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Physical, chemical and sensory characteristics of dried walnut varieties and promising variety candidates in Türkiye

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Summary

In this study some important physical, chemical and sensory characteristics of four walnut varieties (‘Chandler’, ‘Fernor’, ’Yalova 3’ and ‘Şebin’) and five promising variety candidates (‘Orman-77’, ‘İstanbul-2’, ‘144-84’, ‘Antalya-7’, ‘74-C’) were investigated. These findings were the first comprehensive report on the walnut properties of the above-mentioned candidates. ‘Antalya-7’ and ‘Orman-77’ showed attractive fruit characteristics such as high whole kernel separation from shell and easy shell cracking. ‘Antalya-7’ attracts attention with fatty acids composition and appearance and taste scores. On the other hand, for ‘Orman-77’, smooth shell surface, thin shell, high kernel ratio and high whole kernel separation from the shell were determined as positive features. The polyunsaturated fatty acids content order of variety candidates was determined as ‘İstanbul-2’ = ‘Antalya-7’ > ‘144/84’ > ‘Orman-77’ > ‘74-C’ (from high to low).

Key world: *Juglans regia*, new genotype, walnut kernel, walnut oil, shell cracking, linoleic acid

Introduction

Climate change, competitive conditions in the market and consumer expectations significantly affect the variety selection in walnut (*Juglans regia* L.) production (Hassani et al., 2020; Arab et al., 2020). Efforts have been made to develop new varieties to respond to both changing climatic conditions and the high-quality expectations of consumers (Arab et al., 2020). Plant flora of Asia and the Balkans has rich genetic biodiversity that ensures to the breeder to collecting new walnut genotypes and the potential to select higher quality walnut fruits than standard varieties (Vahdati et al., 2019; Jaćimović et al., 2020). Despite the ancient culture of walnut, breeding studies started in the twentieth century. Today, numerous walnut biodiversity assessment and walnut breeding studies have been carried out in many countries (Bernard et al., 2018; Zhao et al., 2020). It has been stated that high differences in fruit characteristics are observed and the use of local walnuts with high variation in breeding programs has potential in the selection of new varieties (Yuemei et al., 2014; Vahdati et al., 2019). Walnut genetic resources have been used in various countries for the discovery of promising genotypes (Chen et al., 2013; Zhao et al., 2020).

In walnut selection studies, it was observed that the agricultural features, production yield and fruit quality were examined (Bujdosó et al., 2010; Vahdati et al., 2019). In these studies, fruit quality characteristics such as color, size, flavor, easy cracking and separation of the whole kernel as well as properties such as oil content and fatty acid composition related to healthy nutrition were determined (Vahdati et al., 2019; Richards et al., 2020; Yoshinaga-Kiriake et al., 2022).

Türkiye is one of the originating centers of walnut and has advantages as a walnut breeder country because of its unique geographic location and existing genetic diversity which trees exhibit considerable variation in respect of fruit characters (Sutyemez et al., 2019; Bozhüyük et al., 2022).

This study aimed to determine the physical, chemical and sensory characteristics of dried fruits belonging to four standard varieties and five promising variety candidates. Variety candidates were selected according to evaluation results of their superior agricultural characteristics such as high yield and disease resistance (Orman, 2018).

Material and methods

Material

Dried fruit of four walnut varieties and five variety candidates were used as materials. Trees were cultivated under the same conditions in Genetic Resources Orchard of Ataturk Horticultural Central Research Institute. Walnuts were harvested in 2017, 2018 and 2019 years. Results were given as average of the three years. Origin and name of varieties and variety candidates were given in Tab. 1. Since the ripening times of the varieties were different from each other, observation for harvest has been started from the end of July. Harvest was carried out until the end of September. Harvest was done by hand when one crack was seen on the green husk of walnut fruit.

Tab. 1: Origin and name of cultivars/candidate cultivars

Material	Origin	Name
Variety	Turkey	‘Yalova 3’, ‘Şebin’
	USA	‘Chandler’
	France	‘Fernor’
Variety candidate	Turkey	‘Orman-77’, ‘İstanbul-2’, ‘144-84’, ‘Antalya-7’, ‘74-C’

Methods

Root vegetable peeler machine (7, Avamore, United Kingdoom) was used for removing the green hull. The walnuts were spread as single row on drying trays and they were dried in a room that has air circulation but does not see the sun (~24 ºC, ~67% relative humidity). The drying process was terminated when the moisture content decreased to approximately 5%. After that, walnut samples separated for kernel analysis and their shells were cracked with a hand-operated cracker (Fınkır, Türkiye). The shell and kernel of the walnut were separated by hand. Graphical abstract of this study was given in Fig. 1.

