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Assessment of Morphological Traits, Nutritional and Nutraceutical Composition in Fruits of 18 Apricot cv. Sekerpare Clones

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Abstract: Apricot (*Prunus armeniaca* L.) is one of the most important members of *Prunus* and its trees bears delicious and nutritious fruits during summer months in the temperate zones in the world. Apricot cultivars are propagated asexually which consists of clones. Information on inter-clonal variations in apricot cultivars can assist us in the selection of better clones from commercial cultivars. We aimed to determine morphological traits (fruit weight, seed weight, kernel weight, flesh/seed ratio, shape index, fruit firmness, color index), nutritional (sugars and organic acids) and nutraceutical (total phenolic, total flavonoids, total carotenoid and antioxidant activity) composition of 18 clones of Sekerpare apricot cultivar grown together in Kagizman district in eastern Turkey. Results showed significant differences among clones concerning most of the morphological traits, nutritional and nutraceutical compositions. Fruit weight, flesh/seed ratio and fruit firmness of clones were in range of 23.14–27.11 g, 11.21–13.14 and 3.88–5.11 kg/cm^2, respectively. Fruit shape index was slightly similar among all clones which was between 0.95 and 1.03. Citric acid and sucrose were found to be the predominant organic acid and sugar among clones which varied from 728 to 915 mg/100 g and 7.11 to 9.94 g/100 g, respectively. The clone 'KS2' exhibited the highest level of total phenol (67.1 mg gallic acid equivalent per 100 g) and antioxidant activity (2.16 µmol trolox equivalent per g). The study confirmed the diversity among Sekerpare clones and effectiveness of combining morphological, nutritional and nutraceutical analyses in assessment of Şekerpare clones and its use for future pre-breeding programs.

Keywords: apricot; Sekerpare; nutraceuticals

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1. Introduction

Due to suitable climate and soil conditions, Turkey is among the most important fruit producer countries in the world in terms of both the number of fruit species and the amount of production. Turkey ranks first in the world's apricot, fig, hazelnut, sweet cherry and quince production [1]. Nine apricot species and subspecies are known in the world. Among these species, *Prunus armeniaca* L. is cultivated in main apricot growing countries and spreads over the widest geographical area in the world [2,3]. The origin of apricot, which has been cultivated since ancient times, covers a wide area from Turkistan to Western China. Although apricots are grown geographically almost everywhere in the world, commercial production mostly occurs in countries of southern Europe, north America and north Africa [4].

Apricot can be consumed fresh, dried and canned throughout the year. The fruits of apricots are important for human nutrition, being rich in sugars, organic acids, fiber, vitamin A, vitamin E and potassium [5–9].

According to the data of the Food and Agriculture Organization (FAO) based on the year 2018, the amount of apricot production increased 19.5% compared to the previous year, while the area shows a decrease of 2% in apricot growing countries. When the data for the last five years (2014–2018) are examined, apricot production increased from 3.3 million tons to 3.8 million tons worldwide, but the production area stayed stable [1]. Turkey is leading world apricot production with a yearly average 750 thousand tons production. The country shares 20% of the world apricot production and is followed by Uzbekistan (13%), Iran (9%), Algeria (6%) and Italy (6%) [1].

In Turkey, apricot trees are grown mainly in the Aegean region, the Mediterranean region, and in particular the Central and Eastern Anatolia regions. Within the regions, Malatya, Elazig, Erzincan, Kahramanmaras, Kars, Mersin and Iğdır provinces are well known for commercial apricot cultivation and significant portions of the apricots are dried traditionally in these areas. Except for drying, apricots are generally used in the fruit juice industry in Turkey as well [10,11]. In recent years, depending on the technological developments, apricot fruits are frozen and become widespread in the market outside of the production period [12].

Each apricot growing region in Turkey has their own apricot cultivars and inter-regional cultivar transfer generally results in negative results. This is because apricots show low environmental adaptability, and the introduction of foreign germplasm may also result in fluctuating or limited yield. This is associated with differences in fertilization, chilling requirements, late-frost resistance, cold-hardiness, etc. [13]. In Turkey, the cultivar–region relationship is very strong as well in apricots. However, the Şekerpare cultivar can be grown in every region and shows great environmental plasticity. The cultivars are mostly grown in Malatya, Erzincan provinces and Aras valley in Turkey and show variable fruit weight ranging from 20 to 40 g [2,4,10,14]. The cultivar called Shakarpara in Pakistan and India and Shekarpareh in Iran shows great phenotypic variability as well. Phenotypic variation within Sekerpare grown in similar ecological conditions arises from an accumulation of somatic mutations due to vegetative propagation during centuries in different Sekerpare growing countries [2,15,16]. The concept of sustainable apricot production can be described as a "three-legged stool", with legs of economic viability, environmental soundness, and social acceptability. Communicating the health benefits of apricot fruit to consumers is an essential ingredient in sustaining apricot product demand, which is a prerequisite for sustainable apricot production. Thus, the cultivar Sekerpare grown in different parts of the world could be adding value for economic viability, environmental soundness, and social acceptability.

