DERİM

Determination of some physicochemical properties in fruits of some avocado (*Persea americana* Mill.) cultivars during the harvesting periods

Süleyman BAYRAM[1] Seyla TEPE[1]

[1] Batı Akdeniz Agricultural Research Institute, Antalya

Sorumlu Yazar/Corresponding Author: suleyman.bayram@tarimorman.gov.tr ORCID: 0000-0001-8476-6553

Makale Bilgisi/Article Info
Derim, 2019/36(1):1-12
doi: 10.16882/derim.2019.410329

Araştırma Makalesi/Research Article
Geliş Tarihi/Received: 28.03.2018
Kabul Tarihi/Accepted: 21.03.2019

Abstract

In this study, certain physical and chemical properties of the Fuerte, Bacon and Zutano avocado cultivars were determined during the harvesting periods between the years 2010-2013. Fruit harvests were performed at intervals of 15-20 days. The dry weight and oil content of Fuerte cultivar increased by 110.2% and 234.2%, respectively, between October and May of the 2010-2011 harvesting period. The dry weight and oil content of the Bacon cultivar increased by 44.7% and 180.7%, respectively, between October and March of the 2010-2011 harvesting period, and increased by 51.0% and 174.1%, respectively, between October and January of the 2012-2013 harvesting period. The dry weight and oil content of the Zutano cultivar increased by 47.4% and 200.0%, respectively, between October and March of the 2010-2011 harvesting period, and increased by 25.9% and 86.3%, respectively, between October and February of the 2012-2013 harvesting period. A very strong positive correlation between certain pomological properties used as fruit maturity indices in avocados were found in the Fuerte, Bacon and Zutano cultivars. As a result of this study; with regard to the dry weight and oil content of fruit grown in the climatic conditions of Antalya, the optimal harvesting periods were determined to be between November and May for the Fuerte cultivar, and between November and January for the Bacon and Zutano cultivars.

Keywords: Avocado; Harvest; Dry weight and oil content; Pomological features; Correlation

Bazı avokado (*Persea americana* Mill.) çeşitlerinin meyvelerinde hasat periyodu boyunca bazı fizikokimyasal özelliklerdeki değişimin belirlenmesi

Öz

Bu çalışmada; 2010-2013 yılları arasında hasat periyodu boyunca, Fuerte, Bacon ve Zutano çeşitlerinde bazı fiziksel ve kimyasal özelliklerin belirlenmesi amaçlanmıştır. Hasat, 15-20 günde bir yapılmıştır. Fuerte çeşidinin kuru ağırlık ve yağ içeriği değerleri, 2010-11 hasat periyodu boyunca Ekim-Mayıs ayları arasında sırasıyla %110.2 ve %234.2 artmıştır. Ayrıca, Bacon çeşidinde kuru ağırlık ve yağ içeriği değerleri, 2010-11 hasat periyodu boyunca Ekim-Mart ayları arasında sırasıyla %44.7 ve %180.7 artarken, 2012-13 hasat periyodu boyunca Ekim-Ocak ayları arasında sırasıyla %51.0 ve %174.1 artmıştır. Bununla birlikte, Zutano çeşidinde kuru ağırlık ve yağ içeriği değerleri, 2010-11 hasat periyodu boyunca Ekim-Mart ayları arasında sırasıyla %47.4 ve %200.0 artarken, 2012-13 hasat periyodu boyunca Ekim-Şubat ayları arasında sırasıyla %26.0 ve %86.3 artmıştır. Fuerte, Bacon ve Zutano çeşitlerinde avokadonun meyvelerinde olgunluk indeksi olarak kullanılan bazı pomolojik özellikler arasında çok yüksek seviyede korelasyon bulunmuştur. Sonuç olarak; Antalya koşullarında meyvenin kuru ağırlık ve yağ içeriği bakımından optimum hasat zamanı Fuerte'de Kasım ve Mayıs ayları arası, Bacon ve Zutano'da Kasım ve Ocak ayları arası en uygun zamanı olarak belirlenmiştir.