Physical analysis

In physical analysis, 30 randomly selected walnuts were taken for each sample group and measurements were made. Fruit length, fruit width and shell thickness were measured with a digital caliper. Kernel ratio was determined by following formula; Kernel ratio (%) = kernel weight / whole walnut weight × 100. The color of the kernel was determined as “light”, “medium” and “dark”. They were scored by the panelists (consists of 5 food and agricultural engineers who are trained and experienced in the physical analy-

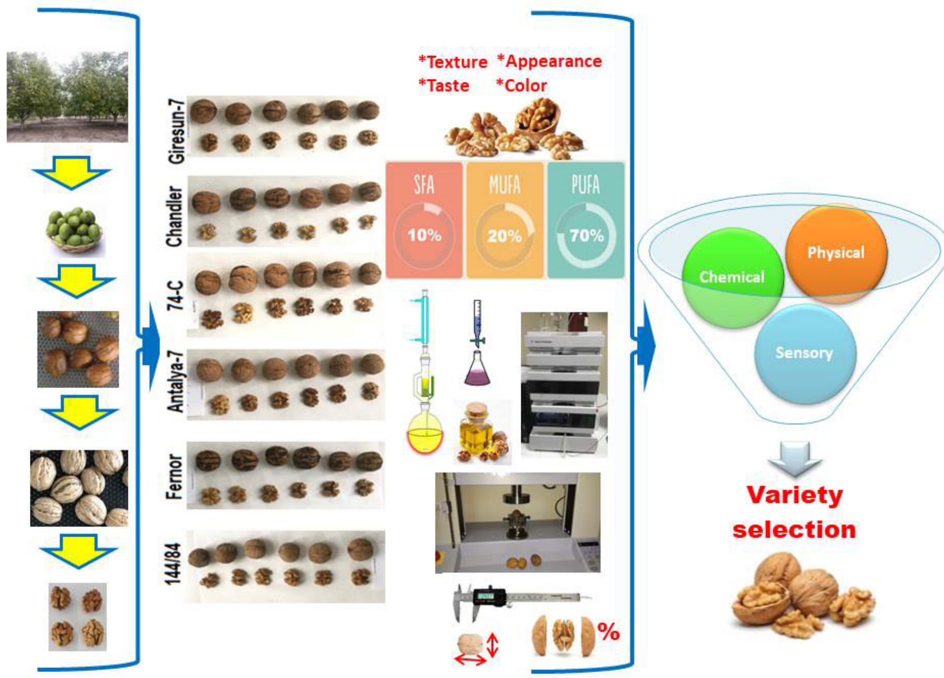

Fig. 1: Graphical abstract of this study

sis of walnuts) as light: 1, medium: 2 and dark: 3 (MURADOGLU, 2005). Shell and kernel roughness was determined by the panelists with scoring as smooth: 1, medium: 2 and rough: 3 (MURADOGLU, 2005). Universal tester machine (Shimadzu AGS-X, Japan) was used for determination of minimum shell cracking force of walnut (the maximum force that could be applied was 45 N). Walnuts were fixed vertically with equipment under the force application probe of this tester machine and the test was terminated when the first crack was observed at the walnut. Numerical color values (L*, a* and b*) of kernels were determined by color meter measuring (Konica Minolta, CD-400, Japan). Sensory kernel color was determined as "light", "yellow", "brown" and "dark" considering the color scale of California Dry Fruit Association (PARIS, 2013). They were scored by the panelists as light: 1, yellow: 2, brown: 3 and dark: 4. Surface roughness of kernel was determined by considering the density of the roughness on the kernel. It has been determined as "smooth", "medium" and "rough" (PARIS, 2013). They were scored by the panelists as smooth: 1, medium: 2 and rough: 3. Number of walnuts showing shriveled (include decayed, incomplete and not fully filled) kernel was counted and expressed as a percentage to determine the shriveled ratio of kernel (YARILGAC, 1997). The shells of walnuts were cracked with a hand operated cracker (Fınkır, Türkiye). It was tried to separate kernel and shell by hand carefully and without damaging the kernel as possible as. The ratio of the number of whole and half kernels to the number of samples was expressed as percentage (YARILGAC, 1997).