Sekerpare is found in most of the apricot growing regions in Turkey and still retains importance and provides interesting economic results in local markets, remaining a popular option for most of the apricot growing regions. This locally adapted cultivar is appreciated for its superior flavor and suitability for both fresh consumption and as a dried product [2].

The Aras valley (Kars-Igdir region) is one of the important apricot growing areas of Turkey. Kagizman district provides almost all of the apricot production in Kars province. In the district, Aprikoz, Sekerpare and wild apricots are grown [17–19]. There are numerous clones of Sekerpare available in the Kagizman district that exhibit differences in key horticultural traits.

Identifying plant varieties is an age-old human endeavor. Historically, morphological traits and later nutritional and nutraceutical characteristics were used to categorize specimens into families, genera, species, cultivars, genotypes, landraces (for perennials: a plant selected from seedlings and asexually re-propagated for its desired characteristics). Thus, varietal characterization based on morphological, nutritional and nutraceutical traits is an important component of fruit tree improvement and breeding [20,21].

Apricot has gained great value in human consumption and commercial importance in recent years, attracting researchers to study its morphological, nutritional and in particular nutraceutical traits.

Advances in fruit species improvement programmes is only possible when intense and more defined genetic variability exists. The phonological expression of any fruit tree species is mostly governed by two factors viz. heredity and environment. Given the fact that environmental variations can be reduced by growing the identical genotypes under uniform site and climatic conditions, studying genetic parameters is of immense use to obtain superior genotypes of any species.

The present study intended to capture variability across morphological, nutritional and nutraceutical parameters of 18 clones of Sekerpare apricot from a particular similar environmental condition.

2. Materials and Methods

2.1. Plant Samples

Twenty fruits were harvested from different parts of trees of 18 Sekerpare clones grown together in Kagizman district during July in 2018. Kagizman is located at 40. 1406° N and 43.1191° E and 1406 m above mean sea-level. All trees of the 18 Sekerpare clones were found at nearly the same altitude in Kagizman district. All examined trees were pre-selected clones according to higher yield, pest and disease free status and more attractive bigger fruit characteristics. Special attention was given on harvest and fruits were harvested in the same period with the same degree of maturity. A total of 80 fruits per clone were collected and then sorted and cleaned. Mature and healthy fruits were transported to the laboratory and divided into two equal parts for morphological measurements and nutritional and nutraceutical analysis.

2.2. Morphological Parameters

A total 40 fruits per clone were used for morphological measurements which included fruit weight, seed weight, kernel weight, flesh/seed ratio, shape index and fruit color coordinates (L, a and b values). Fruit weight (g) was measured with a digital scale sensitive to 0.01 g (Scaltec SPB31). Fruit firmness was determined with a non-destructive Acoustic Firmness Sensor (Aweta B.V., Pijnacker, The Netherlands) expressed as kg/cm^2. Fruit shape index (SI) was calculated with the following equation [22].

$$\mathrm{SI}\frac{\mathrm{W}+\mathrm{T}}{2\mathrm{L}} \quad \text{where W : Width, T : Thickness and L : Length} \tag{1}$$

Color coordinates (L^*, a^*, and b^*) of fruit skin were determined by a Konica Minolta, CR-400 Plus fruit colorimeter (Konica Minolta, Inc., Chiyoda City, Tokyo, Japan) at four different positions around the equator of the fruits [23].

2.3. Nutritional and Nutraceutical Composition

2.3.1. Sample Preparation and Extraction

A representative of 40 fruits/clone were randomly selected from the harvested lot at commercial maturity stage. The fruits were then introduced to a High-Speed Pulp Ejection Juicer (Omega Products International, Corona, CA, USA), allowing the separation of pomace and juice. The juice was stored at −80 °C until use for nutritional and nutraceutical content. During the analysis, the frozen fruits were taken and thawed to 24–25 °C. A laboratory blender was used to homogenize the fruit samples (100 g lots of fruits per clone) and a single extraction procedure (taking 3 g aliquots transferred inside tubes and extracted for 1 h with 20 mL buffer including acetone, water (deionized), and acetic acid (70:29.5:0.5 v/v)) was used [24].

