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The effects of different harvest maturity and methods on fruit and oil quality of olive (*Olea europea* L. cv. Ayvalık Yağlık)*

Farklı hasat olgunluğu ve yönteminin zeytinin (*Olea europaea* L. cv. Ayvalık Yağlık) meyve ve zeytinyağı kalitesine etkilerinin belirlenmesi

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ABSTRACT

Objective: This study was conducted to determine the effects of harvest time and method on fruit and oil characteristics of 'Ayvalık Yağlık', a major olive cultivar in Turkey.

Material and Methods: Early, optimum and late harvests were made by hitting with a wood stick (control), pneumatic beater, and branch shaker in a conventional olive grove located in Edremit district of Balıkesir province in western Turkey. Harvested olive fruits were stored at 18-20°C for 3 days, and physical, biochemical attributes, free acidity, and fatty acid composition, and mechanical damage caused by tested harvest methods were evaluated.

Results: Mechanical damage index and free fatty acidity were lower in olive fruits harvested by branch shakers compared to those dropped down by stick. Fruit weight, maturity index, oil content and linoleic acid content increased with the progress of harvest date, while color, moisture content, free fatty acids, total phenolics, and palmitic, stearic, and linolenic acid ratio decreased at the last harvest date.

Conclusion: The results showed that significant changes in some physical and chemical properties of the olive fruit occur with the progression of maturity, and using branch shakers and harvesting on the 2nd and 3rd harvest dates are recommended for Ayvalık variety under the experimental site conditions.

Keywords: Fatty acid composition, fruit maturity, harvest date, mechanical damage, *Olea europaea* L.,

ÖZ

Amaç: Bu çalışma, farklı hasat zamanı ve yönteminin ülkemizin önemli zeytin çeşitlerinden 'Ayvalık Yağlık' meyvelerine ve zeytinyağının kalitesine etkisini belirlemek amacıyla yürütülmüştür.

Materyal ve Metot: Balıkesir ili Edremit ilçesinde tesis edilmiş zeytin bahçesinden erken, optimum ve geç dönemde odun sırıkla silkerek (kontrol), pnömatik çırpıcı ve dal sarsıcılar ile zeytin meyveleri hasat edilmiştir. Hasat edilen zeytin meyveleri 3 gün 18-20°C'de tutulduktan sonra bazı fiziksel ve biyokimyasal özellikleri, zeytinyağında serbest yağ asitliği, yağ asidi bileşimi ile mekanik zararlanma belirlenmiştir.

Bulgular: Dal sarsıcıları ile hasat edilen zeytin meyvelerinde sırık ile hasat edilenlere göre mekanik zararlanma indeksi ve serbest yağ asitliği daha düşük bulunmştur. Zeytin meyvelerinde hasat zamanın ilerlemesiyle ağırlık, olgunluk indeksi, yağ miktarı ve linoleik asit miktarında artış, son hasatta ise renk değerleri, nem, serbest yağ asidi, toplam fenol miktarı, palmitik, stearik ve linolenik asit oranında azalış görülmüştür.

Sonuç: Sonuçlar, olgunluk ilerlemesiyle zeytin meyvesinin bazı fiziksel ve kimyasal özelliklerinde önemli değişimlerin olduğunu gözlenirken, uygulamada Edremit koşullarında Ayvalık çeşidinde 2. ve 3. hasat tarihlerinin uygun olduğu ve hasatta dal sarsıcıların kullanılması önerilmektedir.

Anahtar sözcükler: Yağ asidi bileşimi, meyve olgunluğu, hasat, mekaniksel zararlanma, *Olea europaea* L.

INTRODUCTION

Although the harvest season of olives varies according to the regions where they are cultivated, it continues from October until the end of January in Turkey. The harvest time of olives varies according to the geographical location, cultivar, climatic conditions, and how the product will be utilized. The quality of olives and olive oil, which carry importance in terms of health (Harwood and Yaqoob, 2002), is influenced by various factors such as cultivar, fruit maturity, yield, ecological conditions, and farming processes (Ayton et al., 2007).