Chemical analysis

For chemical analysis, 30 fruits were taken randomly from each sample group and their kernels were ground and mixed to make them homogeneous. 2.5 g of ground sample was placed in the measuring chamber and the measurement was made with a water activity measuring device (Novasina AG, Switzerland) at 25 °C ambient temperature. Oil content of kernels was determined with soxhlet apparatus with petroleum ether (maximum temperature 55 °C) according to MURADOGLU (2005). Free fatty acid content and peroxide value of walnuts oils which extracted by soxhlet apparatus were determined with titration as reported by official method (TFC, 2014). Fatty acid composition analysis of walnut oils was done with the standard fatty acid methylation method of IUPAC (1992) by using a gas chromatography device (Agilent Technologies, 6890N, USA). Chromatographic conditions were as follows: DB-23 column (60 m × 0.25 mm, 0.15 µm film thickness, Agilent J&W DB-23, USA), split/spiltless injector, split ratio; 1/50, flame ionization detector (280 °C), gas flow speed; 1.5 mL/min, injection volume; 1 µL, injector temperature; 250 °C. The flow rate of the dry air, hydrogen and helium (carrier gas) were 450 mL/min, 40 mL/min and 30 mL/min, respectively. Column temperature held at 50 °C for 1 min, increased by 25 °C/min to 175 °C, increased by 4 °C/min to 230 °C and held at 230 °C for 5 min. Fatty acid methyl ester mix (Sigma-Aldrich, Supelco 37 components FAME Mix, Germany) wad used as a standard to determine the exit times of fatty acids from the column and its relative proportions. The composition (% in fatty acids) of the fatty acid was determined by dividing the area of individual fatty acid peaks by the area of the total peaks. Fatty acid components confirmed with MS detector (Agilent 5975C MS, USA) based on data from WILEY and OIL ADAMS libraries. Chemical analyses were performed at least 3 replications. Saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and unsaturated fatty acids (UFA) were calculated according to the following formulas (BATUN et al., 2017);

SFA (%) = palmitic acid % + stearic acid % + arachidic acid % + myristic acid %

MUFA (%) = oleic acid % + eicosenoic acid %

PUFA (%) = linoleic acid % + linolenic acid %

UFA (%) = MUFA % + PUFA %

Sensory analysis

For sensory analysis, the level of appreciation of the kernel was evaluated with a five-degree (extremely likes: 5, moderately likes: 4, neither like nor dislike: 3, moderately dislikes: 2 and extremely dislikes:1) sensory test form by well-experienced 12 panelists. Panelists scored the appearance, color, texture and taste characters of kernel samples (Bujdosó et al., 2010). The panelist group consisted of an equal number of non-smoking men and women. After the sensory analysis, the test forms of the panelists were randomly divided into 3 groups. Each group was considered as one replication.

Statistical analysis

The research was planned according to one factorial (variety/variety candidates) completely randomized design. Walnut samples of each year were evaluated as one trial. JUMP package program was used for statistical analyses ($p<0.05$).

Result and discussion

Walnut trade depends on whole walnut or kernel business; thus, both whole walnut and kernel characteristics were determined in this study. It has been reported that walnut varieties with smooth shell surfaces, high kernel percentage and thin shell have an advantage in the market (Zhao et al., 2020). Large fruit and ease of shell cracking are among the first desired characteristics in walnuts. In other words, high fruit size/weight and requiring less force for shell cracking are important selection criteria for walnuts. The physical characteristics of dried walnut were given in Tab. 2. Shell color and fruit weight were reported as 1.15 (at 1-3 scale) and 13.41 g (Beyhan and Demir, 2006). Sideli et al. (2020) and Li et al. (2016) reported the average first cracking force of walnuts as 23.58 and 19.1 N. In a walnut breeding study, fruit width, fruit length, fruit weight and shell thickness were reported between 2.8-3.3 cm, 3.5-4.3 cm, 10.5-15.0 g and 1.2-1.8 mm, respectively (Oguz and Askin, 2007). Beyhan and Demir (2006) and Iordănescu et al. (2021) reported the roughness of shell surface as 1.6 and 1.9 by using a three-grade roughness scale.

It has been determined that walnuts of 'İstanbul-2' and 'Fernor' have the highest shell roughness, whereas walnuts of 'Orman-77' have the lowest roughness. '74-C' had the highest dried fruits weight (20.28 g) and it was followed by '144/84', 'Fernor' and 'Yalova-3'. It has been determined that the walnuts with the thickest shell belong to 'İstanbul-2' (2.30 mm) and 'Antalya-7' (2.05 mm). It has been observed that the walnuts, which have the lowest power requirement for shell cracking in the study, belong to 'Şebin' and 'Antalya-7' (16.20 and 17.61 N). The highest power requirement was found for 'İstanbul-2' (45 N <) followed by 'Fernor' (27.29 N). It was seen that some walnut variety candidates have a thinner shell and need lower force for first cracking than the values reported in the literature. Only 'Orman-77' sample has smoother shell surface and all samples had darker shell color than cited literature.