Anahtar Kelimeler: Avokado; Hasat; Kuru ağırlık ve yağ içeriği; Pomolojik özellikler; Korelasyon

1. Introduction

Avocados are an evergreen subtropical species grown in about 50 countries over five different continents (Zentmyer, 1987; Knight, 2002). In 2016, the world's total avocado production was 5 567 044 tonnes and the production area was 563 916 hectares. Mexico, Dominican Republic, Peru, Brazil, Indonesia, and Colombia are known to be largest producers in the world (FAO, 2018). Avocados are grown as a commercially important crop in several countries that have extremely different environmental conditions (Bower and Cutting, 1988). Avocado production can be undertaken in the almost desert-like conditions of Israel and

southern California, in the cool mist-belt conditions of certain regions of South Africa and southern Queensland, and in the tropical high-mountain areas of Mexico (Bower and Cutting, 1988). Researches on avocados began in Turkey with the arrival of the Fuerte, Hass, Bacon and Zutano cultivars from California in the early 1970s. It was concluded that these cultivars could be commercially cultivated as they were well adapted to the region with protecting their characteristic features (Doğrular et al., 1983; Demirkol, 1997). Moreover, some areas of the Turkish Mediterranean coastline were identified as being quite suitable for avocado cultivation (Demirkol, 1998). Avocado cultivation experienced a rapid spread starting in the mid-1980s in the Mediterranean region of Turkey.

The avocado differs from other fruits with respect to its maturation process. Avocados indicate climacteric feature and the fruit of some cultivars may remain on the tree for 6 months or longer after the desired level of commercial maturity is obtained (Schroeder, 1953; Anonymous, 2000; Hofman et al., 2013; Hernández et al., 2016). This feature provides avocado producers with the opportunity to utilize the 'storage on the tree strategy' in order to best profit from the market (Whiley et al., 2013). The harvesting of matured fruits may be delayed by a few weeks or even a few months in the event that market prices are unsuitably low during the harvesting period or in the event that the fruit requires additional time to develop on the tree (Whiley, 2002; Whiley et al., 2013; Woolf et al., 2016).

If the avocado fruit is harvested before reaching maturity, undesirable eating qualities (wrinkled and unsuccesful ripening) may result or the fruit may fail to ripen (Hofman et al., 2000; Blakey, 2011). If the harvest is delayed, the size of the fruit may increase on the tree as the division of cells is allowed to continue (Offer, 1986). However, allowing fruit to remain on the tree and to continue increasing in size may cause some undesirable changes in the fruit such as the fruit peel cracking, the spilling of the fruit, and the deterioration and browning of the fruit flesh (Flitsanov et al., 2000). Legal standards of fruit maturity have been determined in many countries which produce avocados (Ranney et al., 1992; Hofman et al., 2002) as these countries do not want the marketing of unripe fruits which have not yet reached legal levels of maturity. However, avocado producers want to benefit from the high market price advantage of selling early (Hofman et al., 2013) or late in the harvest (Hofman et al., 2000). Therefore, the specification of the fruit maturity index for avocado cultivars is commercially very important (Hofman et al., 2000). However, few studies have been done on avocado maturity standards in Turkey (Doğrular et al., 1983; Kaplankıran and Tuzcu, 1994; Toplu et al., 1998; Toplu et al., 2003; Demirkol et al., 2004; Ozdemir et al., 2009; Bayram et al., 2016).

Certain physical and chemical values belonging to the fruits of the Fuerte, Bacon and Zutano cultivars, which are commercially grown in the Mediterranean region, were determined during the period beginning at the spilling of small fruit and continuing up until harvest (Demirkol, 1997). It was stated in a similar study which was conducted in the Dörtyol/Hatay region where physical and chemical analyses investigating the fruit development of these cultivars were carried out at 15 day intervals beginning on the 80th day up until the 245th day after full bloom (Ozdemir et al., 2009).

The objective of this study was to determine certain physical and chemical features in the fruits of the Fuerte, Bacon and Zutano cultivars during the harvest periods (between October and June) of the years 2010-2011 and 2012-2013. The study also attempted to identify any relationships between these values.

2. Material and Methods

Studies of the harvesting period during the first year were done between October 2010 to June 2011 while the second year studies were conducted between October 2012 and June 2013. Due to frost damage and periodicity there were no studies undertaken during the 2011-2012 harvest period.

The experiment was carried out in a completely randomized design (CRD) with three replications and two trees at each replication. It was taken total 12 fruit samples from the four sides of the trees for each replication at 15-20 days' intervals during the harvest period. The following measurements and analyses were done for the fruit samples at each harvest.