Harvest is an important operation in olive oil production since the harvest date and method impact the taste, quality, and marketability of the oil (Mele et al., 2018). Harvesting is also the most important element in olive production cost depending on factors such as the method and time, age and productivity of the tree, training and crown shape, orchard size and topography the ripening course of the fruit, and the way the product is going to be utilized (Gertsis et al., 2, 013; Famiani et al., 2014; Mele et al., 2018; Aygün et al., 2019). Harvest costs are reported to account for 50-60% of the total production cost (Vieri and Gucci, 2008). The use of machinery in olive harvesting reduces the need for human power, cost of production, and the harvest period (Amirante et al., 2012; Aygün et al., 2019). The Harvesting process needs to be carefully evaluated because it affects the yield in off years. Harvest methods may vary depending on the characteristics of the geographical location, economic resources of the grower, olive cultivar, and other factors such as the growth habit and crown structure of the tree (Aygün et al., 2019). In determining the harvest method, harvesting more olives per unit time should not be the only target, it is necessary to prevent wounding or breaking the shoots and minimize defoliation.

In Turkey, until recently, growers harvested olives foroil production by shaking branches with a stick; however, this traditional method is replaced by mechanical harvesters as branch or trunk shakers. Compared to the traditional harvesting method, mechanical harvesting increases the overall olive productivity by reducing the damage caused to the tree and the fruit and thus the alternate bearing and the requirement for human labor force (Ahmad and Ayoub, 2014). The severity of mechanical damage on olive fruits is higher in the traditional method compared with other harvesting methods. The industry is offering new harvesting technologies in olive production which makes it necessary to analyze the impact of these harvesting tools on the quality of olive and olive oil. The effect of harvest tools on harvest performance and mechanical damage is closely related to fruit maturity and varietal characteristics. For this reason, it carries great importance to test and reveal the effects of harvest methods according to different maturity indexes of the fruit.

Numerous studies are showing that harvest maturity affects on olive oil quality (Salvador et al., 2001; Al-Maaitah et al., 2009; Menz and Vriesekoop, 2010; Kutlu and Şen, 2011). However, studies on the effect of harvest maturity are very limited on the 'Ayvalık oil' olive cultivar. It is known that the chemical composition of the olive fruit changes by promoting or inhibiting different enzymatic activities during the ripening period (Beltran et al., 2004). Delaying the harvest of olive fruits does not increase the oil content whereas some sensory characteristics disappear and fruit drop enhances. In early harvesting, the color of the oil extracted is greener with fruity flavor depending on the cultivar and maturity, but the oil yield is lower; fruit drop is less and the effects of the extreme weather conditions as hail, wind, or storm are reduced, and the mechanical resistance of the fruit and oil quality is higher. For this reason, it is important to determine the optimum maturity and time for harvest for a specific variety and location. This study aimed to determine the effect of optimum harvest maturity and date linked to the harvest method of 'Ayvalik oil' olive cultivar on fruit and olive oil quality in Edremit region of Turkey.

MATERIAL and METHODS

The study was carried out in a commercial olive orchard established with 'Ayvalik Yağlık' olive (*Olea europaea* L.) cultivar. The olive grove is located at 39º37'26.57"N, 26º56'05.95"E at 51 m altitude in Edremit district of Balıkesir province, western Turkey. Cultural practices as irrigation, pruning, and other maintenance operations were carried out traditionally. Fruit samples from the selected olive trees were harvested using 3 different datestaking into account commercial harvest periods in the region, as early (30 November), optimum (3 December), and late (27 December). Three harvest methods were utilized to drop the olive fruit onto a canvas ground cover as shaking by a wood stick (control), pneumatic beaters, and branch shakers. Harvesting with pneumatic beaters was carried out by moving the finger-shaped plastic equipment at the tip with the air pressure supplied from the compressor ensuring that the olive fruits drop on the cover. Harvesting with branch shakers was made by shaking the branches with the hook attached to the small olive branches and fruits dropped onto the cover with the vibration force provided. The study was designed as 3 replications according to the completely randomized experimental design, and every three trees were considered one replication. During each harvest period, a composite sample of 3 kg olive samples was taken randomly per replicate as 1 kg per tree. The samples were kept in plastic boxes for 3 days under ambient conditions, 18-20°C temperature, and 60-70% relative humidity. The following measurements and analyses were performed to evaluate the impact of the tested variables.