Kernel weight, kernel ratio and the ratio of light-colored walnuts of 'Chandler' fruit were reported as 6.5 g, 49% and 90-100% respectively (Anonymous, 2019). Kernel weight and ratio of new walnut genotypes were reported between 5.7-6.9 g and 41.1-50.3% (Oguz and Askin, 2007). Kernel weight, kernel ratio and oil content of dried kernel for 'Yalova-3' variety were reported in order as 6.4 g, 53.8% and 71.0% (Anonymous, 2019). It has been reported that the ratio of whole and half kernels obtained from machine-cracked walnuts to all samples is 84.19%. This rate was reported as 35.81% in hand-cracked walnuts (Hussain et al., 2018). Ratio of shriveled kernel was reported between 0-10% for different walnut genotypes (Simsek, 2010). It was observed that the surface values of kernels belonging to different walnut genotypes were reported between 0.8-1.3 according to a scale of 1-3 (Lynch et al., 2016). Physical characteristics of dried kernel were given in Tab. 3. In this study, dry fruit weight, kernel ratio and oil content (in dry matter) of Yalova-3 were determined as 14.22 g, 50.64%, and 37.27% respectively. In this study fruit weight, kernel ratio and kernel color of 'Chandler' was determined as 13.39 g, 46.89% and 1.2 (light) color. Highest ratio for separation of whole kernel from shell was determined for walnuts of 'Orman-77' with 92.5% ratio. 'Antalya-7' and 'İstanbul-2' followed it. Lowest ratio was determined for '74-C'. Statistically significant difference was not observed among samples in terms of shriveled kernel. The highest kernel ratio value was determined in walnuts belonging to 'Şebin' (59.65%) and 'Orman-77' (56.56%) and the lowest kernel ratio was found for '74-C' (44.99%). Kernel color was darker and roughness was higher than cited literature. On the other hand, averages of whole and half kernel separation and shriveled kernel were lower. Similar results were seen for kernel ratio in cited literature. In the nuts industry, half kernels can be sold at higher prices than broken kernels. Thin shell and/or a fragile shell structure of walnut are favorable characters for walnuts. That makes possible to obtain higher ratio of whole or half kernels for high selling price (Richards et al., 2020).

The kernel color of walnuts is very important in terms of both commerce and consumer attraction. Thus, kernel color is considered as an important selection criterion in selection studies (Sarikhani et al., 2021). In this study, walnut kernel colors were determined as light, yellow and brown by the visual evaluation. Dark color has not been identified. Kernel surfaces were determined in the range of smooth and medium. None of the walnut samples have been determined as high rough. It was determined that there was no statistically signifi-

Tab. 2: Physical characteristics of dried walnut

Sample	Fruit width (cm)	Fruit length (cm)	Shell thickness (mm)	Dried fruit weight (g)	Force for first cracking (N)	Shell color[1]	Roughness of shell surface[2]
'144/84'	3.20±0.15^{b}	3.93±0.11^{cd}	1.59±0.15^{bc}	15.32±0.85^{b}	24.81±1.96^{b}	2.1±0.11	2.0±0.12^{b}
'74-C'	3.90±0.16^{a}	4.45±0.15^{a}	1.70±0.20^{b}	20.28±0.66^{a}	23.55±1.03^{bc}	2.2±0.20	2.6±0.20^{ab}
'Antalya-7'	3.13±0.10^{b}	3.57±0.12^{e}	2.05±0.15^{a}	12.11±0.25^{e}	17.61±0.98^{d}	1.6±0.14	2.2±0.11^{ab}
'Orman-77'	3.17±0.10^{b}	4.10±0.10^{bc}	1.60±0.10b^{c}	14.09±0.43^{cd}	22.67±1.24^{c}	1.5±0.16	1.3±0.13^{c}
'İstanbul-2'	3.20±0.13^{b}	4.13±0.10^{b}	2.30±0.07^{a}	13.51±0.16^{d}	45<	1.7±0.13	2.7±0.20^{a}
'Chandler'	3.13±0.12^{b}	3.75±0.12^{de}	1.35±0.08^{c}	13.39±0.27^{d}	24.01±0.85^{bc}	1.2±0.24	2.0±0.13^{b}
'Fernor'	3.27±0.10^{b}	4.05±0.15^{bc}	1.67±0.08^{b}	14.67±0.33^{bc}	27.29±1.20^{a}	1.3±0.22	2.7±0.15^{a}
'Şebin'	3.37±0.15^{b}	4.00±0.12^{bc}	1.41±0.12^{bc}	11.09±0.48^{e}	16.20±1.41^{d}	1.7±0.15	2.0±0.16^{b}
'Yalova-3'	3.16±0.12^{b}	4.05±0.18^{bc}	1.63±0.09^{bc}	14.22±1.16^{bd}	22.22±1.34^{c}	1.7±0.10	2.1±0.16^{ab}
CV	5.36	2.59	4.60	8.92	5.11	14.00	17.60

