, the ash content of sea buckthorn was higher compared to the data obtained for sea buckthorn berries grown in the Himalayas. According to Ranjith et al. (2006), the ash contents in the seedless berries *H. rhamnoides* and *H. salicifolia* were 1.05% and 0.26%, respectively, which is lower than our results. The sugar/acid ratio of fruit is considered an important indicator of flavor quality (Albertini et al., 2006). The sugar/acid ratio of sea buckthorn was 0.51 and was consistent with the data of Tkacz et al. (2019) who reported that the sugar/organic acid ratio ranged from 0.40 to 2.99.

Table 1. Physical attributes (mean ± SD, n = 20) of fresh sea buckthorn and hawthorn
Çizelge 1. Taze iğde ve alıçların fiziksel özellikleri (ortalama ± SD, n = 20)

Physical characteristic Fiziksel özellik	Kyrgyzstan Kyzyl-Unkur *Hippophae rhamnoides* L. Kırgızistan Kızıl-Ünkür *Hippophae rhamnoides* L.	Literature data for *Hippophae rhamnoides* L. *Hippophae rhamnoides* L için literatür verileri	Kyrgyzstan Kyzyl-Unkur *Crataegus songarica* Kırgızistan Kızıl-Ünkür *Crataegus songarica*	Literature data *Crataegus songarica* *Crataegus songarica* için literatür verileri
Altitude, m	1466	3500 (Jaiswal et al., 2017); 2000-3000 (Yadav et al., 2006); 1025 (Sezen et al., 2015)	1466	
Average length, D_{max} (mm)	6.35 ± 0.63	6.5 ÷ 7.5 (Jaiswal et al., 2017); 5.78 ÷ 7.92 (Yadav et al., 2006); 6.46 ÷ 9.14 (Sezen et al., 2015)	11.06 ± 0.67	19.34 ± 0.18 (Özcan et al., 2005); 12.25 ± 0.064 (Yalçın-Dokumacı et al., 2021); 2.21 ÷ 17.68 (Gundogdu et al., 2014)
Average width, D_i (mm)	4.70± 0.03	5.49 ÷ 6.99 (Jaiswal et al., 2017); 5.51 ÷ 7.24 (Yadav et al., 2006); 5.48 ÷ 7.18 (Sezen et al., 2015)	9.38 ± 0.96	14.39 ± 0.12 (Özcan et al., 2005); 11.37 ± 0.082 (Yalçın-Dokumacı et al., 2021); 1.67 ÷ 15.72 (Gundogdu et al., 2014)
Thickness, D_{min} (mm)	4.60 ± 0.38	4.74 ÷ 6.28 (Jaiswal et al., 2017)	9.08 ± 0.87	
Sphericity, φ (–)	0.81	0.66 ÷ 0.91 (Jaiswal et al., 2017)	0.89 ± 0.04	1.22 ± 0.01 (Özcan et al., 2005); 0.95 ± 0.036 (Yalçın-Dokumacı et al., 2021)
Aspect ratio, R_a (–)	1.37		1.22 ± 0.08	
Surface area, A (mm^2)	17.33 ± 2.22	76.8 ÷ 154.7 (Jaiswal et al., 2017)	68.05 ± 12.90	
Weight, m (g)	10.44 ± 0.69 of 100 berries	3.63 ÷ 9.12 g of 100 berries (Jaiswal et al., 2017); 11.53 ÷18.87 g of 100 berries (Yadav et al., 2006); 15 ÷ 26 g of 100 berries (Sezen et al., 2015)	0.49 ± 0.08 g of 1 berry	3.03 (Özcan et al., 2005); 0.93 (Yalçın-Dokumacı et al., 2021); 0.58 ÷ 3.48 g of 1 berry (Gundogdu et al., 2014)
Volume, V (cm^3)	0.11 ± 0.02		0.56 ± 0.04	3083.3 ± 261.41 mm^3 (Özcan et al., 2005)
Bulk density, ρ_b (kg m^{-3})	0.53 ± 0.02 g cm^{-3}		591.67 ± 1.75	466.06 ± 3.39 (Özcan et al., 2005)
Fruit density, ρ_s (g cm^{-3})	1.05 ± 0.19	0.65 ÷ 1.4 (Jaiswal et al., 2017)	0.88 ± 0.14	1065.98 ± 28.18 kg m^{-3} (Özcan et al., 2005)