2.3.2. Organic Acids

Organic acid composition in fruits of Sekerpare apricot clones was determined by Bevilacqua and Califano [25]. Fruit extracts were obtained by crushing the fruits in cheesecloth. Then, 0.009 N H_2SO_4 was added and shaken for 1 h. The mixture was then centrifuged at 15,000 rpm for 15 min and the supernatants were filtered twice through a

0.45 µm membrane filter with a coarse filter (Millipore Millex-HV Hydrophilic PVDF, Millipore, MA, USA) and passed through a SEP-PAK C18 cartridge. Organic acid readings were performed by HPLC using the Aminex column (HPX-87 H, 300 × 7.8 mm, Bio-Rad Laboratories, Richmond, CA, USA) at 214 and 280 nm wavelengths in the Agilent package program (Agilent Technologies, Santa Clara, CA, USA). Results are expressed as mg/100 g.

2.3.3. Determination of Individual Sugars

For individual sugar (fructose, glucose, and saccharose) analyses, the method of Melgarejo et al. [26] was used. First, homogenized fruits (5 g) were diluted with purified water and homogenate was centrifuged at 6000 rpm for 5 min. Supernatants were filtered through a 0.45 µm membrane filter (Iwaki Glass, Jawa Barat, Indonesia) before the analysis. The HPLC analysis was conducted using a PerkinElmer HPLC system with Amino NH_2 column, and 85% acetonitrile/15% H_2O (v/v) as a mobile phase. Refractive index detector (RID) was used. Samples were identified and quantified by standards. Results were expressed as g/100 g fw. To specify the sweetness perception of 40 fruit per clone, their sweetness indices (SI) were calculated according to Roussos et al. [27]. The SI index considers the relative sweetness as a factor of each of the three sugars measured. It is described in the following equation (1): where *Glu* stands for glucose concentration, *Fru* for fructose concentration, and *Sacch* stands for saccharose concentration.

$$\mathrm{SI} = 1.00 \cdot Glu + 2.3 \cdot Fru + 1.35 \cdot Sacch \quad (2)$$

2.3.4. Total Phenol Content

The total phenolic content (TPC) of the samples was evaluated using the Folin–Ciocalteu method according to Singleton and Rossi [24]. In this procedure, each extract (1 mL) was mixed with Folin–Ciocalteu's reagent and water 1:1:20 (v/v). The samples were incubated for 8 min. Then, sodium carbonate (10 mL) with a concentration of 7% (w/v) was added. After incubation for 2 h, the absorbance at 750 nm was measured. The total phenolic content was calculated against the reference standard calibration curve of gallic acid. The TPC was expressed as mg of gallic acid equivalents (GAE) per 100 g of fresh sample.

2.3.5. Total Carotenoid Content

The total carotenoid content was determined by Lichtenthaler [28]. For total carotenoid content, 1 g of fruit sample was homogenized with 5 mL of acetone in a cold porcelain mortar in an ice bath. Then, 1 g of anhydrous sodium sulfate ($Na_2 \cdot SO_4$) was added to the homogenate, which was elutriated using a paper filter. The filtered solution was made up to 10 mL with acetone and centrifuged at 2600× g for 10 min. The upper phase was collected and the absorbance of the solution at 662, 645 and 470 nm was measured. Acetone was used as control. Total carotenoid content is expressed as mg per 100 g fresh fruit sample.

2.3.6. Antioxidant Capacity

The TEAC value of each sample was detected according to the method described by Rice-Evans et al. [29]. The 7 mM ABTS reagent solutions were prepared and diluted with sodium acetate ($C_2H_3NaO_2$) until 0.700 ± 0.01 spectrophotometrical absorbance level at 734 nm. Following this, 2.97 mL buffered solution was mixed with 30 µL fruit extract and kept in dark at room temperature for 10 min and their absorbance levels were measured at 734 nm using a spectrophotometer. Obtained results were calculated according to TEAC standard calibration curve and expressed as µmol of trolox equivalent/g fresh fruit weight (µmol TE/g FW).

2.4. 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 $p < 0.05$.