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). When statistically insignificant differences were found among the values in the column, lettering was not done. Different letters indicate statistical difference for each column. CV: coefficients of variation.
[1] Light: 1, medium: 2 and dark: 3. [2]Smooth: 1, medium: 2 and rough: 3.

cant difference among the kernel color and the roughness surface for the kernel samples.

In general, walnuts are offered for sale as dried nuts or used in the dessert industry for the purpose of decoration and adding flavor on dessert. High brightness and light colors of kernels are required for both dried nut industry and dessert decoration (BENTO et al., 2016; LI et al., 2022). It was determined that the lightness (L* value) kernel belong to 'Fernor' (50.22), followed by 'Chandler' (41.19) and '144.84' (40.77). The highest yellow color intensity (b* value) was found for 'İstanbul-2 (30.16)' and 'Chandler' (28.36). Color values were given in Tab. 4. L*, a* and b* color values for walnut kernels reported between 39.58-56.49, 6.72-8.75 and 15.37-18.85 respectively (ALTUNTAS and ERKOL, 2009). Lightness of kernels belongs to 'Chandler' and 'Howard' varieties were found between 47.1-49.8 by ORTIZ et al. (2019). In this study similar results were found for L* value with their results but a* and b* values were found higher.

The chemical characteristics of kernels are given in Tab. 5. Kernel belonging to 'Şebin' had the highest oil content (49.66%). On the other hand, kernels of 'İstanbul-2' (33.02%) had the lowest dry matter. It has been determined that the moisture content and water activity values of walnuts are between 4.54-5.56% and 0.44-0.52 respectively. Oil and moisture contents of walnuts belonging to different varieties were reported between 54.07-67.63% and 2.70-3.79% (OGUZ and ASKIN, 2007). Water activity and moisture content of dried walnut kernels were reported between 0.32-0.69 and 3.2-5.0% respectively (TAJ et al., 2023). ADILETTA et al. (2020) found the free fatty acid content and peroxide value of dried kernel as 0.14% (oleic acid) and 2.60 meq O_2/kg oil. Moisture, oil and free fatty acid content and

Tab. 3: Physical characteristics of dried kernels

Sample	Kernel color[1]	Roughness of kernel surface[2]	Separation of whole and half kernel from shell (%)	Shriveled kernel (%)	Kernel ratio (%)
'144/84'	2.8±0.32	2.2±0.13	79.5±2.25^{cd}	4.1±0.22^{c}	52.32±2.27^{b}
'74-C'	2.5±0.36	2.1±0.18	68.03±1.87^{e}	7.3±0.41^{a}	44.99±2.13^{e}
'Antalya-7'	1.5±0.22	1.7±0.11	85.5±2.06$^{a\text{-}c}$	2.0±0.34^{e}	50.38±1.75^{bc}
'Orman-77'	2.0±0.22	2.8±0.0.9	92.50±3.47^{a}	4.3±0.13^{c}	56.56±1.36^{a}
'İstanbul-2'	2.5±0.34	2.1±0.13	88.5±3.05^{ab}	4.2±0.11^{c}	48.16±2.08^{cd}
'Chandler'	1.5±0.16	2.2±0.12	82.00±2.46$^{b\text{-}d}$	3.4±0.23^{d}	46.89±1.23^{de}
'Fernor'	1.1±0.19	1.8±0.17	81.50±3.72$^{b\text{-}d}$	3.1±0.34^{d}	48.19±1.34^{cd}
'Şebin'	1.8±0.13	2.2±0.15	77.24±2.68^{d}	2.9±0.32^{d}	59.65±1.65^{a}
'Yalova-3'	2.1±0.24	2.6±0.18	78.03±3.51^{d}	5.1±0.40^{b}	50.64±1.28^{bc}
CV	32.5	25.1	3.85	16.08	3.34

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). When statistically insignificant differences were found among the values in the column, lettering was not done. Different letters indicate statistical difference for each column. CV: coefficients of variation. [1] Light: 1, Yellow: 2, Brunette: 3 and Dark: 4. [2] Smooth: 1, medium: 2 and rough: 3