Table 2. Chemical composition (mean ± SD, n = 3) of fresh sea buckthorn and hawthorn
Çizelge 2. Taze iğde ve alıçların kimyasal bileşimi (ortalama ± SD, n = 3)

Index Gösterge	Kyrgyzstan Kyzyl-Unkur *Hippophae rhamnoides* L. Kırgızistan Kızıl-Ünkür *Hippophae rhamnoides* L.	Literature data for *Hippophae rhamnoides* L. *Hippophae rhamnoides L* için literatür verileri	Kyrgyzstan Kyzyl-Unkur *Crataegus songarica* Kırgızistan Kızıl-Ünkür *Crataegus songarica*	Literature data for *Crataegus songarica* *Crataegus songarica* için literatür verileri
Moisture content, g per 100 g	66.03 ± 0.15	67.2 ÷ 76.9 (Ranjith et al., 2006); 88.22 ÷ 86.92 (Tkacz et al., 2019); 84.2 ÷ 87.4 (Sytařová et al., 2020)	71.48 ± 0.24	80 ÷ 97.65 (Gundogdu et al., 2014); 68 ÷ 70.13 (Mironeasa et al., 2016)
Invert sugars, g per 100 g	1.03 ± 0.05	1.34 ÷ 2.87 (Tkacz et al., 2019); 0.35 ÷ 1.56 (Criste et al., 2020)	2.69 ± 0.26	15.66 ÷ 32.27 (Gundogdu et al., 2014)
pH	3.23 ± 0.00	2.7 ÷ 2.9 (Tkacz et al., 2019); 2.63 ÷ 2.98 (Ercisli et al., 2007)	4.74 ± 0.02	4.29 ÷ 5.99 (Gundogdu et al., 2014); 3.12 ÷ 4.09 (Türkoğlu et al., 2005)
Titratable acidity, g malic acid per 100 g	1.95 ± 0.11	2.0 ÷ 3.7 (Tkacz et al., 2019); 2.64 ÷ 4.54 (Ercisli et al., 2007)	0.75 ± 0.01	0.22 ÷ 2.40 (Gundogdu et al., 2014); 0.49 ÷ 0.96 mg $100g^{-1}$ (Türkoğlu et al., 2005)
Total crude fibre, g per 100 g	6.13 ± 0.66	6.2-7.3 (Ranjith et al., 2006)	2.25 ± 0.19	4.67 (Özcan et al., 2005)
Ash content, g per 100 g	1.75 ± 0.04	0.26 ÷ 1.05 (Ranjith et al., 2006); 0.31 ÷ 0.43 (Tkacz et al. (2019)	0.66 ± 0.06	2.28 (Özcan et al., 2005); 2.77 (Yalçın-Dokumacı et al., 2021)
Sugar/acid ratio	0.52	0.40 ÷ 2.99 (Tkacz et al., 2019); 0.40 ÷ 1.90 (Tiitinen et al., 2005)	3.36	7.75 (Lou et al., 2020)

The moisture content of hawthorn berries was close to the values obtained by Mironeasa et al. (2016) (68.0 ÷ 70.13%) and slightly lower than those reported by Gundoğdu et al. (2014) (80 ÷ 97.6%) in Turkish hawthorn berries. The titratable acidity and pH of fresh hawthorn berries were 0.08 and 4.74, respectively, which were in the same range as Gundoğdu et al. (2014) (0.22 and 4.26), but higher than those reported by Türkoğlu et al. (2005) (0.49 and 3.12). The ash content of hawthorn berries was lower (0.66 g per 100 g) compared to Turkish hawthorn (2.28 g per 100 g) (Özcan et al., 2005). Inverted sugars in studied hawthorn berries were found to be very low compared to hawthorn from Turkey (15.66 g per 100 g) (Gundogdu et al., 2014), and from China (12.32 g per 100 g) (Liu et al., 2010). In this study, the total crude fibre content of hawthorn was determined to average 2.25 g per 100 g, whereas the crude cellulose determined by Özcan et al. (2005) averaged 4.67 g per 100 g. The determined ash content of Kyrgyz hawthorn berries was found to be low compared to the values reported by Mironeasa et al. (2016) and Yalçın-Dokumacı et al. (2021). The sugar/acid ratio of hawthorn berries was found to be 3.36, which is significantly lower than the sugar/acid ratio from China, which was 7.75 for frozen hawthorn (Lou et al., 2020). Cultivated genotypes from Russia and Finland have a sugar/acid ratio of 0.4 ÷ 1.9 (Tiitinen et al., 2005).