3. Results and Discussion

3.1. Morphological Traits

As presented in Table 1, statistically significant differences ($p < 0.05$) were recorded in fruits of among 18 clones of cv. Sekerpare for most of the morphological traits. Fruit weight and skin color are the most important and distinct external fruit traits in apricots for consumer acceptance. Skin color is a practical and simple indicator with which to instruct harvesters on what to harvest. In addition, consumers in general prefer attractive medium-sized apricot fruits. The flesh/seed ratio is also an important fruit characteristic for apricots [2].

Table 1. Fruit weight, seed weight, kernel weight, flesh/seed ratio, shape index and fruit firmness of 18 Sekerpare clones.

Clones	Fruit Weight (g)	Seed Weight (g)	Kernel Weight (g)	Flesh/Seed Ratio	Shape Index	Fruit Firmness (kg/cm^2)
KS1	23.02c	1.85bc	0.78bc	11.44bc	0.98b	4.96ab
KS2	24.56bc	1.86bc	0.68de	12.20ab	0.99ab	4.55ab
KS3	27.11a	2.09a	0.84a	11.97bc	1.01ab	3.98c
KS4	24.03bc	1.93bc	0.74cd	11.45bc	1.00ab	4.32b
KS5	26.33ab	2.01ab	0.79b	12.09abc	0.95c	3.95c
KS6	25.18abc	1.90bc	0.75c	12.25ab	1.03a	4.20bc
KS7	26.55ab	2.03ab	0.82ab	12.08b	1.00ab	4.32b
KS8	25.78ab	1.89bc	0.72cd	12.64ab	0.98b	4.56ab
KS9	25.30b	1.85bc	0.72cd	13.14a	1.00ab	4.30b
KS10	23.14c	2.02ab	0.74c	10.46cd	0.98b	5.11a
KS11	24.98bc	1.85c	0.70d	12.50ab	1.03a	4.74ab
KS12	23.66bc	2.04ab	0.73cde	10.60c	0.97bc	4.70ab
KS13	24.58bc	1.94abc	0.81ab	11.67bc	0.99ab	4.55ab
KS14	23.86bc	1.83bc	0.70d	12.04b	0.96bc	4.85ab
KS15	23.44bc	1.92bc	0.76c	11.21bc	0.98b	5.02ab
KS16	23.40bc	1.80cd	0.70d	12.00b	0.96bc	4.80ab
KS17	26.13ab	1.96b	0.84a	12.33ab	0.97abc	3.88c
KS18	25.41ab	1.92bc	0.75c	12.24ab	1.00ab	4.33b

Different letters in the same column indicate significant differences ($p < 0.05$) among clones.

Fruit weight, seed weight and kernel weight of Sekerpare clones differed from each other statistically ($p < 0.05$) which ranged from 23.02 to 27.11, 1.80 to 2.09 and 0.68 to 0.84 g, respectively (Table 1). The variation in fruit and seed weight of the clones was also reflected in the fruit flesh/seed ratio which were in the range of 10.46–13.14.

Shape index and fruit firmness of clones were found between 0.96–1.03 and 3.88–5.11 kg/cm^2 (Table 1). KS3 and KS9 were notable among clones due to relatively high fruit weight and flesh/seed ratio.

Studies on apricots in different parts of Turkey identified variations in apricot fruit weight [18,30–32]. Turkish national apricot cultivars have relatively small fruit size and previous studies indicated this fact. For example, Akin et al. [33] studied main apricot cultivars grown in Malatya and determined fruit weight between 21.16 and 38.24 g. Asma and Ozturk [31] reported that 128 Turkish apricot cultivars that belong to the Iran-Caucasian ecogeographical group generally had low fruit weight (lower than 50 g). The authors reported that the fruit weight of only seven apricot cultivars was over 50 g, and the rest of cultivars had lower fruit weight. Karaat and Serce [10] reported fruit weight as 25.12 g in Cagataybey cultivar and 25.65 g in Sekerpare cultivar in Malatya which supports our findings. They also found seed weight to be 1.97 g, flesh/seed ratio as 12.02 and fruit firmness as 2.58 kg/cm^2 in cv. Sekerpare. Akca and Asma [34] conducted a clonal selection study on cv. Kabasi that aimed to find better Kabaasi clones with promising horticultural characteristics. They determined 13 promising clones among 450 Kabaasi trees. Fruit weight, seed weight, kernel weight and flesh/seed ratio were found between 31.81 and

60.91 g, 2.35–3.01 g, 0.52–0.98 g and 12.38–16.64, respectively, indicating similarities with our study. Previously, the flesh/seed ratios of the foreign apricot cultivars grown in Turkey varied between 8.9 and 21.8 [35,36]. In the literature, the shape index of apricots was reported between 0.91 and 1.09 [37,38]. In apricots, if fruit shape index values are found around 1, fruit tend to have a round shape. The Sekerpare cultivar in general gave round shaped fruits while if these values are higher than 1, fruits correspond to ovoid shape.