The mechanical damage status of olive fruits was determined by four trained panelists using a scale of 1-5. One hundred olive fruits taken from each replicate were visually divided into 5 classes as 1: None (0% damage), 2: Less (<10% of the skin affected), 3: Medium (10-30% of the skin), 4: Severe (30-50% of the skin) and 5: Very Severe (>50% of the skin). The mechanical damage index was calculated based upon the number of fruits in each damage class as:

Mechanical damage index = (None% *1+Less%*2+Medium%*3+Severe%*4+Very severe%*5)/Fruit number

Fruit quality parameters

The average fresh fruit and pit weight (g) was calculated by weighing 100 olive fruits harvested from each repeat with a digital scale sensitive to 0.05 g. The flesh/pit ratio was obtained by subtracting the average pit weights from the fruit weight and dividing by the pit weight. The fruit width and length were measured in mm with a digital caliper with 0.01 mm precision.

The fruit skin color was measured with a color meter (CR-400, Konica Minolta Sensing Inc., Japan) in CIE L^* a^* b^* from both sides of the equatorial section of 25 fruits per replication. Hue angle (h°) value from a* and b* values were calculated with $h° = \tan^{-1}(b^*/a^*)$ formula (McGuire, 1992).

Fruit color was used to calculate the maturity index developed by Boskou (1996) in 100 fruits selected randomly per replicate. Fruits were divided into 7 color classes according to the color of the skin and the flesh, and the number of fruits in each class was multiplied by the class value and the total value was divided by 100, to determine the average fruit color class.

Fruit firmness was measured with fruit a texture meter device (GS-15, GÜSS Manufacturing Ltd., South Africa) by inserting the 5 mm-diameter tips to 6 mm depth with 10 cm/minute speed at the equatorial section of the olive fruit; and the results were expressed in Newton (N) force.

For dry weight and moisture content, the fresh weight of fruit flesh samples was weighed and dried until the last two weights became constant in an oven (UM400, Memmert, Germany) at 105°C, and the fruit moisture content was determined as a percentage (Anonymous, 2001). The oil content was determined by extraction from dried fruit samples using n-hexane as a solvent with Soxhlet Henkel extraction mechanism as specified in TS 973 (Anonymous, 2000); The results are given as the percentage of dry weight.

Fruit composition

Olive oil was extracted as cold extraction using the method. Free fatty acidity was determined by adding 50 ml alcohol/diethyl ether mixture (1:1) on 5 g of oil sample and adding 1-2 drops from phenolphthalein indicator and titrating with 0.1 NaOH until the pink color was formed; The results are presented as % oleic acid (Anonymous, 1973).

To determine the composition of fatty acids, the cold methylation method approved by the International Olive Oil Council (IOOC-UZK) was applied (Anonymous, 1987). Fatty acids analyses of oil samples converted to methyl esters were performed with Hewlett Packard 6890N gas chromatography using flame ionization detector and Spelco 2380 capillary clone (60 m x 0.25 mm i.d., 0.20 µm film thickness; Supelco, Bellefonte, PA, USA).

To determine the total phenolic content and antioxidant activity, a 5 g fruit sample was extracted with methanol. Total phenolic content was measured with a spectrophotometer (Carry 100 Bio; Varian, Australia) by modifying the Folin-Ciocaltaeu colorimetric method (Zheng and Wang, 2001) and was given as mg gallic acid equivalent (GAE)/100 g). In determining antioxidant activity, Ferric Reducing Antioxidant Power (FRAP) method was used and the results were expressed in µmol Trolox equivalent (TE)/g (Benzie and Strain, 1996).

Statistical analysis

All data were subjected to analyses of variance (ANOVA) by using IBM® SPSS® Statistics 19 statistical software (IBM, NY, USA). The differences between the averages of the data were determined with The Duncan test (P≤0.05).

RESULTS

Mechanical damage index values determined in olive fruits according to harvest methods as linked to the harvest time are given in Table 1. In the 2nd and 3rd harvests, the mechanical damage index was found the highest in olive fruits harvested by branch shakers and determined as 2.72 and 3.34, respectively. The fruit mechanical damage index for the 2nd harvest was lower in pneumatic beater (2.40) and branch shaker (2.53), whereas it was lower only in-branch shaker (3.15) compared to traditional stick harvest. At the first harvest, the mechanical damage rates varied between 2.00 and 2.18, which were statistically similar to each other. As harvest time progressed, the damage index increased and averaged to 2.08, 2.55, and 3.26 at the 1st, 2nd, and 3rd harvests, respectively.