Tab. 4: L*, a* and b* values of kernels

	'144/84'	'74-C'	'Antalya-7'	'Orman-77'	'İstanbul-2'	'Chandler'	'Fernor'	'Şebin'	'Yalova-3'
L*	40.77±1.84^{bc}	34.26±0.80^{j}	36.18±1.23^{hi}	39.65±1.20$^{c\text{-}f}$	39.17±1.33$^{d\text{-}f}$	41.19±1.08^{b}	50.22±1.16^{a}	38.62±1.06^{f}	33.81±1.13^{j}
a*	8.38±0.95$^{b\text{-}f}$	9.48±0.54^{a}	9.34±0.87^{ab}	9.12±0.36a^{bc}	8.94±0.55$^{a\text{-}d}$	7.79±0.26$^{e\text{-}g}$	6.84±0.49^{fg}	8.40±0.38$^{b\text{-}f}$	9.17±0.46$^{a\text{-}c}$
b*	26.53±1.06^{bc}	25.48±1.20^{cd}	25.23±1.14$^{c\text{-}e}$	22.52±1.17^{ef}	30.16±0.92^{a}	28.36±1.18^{ab}	25.14±1.11$^{c\text{-}e}$	26.47±1.11^{bc}	23.56±1.18$^{d\text{-}f}$

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). Different letters indicate statistical difference for each row. Coefficients of variations for L, a and b were 3.32, 7.54 and 4.69 respectively.

Tab. 5: Chemical characteristics of kernels

Sample	Water (%)	Oil in dry matter (%)	Water activity	Free fatty acid content (% oleic acid)	Peroxide value (meq O_2/kg oil)
'144/84'	5.13±0.18^{ab}	44.27±1.65^{b}	0.47±0.11	0.28±0.12^{d}	2.87±0.18$^{e\text{-}g}$
'74-C'	5.10±0.13^{ab}	41.7±1.87b^{c}	0.48±0.14	0.78±0.04^{a}	2.59±0.12^{fh}
'Antalya-7'	5.34±0.26^{ab}	43.81±2.13^{b}	0.48±0.12	0.46±0.03^{c}	4.52±0.20^{ac}
'Orman-77'	5.23±0.22^{ab}	39.47±2.54^{cd}	0.49±0.08	0.27±0.12^{d}	3.78±0.17^{cd}
'İstanbul-2'	5.39±0.15^{ab}	33.02±1.11^{e}	0.52±0.13	0.27±0.11^{d}	2.89±0.12$^{d\text{-}g}$
'Chandler'	5.56±0.16^{a}	36.54±1.05^{de}	0.44±0.15	0.60±0.08^{b}	1.72±0.11^{i}
'Fernor'	4.96±0.31^{bc}	38.71±1.26^{cd}	0.46±0.17	0.38±0.10^{cd}	4.50±0.12^{bc}
'Şebin'	4.54±0.22^{c}	49.66±1.32^{a}	0.47±0.11	0.31±0.08^{d}	1.88±0.09^{hi}
'Yalova-3'	5.23±0.22^{ab}	37.27±1.05^{d}	0.51±0.13	0.29±0.06^{d}	2.38±0.10^{gi}
CV	4.22	4.77	8.21	2.76	9.80

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). When statistically insignificant differences were found among the values in the column, lettering was not done. Different letters indicate statistical difference for each column. CV: coefficients of variation.

peroxide value of samples determined between 4.54-5.56%, 33.02-49.66%, 0.27-0.78% (oleic acid) and 1.72-4.52 meq O_2/kg oil. 'Şebin' has the highest oil content. All samples have lower water activity than the limit of safety storage, which is indicated for dried fruits (Syamaladevi et al., 2016).

More than 90% of walnut kernel oil was reported as UFA and the oleic acid content ranges from 12 to 20% (Maguire et al., 2004; Huang et al., 2020). Yoshinaga-Kiriake et al. (2022) reported the linoleic, oleic, linolenic and palmitic acid of dried walnut kernel oils were reported as 71.7, 13.0, 11.1 and 2.8% (in fatty acids). Walnuts have a rich content of PUFA, especially linoleic acid and linolenic acid (Moigradean et al., 2013). Fatty acid composition of walnut oils was given in Tab. 6. In this study, the highest linoleic acid content was determined in walnuts belonging to '144/84', 'Antalya-7', 'Fernor' and 'İstanbul-2'. It was also reported that the high linoleic acid in walnut oil makes it a unique food (Yoshinaga-Kiriake et al., 2022; Bozhüyük et al., 2022). This feature attracts the attention of consumers who desire a healthy diet. The highest linolenic acid content was determined in walnuts belonging to '74-C', 'Chandler', 'İstanbul-2' and 'Şebin'. Oleic acid is one of the most important MUFA in diet because of its significant nutritious and therapeutic effects (Chen et al., 2018). In this study '74-C' (25.95% in fatty acids) had the highest oleic acid content and it was followed by 'Orman-77' and 'Yalova-3'.