L^*, a^* and b^* color coordinates of clones are given in Table 2 and it was found that the L^*, a^* and b^* values of the Sekerpare clones significantly differed from each other at $p < 0.05$ (Table 2).

Table 2. Fruit skin color parameters of 18 Sekerpare clones.

Clones	L^*	a^*	b^*	Ground Color	Red Blushed Skin
KS1	61.21cd	11.38d	42.56ab	Yellow	Absent
KS2	63.45bc	14.29bc	40.14c	Yellow	Present
KS3	59.89de	14.90bc	44.13a	Dark yellow	Present
KS4	63.11bc	15.57ab	39.88cd	Yellow	Present
KS5	60.18d	15.39b	40.55bc	Light orange	Present
KS6	64.10b	12.55cd	38.15d	Light yellow	Absent
KS7	63.23bc	10.67de	41.23bc	Yellow	Absent
KS8	56.15f	14.44bc	43.32ab	Dark yellow	Present
KS9	58.33de	10.14def	42.56ab	Dark yellow	Absent
KS10	65.41ab	12.80cd	37.45de	Yellow	Absent
KS11	58.45de	13.38c	37.89de	Light orange	Present
KS12	57.10ef	17.12a	39.11cd	Light orange	Present
KS13	64.96ab	10.77de	40.15c	Yellow	Present
KS14	66.32a	14.20bc	38.68cd	Light yellow	Present
KS15	63.50bc	16.41ab	43.33ab	Dark yellow	Absent
KS16	60.25d	11.00de	41.22bc	Yellow	Absent
KS17	62.27c	10.70de	43.09ab	Dark yellow	Present
KS18	58.00e	12.07cd	42.25b	Light orange	Absent

Different letters in the same column indicate significant differences ($p < 0.05$) among clones.

Color is of primary importance for consumers in the judgment of different fruit groups and accepted as one of the important quality attributes. Lightness (L^*), red/greenness (a^*), and yellow/blueness (b^*) values of the 18 clones of cv. Sekerpare are shown in Table 2. The highest L^* values were observed in clones KS14 as 66.32 and followed by KS10 (65.41) while KS18 had the lowest L^* values (58.00) compared to the other clones. The lightness (L^*) was dependent on exposure to sun [39]. Higher a^* and b^* values were observed in KS12 (17.12) and 44.13 (KS3). The chromaticity coordinate a^* is the most important factor of maturity appearance describing color of the fruit. The intensity of red color normally indicates full maturity and ripeness [40]. Karaat [41] indicated L^*, a^* and b^* values in Sekerpare fruit as 64.17, 14.07 and 42.27, respectively, which is in agreement with our results. Karatas and Sengul [4] reported L^*, a^* and b^* values as 48.66, 19.41 and 19.72 in Sekerpare fruits which indicated differences with our study. In India, L^*, a^* and b^* values of cv. Shakarpara (Sekerpare) were 71.51, 1.03 and 40.56, respectively [16]. These results also reveal that Sekerpare is probably the name of a group of apricots because quite diverse results were obtained from different countries even in the same countries and also strong clonal variation is evident because different clones of the cultivar show significant variation in color values as well.

Among 18 clones, seven had yellow ground color, five clones had dark yellow ground color, four clones had light orange ground color and two clones had light yellow ground color (Table 2).

The majority of clones had red blushed skin and eight clones lacked red blushed skin development (Table 2). The majority of apricot (*Prunus armeniaca* L.) cultivars display orange or yellow background skin, whereas some cultivars are particularly preferred by consumers because of their red blushed skin on the background. Anthocyanins are

responsible for the blushed skin of apricots and the PaMYB10 gene was found as a positive regulator of anthocyanin biosynthesis in apricots and demonstrates that blush formation depends on light [42]. Apricots with a blush on orange or yellow skin are becoming more and more popular in the market due to their colorful appearance and excellent nutritional value [43].