Table 1. Effects of harvest time and method on mechanical damage index of olive fruits

Çizelge 1. *Hasat zamanı ve yönteminin zeytin meyvelerinin mekanik zararlanma indeksine etkileri*

Harvest methods	Harvest time		
	1st harvest	2nd harvest	3rd Harvest
Traditional	2.06^{NS}	2.72 a^{z*}	3.34 a*
Pneumatic beaters	2.18	2.40 b	3.28 ab
Branch shakers	2.00	2.53 b	3.15 b
Average	2.08 C**	2.55 B	3.26 A

^{z} Means separation within columns by Duncan's multiple range test, P≤0.05.

^{NS}, *, **, Nonsignificant or significant at P≤0.05, or 0.01, respectively.

The effect of harvest time on average fruit weight and flesh/pit ratio of olive fruits was found to be statistically significant (P≤0.05). The fruit weights determined as 2.21 g and 2.28 g at the 2nd and 3rd harvest, respectively were higher than the first harvest (2.01 g). The flesh/pit ratio was 2.91 in the 2nd harvest and higher than the other harvests (Table 2).

The fruit width of olive fruits varied significantly at different harvest times (P≤0.05), while fruit length was not affected by harvest date and ranged between 18.47 mm and 19.22 mm (Table 3). The fruit width was higher at the second harvest (14.80 mm) compared with the other two harvest dates.

Table 2. Effects of harvest time and method on fresh weight and flesh/pit ratio of olive fruits

Çizelge 2. *Hasat zamanı ve yönteminin zeytin meyvelerinin ağırlığı ve et/çekirdek oranına etkileri*

Harvest methods	Fruit weight (g)			Flesh/pit ratio		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	2.02^{NS}	2.30^{NS}	2.35^{NS}	2.42^{NS}	2.92^{NS}	2.53^{NS}
Pneumatic beaters	2.08	2.15	2.24	2.59	2.90	2.63
Branch shakers	1.93	2.17	2.25	2.50	2.92	2.48
Average	2.01 B*	2.21 A	2.28 A	2.50 B*	2.91 A	2.55 B

^{NS}, *, Nonsignificant or significant at *P*≤0.05.

Table 3. Effects of harvest time and method on width and length olive fruits

Çizelge 3. *Hasat zamanı ve yönteminin zeytin meyvelerinin enine ve boyuna etkileri*

Harvest methods	Fruit width (mm)			Fruit length (mm)		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	13.94^{NS}	15.03^{NS}	13.97^{NS}	17.84^{NS}	19.57^{NS}	18.42^{NS}
Pneumatic beaters	14.10	14.52	14.12	18.59	18.78	18.76
Branch shakers	14.17	14.85	13.71	20.76	19.31	18.22
Average	14.07 B*	14.80 A	13.93 B	19.06^{NS}	19.22	18.47

^{NS}, *, Nonsignificant or significant at *P*≤0.05.

The h° and maturity index of olive fruits harvested by three different means was similar at all three harvest times. The effect of harvest time on h° and maturity index values were statistically significant. As the harvest time progressed, the decreases in the h° value of olive fruit color became more pronounced and were 43.40, 31.83, and 18.98, respectively. The maturity index (4.15) of olive fruits in the last harvest period showed a significant increase (42%) compared to previous harvest periods (Table 4).

Table 4. Effects of harvest time and method on h° value and maturity index of olive fruits

Çizelge 4. *Hasat zamanı ve yönteminin zeytin meyvelerinin h° değeri ve olgunluk indeksine etkileri*

Harvest methods	h°			Maturity index		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	44.09^{NS}	28.34^{NS}	21.13^{NS}	2.70^{NS}	2.87^{NS}	4.23^{NS}
Pneumatic beaters	39.46	33.01	16.74	2.82	3.33	4.32
Branch shakers	46.66	34.13	19.07	2.82	2.98	3.90
Average	43.40 A**	31.83 B	18.98 C	2.78 B*	3.06 B	4.15 A

^{NS}, *, **, Nonsignificant or significant at *P*≤0.05, or 0.01, respectively.