Antioxidant Compounds and Antioxidant Activity of Sea Buckthorn and Hawthorn

The measured content of vitamin C, total phenolics, and antioxidant activity of sea buckthorn and hawthorn are given in Table 3. Fresh sea buckthorn contained on average 181.9 mg per 100 g of vitamin C and complied with the findings of other researchers. For example, Tkacz et al. (2019) measured vitamin C content in the range of 61.02 ÷ 158.81 mg per 100 g of fresh weight (f.w.). According to Araya-Farias et al. (2011), fresh sea buckthorn fruits harvested in Quebec (Canada) contain 184.63 mg per 100 g of vitamin C, also from Himalaya was in the same range of 168.3 ÷ 184.0 mg per100 g (Ranjith et al., 2006). In addition, the investigated samples of sea buckthorn contain high amounts of total phenolic compounds (TPC) 386.23 GAE mg per 100 g of f.w. For comparison, sea buckthorn from Canada contains TPC of 175.25 mg per 100 g f.w. (Araya-Farias et al., 2011), berries from Poland feature 55.13 ÷ 115.70 mg of phenolic compounds in 100 g f.w. (Tkacz et al., 2019). According to Sytařová et al. (2020), the total polyphenol content in sea buckthorn ranged from 70 ÷ 362 mg GAE per 100 g (in berries) and 188 ÷ 372 mg GAE per 100 g (in leaves) of fresh matter.

Table 3. Content of vitamin C, total phenolics and antioxidant activity (mean ± SD, n = 3) of sea buckthorn and hawthorn (f. w.)

Çizelge 3. İğde ve alıç (t. a.) C vitamini içeriği, toplam fenolikler ve antioksidan aktivite (ortalama ± SD, n = 3)

Sample Numune	Vitamin C, mg per 100 g C vitamin, mg 100 g'da	Total phenolic content, mg GAE per 100 g Toplam polifenol içeriği, mg GAE 100 g'da	Antioxidant activity by DPPH, IC_{50} µg mL^{-1} DPPH, IC_{50} µg mL^{-1} ile antioksidan aktivite
Hippophae rhamnoides L.	181.88 ± 5.00	386.23 ± 5.00	3.8 ± 0.30
Literature data	61.02 ÷ 158.81 (Tkacz et al., 2019); 184.63 mg per 100 g f. w. (Araya-Farias et al., 2011)	175.25 mg per 100 g f. w. (Araya-Farias et al., 2011); 10.12 ÷ 18.66 mg g^{-1} (Criste et al., 2020)	0.11 ÷ 2.27 (Chaman et al., 2011)
Crataegus songarica	43.34 ± 0.30	669.57 ± 5.00	2.5 ± 0.05
Literature data	20 ÷ 90 mg per 100 g f. w. (García-Mateos et al., 2013) 1.55 ÷ 9.42 mg per 100 g f. w. (Gundogdu et al., 2014)	52 ÷ 558 mg per 100 g f. w. (García-Mateos et al., 2013); 184 ÷ 248 mg per 100 g f. w. (Edwards et al., 2012)	0.08 ÷ 0.35 µg mL^{-1} (García-Mateos et al., 2013)