3.2. Nutritional Traits

3.2.1. Organic Acids

The results on organic acid content in fruits of 18 clones of cv. Sekerpare apricots are reported in Table 3. The order of organic acid depending on their content was in descending order citric > malic > ascorbic > tartaric for all clones. Citric acid was the predominant organic acid for all studied clones that ranged from 728 to 915 mg/100 g. Malic acid and tartaric acid content of 18 Sekerpare clones were in range of 261–452 and 2.8–5.7 mg/100 g, respectively (Table 3). Ascorbic acid was identified in all clones from 13.9 mg to 18.6 mg/100 g and this indicates that apricot fruits contain a moderate level of ascorbic acid among fruit species. Organic acid results also indicated that citric, malic, tartaric and ascorbic acid concentrations are greatly varied among clones ($p < 0.05$). Organic acids are of increasing interest because of their role in plant physiology as cofactors, buffering agents, etc. [44]. The organic acid content and profile of fruit species differs depending on species, cultivars, accessions, etc. Alajil et al. [16] showed that citric acid comprised approximately 55% of the organic acids in apricot fruits and ranged from 550 to 1170 mg/100 g, followed by malic acid, which comprised approximately 25% of the organic acids and ranged from 400 to 1430 mg/100 g. Some organic acids have an antioxidant role (tartaric, malic and citric acids). Fruit acids that allow nutrient digestion and stimulate blood circulation are considered among the quality parameters of apricot fruits. Numerous studies have quantified and detailed the organic acid content of apricot fruits and there have been differences between them due to the species, location, used methods, sampling periods, etc. [16,44–52]. Fan et al. [49] showed that malic acid was mainly responsible for sourness of apricots, although malic acid was not the prominent organic acid in all apricot cultivars. It has also been reported that malic acid has an apparent acidic taste compared to citric acid or other organic acids in fruit [53].

Table 3. Organic acids in fruits of 18 Sekerpare clones (mg/100 g).

Clones	Citric Acid	Malic Acid	Ascorbic Acid	Tartaric Acid
KS1	880ab	275de	17.2ab	5.0ab
KS2	915a	261e	18.0ab	3.2cd
KS3	885ab	296de	18.6a	3.6c
KS4	904ab	405bc	17.6ab	4.4bc
KS5	822bc	350cd	15.0bc	4.0bc
KS6	816bc	427ab	15.8bc	5.7a
KS7	734cd	304d	14.0c	5.0ab
KS8	829bc	380bc	15.1bc	2.8cd
KS9	728d	369c	14.7bc	4.0bc
KS10	763cd	387bc	16.0b	5.0ab
KS11	838b	344cd	13.9c	3.6c
KS12	874ab	395bc	18.4ab	4.7b
KS13	769c	360cd	17.9ab	5.5ab
KS14	745cd	452a	15.7bc	4.2bc
KS15	796bc	412b	18.0ab	4.0bc
KS16	778c	435ab	18.2ab	3.4c
KS17	810bc	365cd	14.0c	3.2cd
KS18	785bc	422ab	14.4bc	3.6c

Different letters in the same column indicate significant differences ($p < 0.05$) among clones.

3.2.2. Individual Sugars and Sweetness Indices

Sugar content in different Sekerpare clones is shown in Table 4. The dominant sugar was sucrose in 18 clones that ranged from 7.11 to 9.94 mg/100 g, followed by glucose in the range of 2.03–3.31 g/100 g, respectively. Fructose content of fruits was relatively lower and found between 0.78 and 1.05 g/100 g (Table 4). Overall, the highest sucrose, glucose and fructose contents were found in KS17, KS1, KS3 and KS4 clones, respectively. Sweetness index (SI) was obtained between 13.35 (KS13) and 18.46 (KS17). Alajil et al. [16] used a number of apricots including Sekerpare in nutritional analysis and reported that sucrose was the dominant sugar, accounting for more than 63% of total sugars and ranged from 4.15 to 10.13 g/100 g, glucose contributed about 22% of total sugars and ranged from 2.28 to 4.31 g/100 g, and fructose contributed about 15% of total sugars and ranged from 1.22 to 4.19 g/100 g which shows parallel values with our study. Saridas and Agcam [44] examined individual sugars and organic acids in Agerik and Teberze apricot cultivars and reported that both contents change greatly according to cultivars. They reported sucrose, glucose and fructose content between 5.33 and 8.57, 1.90 and 2.95 and 0.60 and 0.88 g/100 g, respectively. Furthermore, the composition of individual sugars in the current study agrees with that documented by Akin et al. [33] for different Turkish apricot cultivars. İmrak et al. [45] found that the dominant sugar in apricot fruits was sucrose. Karataş and Sengul [4] reported sucrose content between 1.83 and 3.97 g/100 g in main apricot cultivars sampled in Malatya province in Turkey. Su et al. [46] used local apricots in sugar analysis and found that sucrose was the main sugar. Individual sugars differ in sweetness, with fructose perceived as sweeter than sucrose and sucrose perceived as sweeter than glucose [27]. The sweetness is important to apricot consumers and breeders, and it also leads to market acceptance of the fruit [47].