During the harvest period, the firmness and moisture content of olive fruits were similar under all three harvest methods. The effect of different harvest times on the firmness of olive fruits was found to be significant (*P*≤0.01). A decrease in the firmness and moisture content of olive fruits in the last harvest was observed compared to the first two harvest times. During the last harvest date, the decrease in firmness and moisture content compared to the first was 26% and 32%, respectively. In the last harvest, the firmness content to 11.36 N, and the moisture content decreased to 31.24% (Table 5).

The oil content and free fatty acidity values of olive fruits at different harvest times and methods are given in Table 6. The oil content of olive fruit was similar to each other in three tested harvest methods at all harvest times. The effect of different harvesting methods on free fatty acidity in olive oil was significant in the 3rd harvest (*P* ≤0.05) and non-significant in other harvests. The free fatty acidity value in olive oil obtained from fruits harvested with branch shakers (0.66%) in the 3rd harvest was lower than other harvest methods. The effect of harvest time on oil content and free fatty acidity was significant ($P \leq 0.01$) and both values increased steadily with the progress of harvest date. The oil content was determined as 17.55%, 24.23%, and 27.95%, and free fatty acidity was 0.48%, 0.64%, and 0.79% in the three harvest dates, respectively.

Table 5. Effects of harvest time and method on firmness and moisture content of olive fruits

Çizelge 5. *Hasat zamanı ve yönteminin zeytin meyvelerinin sertliği ve nem miktarına etkileri*

Harvest methods	Fruit firmness (N)			Moisture content (%)		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	15.82^{NS}	14.00^{NS}	11.59^{NS}	44.16^{NS}	42.58^{NS}	32.46^{NS}
Pneumatic beaters	14.72	13.60	11.56	47.97	44.84	31.19
Branch shakers	15.44	14.25	10.94	45.11	43.06	30.06
Average	15.33 A**	13.95 A	11.36 B	45.74 A	43.49 A**	31.24 B

^{NS}, **, Nonsignificant or significant at $P \leq 0.01$.

Table 6. Effects of harvest time and method on oil content and free fatty acidity of olive fruits

Çizelge 6. *Hasat zamanı ve yönteminin zeytin meyvelerinin yağ miktarı ve serbest yağ asitliğine etkileri*

Harvest methods	Oil content (%)			Free fatty acidity (oleic %)		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	17.87^{NS}	24.95^{NS}	26.37^{NS}	0.48^{NS}	0.70^{NS}	0.79 a^{z*}
Pneumatic beaters	16.72	22.94	28.18	0.55	0.63	0.81 a
Branch shakers	18.06	24.81	29.30	0.41	0.58	0.66 b
Average	17.55 C**	24.23 B	27.95 A	0.48 C**	0.64 B	0.79 A

^{z} Means separation within columns by Duncan’s multiple range test, $P \leq 0.05$.

^{NS}, *, **, Nonsignificant or significant at $P \leq 0.05$, or 0.01, respectively.

The effect of harvesting methods on the total phenolic content and antioxidant activity of olive fruit was not significant at all harvest times. The total phenolic content of olive fruits was 124.8-130.0 mg GAE/100 g and 117.5-123.4 mg GAE/100 g at the first and last harvest, respectively. The antioxidant activity ranged from 79.9-86.4 μmol TE/g and 62.9-78.4 μmol TE/g, respectively. The harvest time had a marked effect on the total phenolic content and antioxidant activity of olive fruits ($P \leq 0.05$). The total phenolic content and antioxidant activity of olive fruits were higher in the 1st harvest than in the 3rd harvest (Table 7).

Table 7. Effects of harvest time and method on total phenol content and antioxidant activity of olive oil

Çizelge 7. *Hasat zamanı ve yönteminin zeytin meyvelerinin toplam fenol miktarı ve antioksidan aktivitesine etkileri*

Harvest methods	Total phenolic content (mg GAE/100 g)			Antioxidant activity (μmol TE/g)		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	124.83^{NS}	125.52^{NS}	117.53^{NS}	79.92^{NS}	74.23^{NS}	62.88^{NS}
Pneumatic beaters	126.74	125.78	122.92	86.36	82.69	78.43
Branch shakers	129.95	122.49	123.41	82.76	73.31	67.24
Average	127.18 A*	124.59 AB	121.29 B	83.01 A*	76.74 AB	69.52 B

^{NS}, *, Nonsignificant or significant at $P \leq 0.05$.