In hawthorn, vitamin C content was 43.34 mg 100 g of f.w. For comparison, hawthorn from Mexico has a vitamin C content of 20 ÷ 90 mg per 100 g f.w. (García-Mateos et al., 2013), while hawthorn from Turkey has a significantly lower content of vitamin C 1.55 ÷ 9.42 mg per 100 g f. w. (Gundogdu et al., 2014). The TPC of the hawthorn was 669.57 GAE mg per 100 g, which was higher than that of hawthorn from Mexico 52 ÷ 558 mg 100 g f.w. (García-Mateos et al., 2013). However, Edwards et al. (2012) reported TPC of hawthorn in the range of 184 ÷ 248.18 mg per 100 g f.w. The TPC of dried hawthorn was 3450 mg GAE per 100 g (Tadić et al., 2008), due to the concentration of solids during drying. In hawthorn fruits in this study, the TPC was significantly higher than that of sea buckthorn ($p<0.01$).

A higher content of total polyphenols was also found in barberry 891 mg per 100 g f.w. and rosehip 813 mg per

100 g f.w. from the Kyzyl-Unkur walnut-fruit forest (Smanalieva et al., 2020).

The radical scavenging concentration IC_{50} is the antioxidant concentration at which 50% inhibition of free radical activity is observed. If this concentration is low, the antioxidant capacity or activity is considered to be high. The measured IC_{50} of the investigated sea buckthorn in ethanol extract was 3.8 μg mL^{-1}, and hawthorn was 2.5 μg mL^{-1}. For comparison, the free radical scavenging concentration IC_{50} of sea buckthorn from Pakistan was 0.11 and 2.27 μg mL^{-1} in methanolic and aqueous extracts, respectively (Chaman et al., 2011). In the study of Varshneya et al. (2012), the antioxidant activity in methanol extracts of sea buckthorn pomace from the Himalayas was 179.77 μg mL^{-1}. The IC_{50} of hawthorn (2.5 μg mL^{-1}) was significantly lower than that of sea buckthorn, but higher than that of barberry (1.7 μg mL^{-1}) and rosehip (1.3 μg mL^{-1}) (Smanalieva et al., 2020). García-Mateos et al. (2013) found an inhibitory concentration IC_{50} of 20 hawthorn genotypes in methanolic extracts in the range of 0.08 ÷ 0.35 μg mL^{-1}. It should be noted that the antioxidant extract in methanol exhibits the maximum activity in all antioxidant methods (Chaman et al., 2011).

CONCLUSION

Physical characteristics and chemical composition, as well as bioactive components, such as vitamin C and phenolic compounds of wild sea buckthorn (*Hippophae rhamnoides* L.) and hawthorn (*Crataegus songarica)* of the walnut-fruit forests of Kyrgyzstan, were determined for the first time and compared with all available data from other researchers documented in the scientific literature. The results showed that the moisture content of sea buckthorn is significantly lower than in berries from Europe. In terms of physical characteristics, sea buckthorn and hawthorn can be placed in the medium range for size, weight, and other physical attributes. Hawthorn berries harvested in the walnut-fruit forests of Kyrgyzstan are significantly smaller than berries grown in Turkey. The contents of crude fibre and ash in hawthorn were below other recorded values. This can be explained by the huge difference in the varieties of hawthorn and the climatic conditions of the locations. High vitamin C values were measured in sea buckthorn, however, the total phenolic content and antioxidant activity were higher in hawthorn. Therefore, wild berries are recommended to be consumed in daily nutrition, which requires further research on the development of new recipes and processing technologies. An integrated approach to agroforestry is needed to grow more productive hawthorn and sea buckthorn genotypes.

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Author's Contribution

The plant material belonging to this study was collected by Zh.O. Designing the study and deciding on the appropriate experimental methods were carried out by J.I. and J.S. Experimental analyses of the study were performed by J.I. and Zh.O. Formal and statistical analyzes were performed by J.S. Article draft text was written by J.I., Zh.O., and J.S. The manuscript was finalised with the critical feedback on the study, analysis and article provided by J.I., Zh.O., and J.S.

Conflict of Interest

The authors have no conflicts of interest to declare that they are relevant to the content of this article.

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