Table 4. Individual sugars (g/100 g) and sweetness indices (SI) in fruits of 18 Sekerpare clones.

Clones	Sucrose	Glucose	Fructose	Sweetness Index (SI)
KS1	9.06ab	3.24a	0.95ab	17.66ab
KS2	7.67bc	2.70bc	0.89b	15.10bc
KS3	8.23bc	3.02ab	1.05ab	16.55b
KS4	7.77bc	2.90abc	1.09a	15.90bc
KS5	8.11bc	3.10ab	0.86bc	16.03bc
KS6	7.90bc	2.22cd	0.67c	14.43cd
KS7	7.61bc	2.03d	0.78bc	14.09cd
KS8	8.10bc	2.78bc	0.99ab	16.00bc
KS9	8.40b	2.55bc	0.80bc	15.73bc
KS10	7.86bc	3.20a	1.02ab	16.16bc
KS11	8.33b	3.31a	0.90b	16.63b
KS12	7.85bc	2.39bcd	1.00ab	15.29bc
KS13	7.11c	2.14cd	0.70c	13.35d
KS14	7.56bc	2.29cd	0.82bc	14.39cd
KS15	8.06bc	2.63bc	1.02ab	15.78bc
KS16	7.37bc	2.55bc	1.05ab	14.92c
KS17	9.94a	2.85b	0.95ab	18.46a
KS18	9.12ab	2.47c	0.75bc	16.33bc

Different letters in the same column indicate significant differences ($p < 0.05$) among clones.

The sweetness index (SI) in fruits of Sekerpare clones ranged from 13.35 to 18.46 (Table 3). Previously, the sweetness index (SI) ranged from 13.58 to 22.30 in apricot fruits grown in India and Shakarpara reported a SI of about 13.58 [16], indicating lower values than our study. In Greece, SIs were found between 8.16 and 11.25 among apricot cultivars [27]. Our findings are consistent with those published SIs for Spanish apricot genotypes ranging from 8.5 to 15.9 [48]. Despite the fact that SI determines taste, the final perception of fruit sweetness is influenced by the presence of other compounds such as phenolics and other aroma compounds [49].

3.3. Nutraceutical Traits

Total Phenolic Content, Total Flavonoids, Total Carotenoids and Antioxidant Activity

Table 5 shows total phenolic, total flavonoid, total carotenoid content and antioxidant activity in fruits of 18 clones of cv. Sekerpare. We found statistically significant differences among clones in terms all nutraceutical traits at 0.05 level (Table 5).

Table 5. Nutraceuticals in fruits of 18 Sekerpare clones (fresh weight basis).

Clones	Total Phenolic Content (mg GAE/100 g)	TEAC (µmol TE/g)	Total Flavonoids (mg CE/100 g)	Total Carotenoid (mg/100 g)
KS1	58.4c	1.96bc	11.9c	7.80e
KS2	67.1a	2.16a	13.8ab	7.72e
KS3	56.0cd	1.92bc	12.7abc	9.30bc
KS4	61.3bc	2.06ab	10.5de	8.84c
KS5	59.3bc	1.96bc	9.3ef	10.05ab
KS6	64.4ab	2.12ab	12.9b	8.28cd
KS7	62.0b	2.09ab	12.1bc	8.65bc
KS8	58.0c	1.94bc	10.5de	9.25abc
KS9	49.9e	1.88bc	9.8e	9.10bc
KS10	55.0d	1.90bc	9.2ef	8.58cd
KS11	59.0bc	1.98bc	10.9d	8.51cd
KS12	63.0ab	2.09ab	13.3ab	10.13a
KS13	61.0bc	2.04ab	11.7abc	9.41b
KS14	58.9bc	1.99bc	13.6ab	8.44cd
KS15	49.5e	1.86c	11.4bc	8.16d
KS16	57.2cd	1.92bc	10.5de	8.95bc
KS17	60.4bc	2.01b	11.4cd	8.40cd
KS18	60.7bc	2.04ab	14.1a	8.88c

Different letters in the same column indicate significant differences ($p < 0.05$) among clones.