Changes in fatty acids determined as palmitic, stearic, oleic, and linoleic acid contents in olive oil according to different harvest times and methods are presented in Table 8. The effect of harvesting methods on the fatty acid composition of olive oil was similar throughout the harvest periods. The palmitic acid, stearic acid, oleic acid, and linoleic acid contents of olive oil ranged between the following values 12.81-13.67%, 2.88-3.43%, 68.97%-70.17%, and 10.56%-12.00%, respectively. The effect of harvest dates on palmitic, stearic, and linoleic acid contents of olive oil was significant ($P \leq 0.05$), while non-significant for oleic acid. The palmitic acid and stearic acid were the highest in the 1st harvest and lowest in the 3rd harvest. The linoleic acid was higher in the 3rd harvest than the previous harvests. Other fatty acids found in olive oil were and ranged as follows: palmitoleic acid (C16:1) 0.78-0.96%, margaric acid (C17: 0) 0.17-0.22%, heptadecanoic acid (C17: 1) 0.24-0.27%, linolenic acid (C18: 3) 0.65-0.82%, arachidonic acid (C20: 0) 0.21-0.52%, and eicosenoic acid (C20: 1) 0.32-0.41%.

Table 8. Effects of harvest time and method on palmitic, stearic, oleic, and linoleic acid contents of olive oil

Çizelge 8. *Hasat zamanı ve yönteminin zeytin yağının palmitik asit, stearik asit, oleik asit ve linoleik asit oranına etkileri*

Harvest methods	Palmitic acid (C16:0)			Stearic acid (C18:0)		
	1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
Traditional	13.64^{NS}	13.07^{NS}	12.81^{NS}	3.32^{NS}	2.93^{NS}	2.92^{NS}
Pneumatic beaters	13.32	12.97	13.06	3.26	2.98	2.88
Branch shakers	13.15	12.95	12.83	3.43	2.94	2.89
Average	13.37 A*	12.99 AB	12.90 B	3.34 A*	2.95 B	2.90 B
	Oleic acid (C18:1)			Linoleic acid (C18:2)		
Traditional	68.97^{NS}	69.67^{NS}	70.17^{NS}	11.17^{NS}	11.39^{NS}	11.61^{NS}
Pneumatic beaters	70.07	70.14	69.40	10.65	10.91	12.00
Branch shakers	70.13	69.93	69.75	10.56	11.18	11.69
Average	69.72^{NS}	69.91	69.78	10.79 B*	11.16 B	11.76 A

^{NS}, *, Nonsignificant or significant at $P \leq 0.05$.

DISCUSSION and CONCLUSION

The mechanical damage index in olive fruits harvested by branch shakers was lower than those harvested by the traditional method, beating with a stick. Since branch shakers shake the branches without direct contact with fruit, the fruit was free from mechanical damage. In the last harvest, the rate of severely damaged olive fruits was significantly higher than in the previous harvests. The damaged rate was influenced since mechanical resistance decreases with aging making fruit more susceptible to damage (Wills et al., 1998; Karaçalı, 2016).

Fruit size is one of the important quality criteria required in olive fruits. The size of olive is a desirable feature in terms of harvesting both table and oil cultivars (Scaramuzzi and Roselli, 1986). The average fresh weight was higher in the 2nd and 3rd harvests compared with the 1st harvest, as supported by higher fruit width at the 2nd harvest. Depending on the delay of the harvest, the weight increase continues for some time (Nergiz and Engez, 2000).

The flesh/pit ratio defines the edible ratio of olive fruit and this ratio should be high. In table olive cultivars, a high flesh/pit ratio showing high quality and is the desired feature. In the second harvest, the flesh/pit ratio is higher than the other harvests since fruit size increases with the advancement of maturity in the olives while the changes in the pit weight are very limited. In olive, fruit growth displays a double sigmoid curve and the pit development is completed during the first rapid development and second slow development stages (Karaçalı, 2016). This leads to an increase in the fruit/pit ratio in olives.