PUFA content of walnut oil was reported between 61.8-75.3% (Bakkalbasi et al., 2012). PUFA, MUFA and SFA of walnut oil samples were reported 84%, 13% and 2%, respectively (Hama and Fitzsimmons-Thoss, 2022). The SFA/UFA ratios of walnut oils were reported between 0.06-0.17 (Batun et al., 2017). Lower SFA/UFA may be evaluated as higher nutritional quality regarding to fatty acid composition of food (Javidipour and Tunçtürk, 2007). SFA, MUFA, PUFA and UFA ratios were determined between 9.19-10.37%, 13.04-25.86%, 60.74-72.14% and 84.98-88.06% in this study. PUFA order of variety candidates were determined as 'İstanbul-2' = 'Antalya-7' > '144/84' > 'Orman-77' > '74-C' (from high to low).

Sensory analyze scores of kernels were given in Tab. 7. Significant sensory differences were reported among walnut varieties (Sinesio et al., 2001; Amin et al., 2017). Kernel appearance and taste were reported between 7.6-8.9 and 6.26-7.13 in sensory evaluation according to a nine-point hedonic scale (Amin et al., 2017). Kernel color and taste of Hungarian bred walnut cultivars were reported between 3.0-4.0 and 3.6-3.8 in a five-degree sensory test (Bujdosó et al., 2010). Colarič et al. (2006) reported the texture and taste of dried walnut kernels between 5.2-6.6 and 5.9-7.1 in a ten points scale.

Taste and color values were determined higher than Colarič et al. (2006) and Bujdosó et al. (2010) and similar with results of Amin et al. (2017). In this study, statistically significant differences were found for appearance, color, texture and taste characters in this study as a result of genetic variation of walnuts. It was determined that 'Antalya-7' and 'İstanbul-2' were in the highest statistical group in all of the evaluated sensory characteristics. On the other hand, '144/84' and 'Chandler' were found to be in the highest statistical group in three of the evaluated characters.

Conclusions

In this study, the characteristics of walnuts grown under the same conditions, harvested when they reach maturity at the same level, peeled off the husk with the same method and dried under the same conditions were determined. In this way, only differences arising from genetic diversity were determined. Within this study, the required knowledge was reached for the final selection step of variety candidates. Also, walnut and kernel characteristics of widely cultivated standard varieties were reported.

Since the walnut kernel is used in the pastry, bakery and dried nuts sector, it is desired to have attractive properties such as light color and unfragmented kernel. High mass ratio, size and taste also can maximize the income of walnut farmerss or processor. Therefore,

Tab. 6: Fatty acid composition of walnut oils (% in fatty acids)