As mentioned in Table 5, total phenolic content was found between 49.5 and 67.1 mg GAE/100 g fresh weight basis. Saeed et al. [54] used fruits of eight apricot cultivars sampled from Pakistan and reported total phenolic content between 50 and 220 mg GAE/100 g FW indicating higher values than our results. Gecer et al. [18] used a number of wild apricots and cv. Aprikoz and found total phenolic content between 34.2 and 52.8 mg GAE/100 g which is in accordance with our study. In Hungary, a large number of apricot cultivars were used in nutraceutical analysis and total phenolic content greatly varied among cultivars from 12.0 to 89.0 mg GAE/100 g [7]. In Turkey, Karaat and Serce [10] used main apricot cultivars in Malatya and reported total phenolic content between 35.1 and 90.7 mg GAE/100 g. In the Mediterranean region in Turkey, apricots show total phenolic content between 14.4 and 177.1 mg GAE/100 g, with a mean value of 64.4 mg GAE/100 g indicating similarities with our samples [55]. Alajil et al. [16] reported total phenolic content among apricots, ranging from 25.31 (Shakarpara) to 89.95 mg GAE/100 g (Roxana). Wani et al. [56] and Leccese et al. [57] previously reported similar findings in apricots grown in India and Italy, respectively.

Total flavonoids were in range of 9.2–14.1 mg CE/100 g (Table 5). Saeed et al. [54] reported total flavonoids between 48 and 382 mg QE/100 g on fresh weight basis in apricots indicating higher values than our results. Alajil et al. [16] found that total flavonoid amounts in apricot genotypes ranged from 5.00 to 15.46 mg CE/100 g which indicated good agreement with our study. Our results are also consistent with those reported by Carbone et al. [58], who reported total flavonoid content (TFC) ranging from 1.9 to 12.0 mg CE/100 g for different apricot genotypes. Kafkaletou et al. [59] and Wani et al. [56] found TFC values ranging from 16.87 to 41.42 and 12.2 to 36.2 mg/100 g in apricot genotypes grown in Greece and India, respectively. Phenolics and flavonoids are essential measures of nutraceutical quality and have been linked to the treatment of a variety of chronic diseases, including cancer, cardiovascular disease, and neurodegeneration [60–64].

Total carotenoid content of 18 apricot clones of cv. Sekerpare were found between 7.72 and 10.13 mg/100. Gecer et al. [18] reported total carotenoid content ranged from 1.1 to 12.5 mg/100 g of edible portion in wild apricots and cv. Aprikoz. Ruiz et al. [65] found total carotenoid content between 1.5 and 16.5 mg/100 g among a large number of apricot cultivars in Spain. Shemesh et al. [66] found total carotenoid content between 0.5 and 9.5 mg/100 g among 113 apricot cultivars in Israel. These studies are in harmony with our results. The content and composition of carotenoids in apricots determine their fruit color. Apricots are high in carotenoids, which influence the color and visual appearance of the fruit; the color of the fruit can vary from yellow to orange depending on the carotenoids content [67]. Carotenoids are also essential dietary sources of vitamin A.

The antioxidant activity determined by TEAC assay in fruits of the 18 Sekerpare clones were evaluated and the results are presented in Table 5. Amongst the 18 clones of Sekerpare cultivar, the KS15 clone showed the lowest antioxidant activity (1.88 µmol TE/g), whereas the KS2 clone showed the highest antioxidant activity (2.16 µmol TE/g) (Table 5). The KS6 clone showed the second highest antioxidant activity (2.12 µmol TE/g) and the clones KS7 and KS12 showed the third highest antioxidant activity (2.09 µmol TE/g). In Italy, among the apricot cultivars analyzed, the variability of the antioxidant capacity was obtained showing a range from 1.36 to 4.55 µmol TE/g. They found that the latest cultivars had two-fold higher TEAC values with respect to the earliest ones [68].

Previous studies conducted in different horticultural plants indicated that horticultural crops rich for antioxidant components and antioxidant activity were found to be cultivar/genotype/clone dependent [69–80].

4. Conclusions

A detailed morphological, nutritional and nutraceutical traits analysis was reported here for the first time in a large number of clones of cv. Sekerpare. The results indicated that even in a small single growing location, Sekerpare clones showed rich diversity on most of the morphological traits and nutritional and nutraceutical compositions. The KS3 clone showed the highest fruit weight as 27.11 g. KS2, KS7 and KS12 had the highest antioxidant activity. The promising clones could be used as breeding material. The results could have practical implications for orchard management to select better Sekerpare clones and bring them into production.

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