Significant decreases in the h° value of olive fruits in the last harvest are in harmony with the aging of the fruit. In the 1st harvest, olive fruits appeared green, bright-vivid, while the fruit color began to darken with the progress of harvest time. The color of olive fruits changes from green to black as the harvest is delayed (Civantos, 1986). In determining fruit ripening and optimum harvest maturity, the most commonly used method is the maturity index that determines the fruit color, even if the index value is subjective (Garcia and Yousfi, 2005). The increase in the maturity index values of olive fruits with the progress of harvest time was found to be consistent with changes in olive color from green to black.

The fruit firmness decreased in the last harvest, so the higher firmness levels seen during the first two harvest times are compatible with the age of the fruits that lose water and turgid nature. With the progression of maturity, a decrease in resistance of fruit flesh is seen in olive fruits (Wills et al., 1998).

As the harvest date was extended, the oil content of olive fruits increased steadily. In studies of different olive cultivars, it is reported that the quantity of oil increased with the progression of maturity and increase of dry weight due to water loss (Nergiz and Engez, 2000; Baccouri et al., 2008; Kutlu and Şen, 2011; Dag et al., 2011). A significant decrease in the moisture content of olive fruits was seen in the last harvest compared to the first two harvests, which is consistent with the results of similar studies in olives (Nergiz and Engez, 2000; Brescia et al., 2007; Kutlu and Şen, 2011). Its fruit moisture content also depends on climatic factors and practices as irrigation, precipitation, relative humidity, and temperature (Brescia et al., 2007). The main ingredients that make up olive fruit flesh are water and oil. The amount of these varies in the reverse directions during the development period. Thus, there is a significant relationship between oil accumulation and water reduction in fruit (Alowaiesh et al., 2016).

The free fatty acidity value in olive oil obtained from olive fruits harvested with branch shakers in the last harvest is lower than other harvesting methods due to the low levels of mechanical damage which is known to elevate free fatty acidity. With the progression of harvest time, the acidity in olive oil has increased steadily as found for Gemlik (Kutlu and Şen, 2011), Blanqueta, Arbequina (Garcia et al., 1996), and Cornicabra olive varieties (Salvador et al., 2001). Yousfi et al. (2006) stated that free fatty acid increases with maturity. The increase in free fatty acid value linked with maturity is associated with an increase in enzymatic activity especially an increase in lipolytic enzymes. In addition, olive fruits are prone to pest and mechanical damages towards maturity, which also leads to high free fatty acid values (Salvador et al., 2001; Romero et al., 2002).

The total phenolic content and antioxidant activity of olive fruits is higher in the first harvest than in the last harvest, in which the increase in the breakdown of phenolic compounds with the progression of maturation is effective. Early harvested olive fruits contain high levels of polyphenols, which contributes to acerbity and pungency (Dıraman and Dibeklioğlu, 2009; Dag et al., 2011). Phenolic compounds vary greatly during fruit ripening according to the cultivar, level of maturity, and growing conditions (Yousfi et al., 2006; Gómez-Rico et al., 2006).

The palmitic and stearic acid contents in olive oil were the highest in the first harvest, whereas the linoleic acid content was the highest in the last harvest. In general, as the fruit matures, the oil becomes less stable due to the increase in polyunsaturated fatty acids and the decrease in total polyphenol content (Morello et al., 2004; Ayton et al., 2007; Dag et al., 2011). These changes are of high commercial importance as they significantly affect the sensory properties and shelf life of the oil. The composition of olive oil can vary significantly with the progression of maturity depending on the cultivar and climatic conditions (Ünal and Nergiz, 2003; Kutlu and Şen, 2011).

The mechanical damage index and free fatty acidity of olive fruits harvested with branch shakers were lower than those harvested traditionally by beating with a stick. Olive fruits showed an increase in weight, maturity index, oil content, and linoleic acid content with the progression of harvest time, and a decrease in h° value and moisture, free fatty acidity, total phenolic, and palmitic, stearic, and linolenic acid contentsin the last harvest, while, in the 2nd harvest, fruit width and flesh/pit ratio were found as the highest. The results showed that significant changes in some physical and chemical properties of the olive fruit were observed with the progression of maturity. As conclusion, olive growers in Edremit region are recommended to use branch shakers and prefer to harvest in December for Ayvalık yağlık olive variety.

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