Fatty acids	'144/84'	'74-C'	'Antalya-7'	'Orman-77'	'İstanbul-2'	'Chandler'	'Fernor'	'Şebin'	'Yalova-3'	CV
Myristic acid	1.17±0.25	1.13±0.22	1.23±0.20	1.24±0.23	1.24±0.20	1.11±0.16	1.19±0.15	1.15±0.14	1.05±0.12	6.15
Palmitic acid	5.86±0.44	5.98±0.48	5.72±0.36	5.73±0.46	5.67±0.63	5.79±0.39	6.50±0.74	6.06±0.77	5.98±0.51	7.13
Stearic acid	3.01±0.85	2.38±0.74	2.45±0.58	2.48±0.71	3.12±0.58	2.45±0.65	2.52±0.58	2.67±0.56	2.51±0.68	6.36
Oleic acid	17.94±0.92^{d}	25.95±1.23^{a}	16.80±0.89^{de}	22.99±1.28^{b}	15.19±1.13^{e}	13.66±0.76^{f}	13.22±0.93^{f}	20.76±1.22^{c}	23.12±1.43^{b}	8.23
Linoleic acid	58.20±3.64^{a}	50.69±2.77^{c}	59.87±3.67^{a}	54.91±2.65^{b}	58.91±3.26^{a}	59.05±3.56^{a}	61.07±3.30^{a}	53.29±3.68^{b}	54.00±2.49^{b}	4.13
Linolenic acid	9.17±0.87^{d}	11.13±0.94^{bc}	11.23±0.80^{bc}	9.36±0.84^{d}	13.03±0.96^{a}	12.72±0.94^{a}	11.57±0.87^{b}	11.65±0.81^{b}	10.59±0.54^{c}	3.96
Arachidic acid	0.13±0.08	0.16±0.08	0.12±0.08	0.13±0.09	0.22±0.10	0.11±0.07	0.13±0.10	0.18±0.11	0.16±0.08	7.50
Eicosenoic acid	0.16±0.07	0.20±0.08	0.16±0.06	0.20±0.06	0.18±0.05	0.15±0.08	0.15±0.06	0.16±0.07	0.16±0.05	7.54
SFA	10.37±1.09	9.65±0.42	9.19±0.63	9.75±0.62	10.25±0.42	9.79±0.62	10.27±0.38	10.06±0.26	9.83±0.18	2.98
MUFA	18.10±0.46^{d}	25.86±0.21^{a}	16.96±0.44^{e}	23.75±0.57^{b}	15.37±0.15^{f}	14.48±0.49^{g}	13.04±0.46^{h}	20.92±0.24^{c}	23.27±0.38^{b}	1.34
PUFA	67.37±0.09^{b}	60.74±1.11^{e}	71.10±0.78^{a}	62.76±1.07^{d}	71.12±1.36^{a}	70.50±0.49^{a}	72.14±1.04^{a}	64.94±0.44^{bc}	64.59±0.97^{cd}	0.82
SFA/UFA	0.12±0.009	0.11±0.005	0.11±0.006	0.11±0.009	0.12±0.008	0.11±0.007	0.12±0.001	0.12±0.009	0.11±0.008	3.15

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). When statistically insignificant differences were found among the values in the row, lettering was not done. Different letters indicate statistical difference for each row. CV: coefficients of variation.

Tab. 7: Sensorial analyze scores (0-5)

Characters	'144/84'	'74-C'	'Antalya-7'	'Orman-77'	'İstanbul-2'	'Chandler'	'Fernor'	'Şebin'	'Yalova-3'	CV
Appearance	4.57±0.25^{a-c}	4.13±0.17^{d}	4.52±0.19^{a-c}	4.10±0.22^{d}	4.67±0.17^{ab}	4.72±0.20^{a}	4.40±0.22^{b-d}	4.47±0.18^{a-c}	4.28±0.16^{cd}	4.52
Color	4.47±0.21^{a-d}	4.35±0.25^{b-f}	4.58±0.14^{a-c}	3.98±0.21^{fg}	4.70±0.33^{ab}	4.85±0.26^{a}	4.75±0.20^{ab}	4.58±0.22^{a-c}	4.53±0.24^{a-d}	4.63
Texture	4.20±0.17^{a-d}	3.70±0.18^{e}	4.27±0.28^{ac}	3.95±0.27^{b-e}	4.30±0.25^{ab}	4.10±0.19^{a-e}	4.13±0.18^{a-d}	3.88±0.17^{c-e}	4.20±0.16^{a-d}	6.61
Taste	4.12±0.15^{bc}	4.10±0.18^{c-e}	4.80±0.26^{a}	4.12±0.16^{cd}	4.85±0.28^{a}	4.25±0.17^{b-d}	3.95±0.23^{d-f}	4.10±0.23^{c-e}	4.38±0.20^{bc}	6.62

Values expressed as the mean ± standard deviation derived from the analyses results of three years (n = 3). Different letters indicate statistical difference for each column. CV: coefficients of variation.

that in this research, these important walnut and kernel characteristics were determined. In addition to economically important walnut and kernel characteristics, oil content and fatty acid composition, which are related to nutritional physiology, were determined. Walnut has an important place in the diets of healthy eating. It is thought that '74-C' with high MUFA 'may be liked by consumers who care about healthy nutrition. 'Antalya-7' had high whole or half kernel separation from the shell, easy shell cracking, as well as high sensory scores. 'Orman-77' also has a smooth shell surface, thin shell, high kernel ratio, high whole kernel separation from shell and free fatty acid content. The overall evaluation showed that walnut of 'Antalya-7' and 'Orman-77' had promising characteristics. Therefore, they have the potential to attract consumer and producer attention. They will be able to offer higher profit opportunities with kernel mass and whole or half separation ratio and color value. As a result, it seems possible to obtain new walnut varieties that are both healthier and more attractive features, with breeding and selection studies to be carried out in the future.

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Conflict of interests

No potential conflict of interest was reported by the author.

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