Fruit weight (g): The weight was determined by a scale with 0.01 g precision.
Fruit length (mm): Distance between the fruit stalk and the end of the flower was measured using calipers with 0.01 mm precision.
Fruit width (mm): The width was measured at the widest part of the fruit with calipers with 0.01 mm precision.
Percentage of fruit flesh (Edible portion) (%): Whole fruit weight minus peel and seed weight divided by whole fruit weight and multiplied by 100.
Seed weight rate (seed portion) (%): Seed weight divided by whole fruit weight and multiplied by 100.
Fruit flesh /seed ratio: The ratio was calculated as the edible portion of the fruit divided by portion of the seed.
Dry weight (%): Analysis was conducted according to Lee and Coggins (1982).
Oil content of flesh (%): Oil content was determined using the Soxhlet method, using petroleum ether as the extraction solvent (Lee, 1981).

Calculated fruit volume (ml):

$$\frac{4}{3} x\ \pi\ x\ \frac{m}{2}\ x \left(\frac{n}{2}\right)^2 x\ f$$

m: fruit length (mm)
n: fruit width (mm)
f: determined factor for Fuerte (0.84), Bacon (0.98) and Zutano (0.91) cultivars.

Fruit volume (ml): Fruit volume was calculated with the following formula according to the method reported by Lee (1981).
Fruit density (gml^{-1}): It was calculated as the rate that is measured in fruit weight (g) per fruit volume (ml).
Statistical analysis: The physical and chemical traits of samples of the Fuerte, Bacon and Zutano cultivars that were taken at different harvest times were analyzed using the JUMP software program while differences between means were determined by the LSD test.

3. Results and Discussion

The pomological measurements performed for the Fuerte, Bacon and Zutano cultivars during the 2010-11 and 2012-13 harvest periods are given in Table 1-3, respectively. For the Fuerte cultivar; measurements were taken in the first year of the study but not in the second as there were not adequate fruits available for analysis. In this harvesting period, an increase in the fruit weight, size and width were typically observed from the first harvest to the ninth harvest (March 10, 2011) whereas the period between the ninth harvest and the fourteenth harvest showed a fluctuation in weight, size and width (Table 1). However, a general increase trend was determined in the values for both the Bacon and Zutano cultivars throughout the harvests of both periods (Table 2 and 3).

Table 1. Pomological values of the Fuerte cultivar

	Harvest	Harvesting time	Fruit weight (g)*	Fruit length (mm)*	Fruit width (mm)*	Edible portion (%)*	Seed portion (%)*	Edible portion/ seed ratio*
2010-2011	1	05.10.2010	215.70 gh	108.64 eg	65.01 g	72.09 cf	15.64 ac	4.63 df
	2	19.10.2010	208.92 h	106.58 g	65.21 g	71.70 df	14.43 bd	5.06 cf
	3	03.11.2010	221.81 fh	107.70 fg	65.35 g	70.25 ef	17.08 ab	4.11 ef
	4	23.11.2010	222.31 fh	106.16 g	64.61 g	70.60 ef	17.20 a	4.12 ef
	5	12.12.2010	241.34 eg	113.00 dg	66.12 fg	69.21 f	17.33 a	3.99 f
	6	29.12.2010	270.73 d	117.54 cd	69.56 de	72.77 ce	15.03 ac	4.87 cf
	7	13.01.2011	275.79 cd	116.98 cd	70.18 ce	72.10 cf	15.57 ac	4.72 df
	8	17.02.2011	268.58 de	115.25 ce	70.08 ce	72.94 ce	14.11 cd	5.31 be
	9	10.03.2011	349.20 a	130.41 a	76.97 a	73.99 bd	14.43 bd	5.26 be
	10	23.03.2011	318.42 b	126.24 ab	73.77 b	72.93 ce	13.62 cd	5.47 bd
	11	08.04.2011	301.03 bc	122.13 bc	72.62 bc	74.70 ac	12.26 de	6.12 bc
	12	25.04.2011	248.65 df	113.58 df	68.26 ef	76.13 ab	11.98 de	6.38 b
	13	10.05.2011	276.87 cd	117.80 cd	71.04 cd	77.65 a	9.99 e	7.79 a
	14	24.05.2011	273.91 cd	118.95 bd	70.13 cde	75.37 ac	13.81 cd	5.45 be
		LSD	28.58	6.98	2.65	2.97	2.74	1.24

* The differences between the averages indicated by different letters in the same column are statistically significant ($p<0.05$).

Table 2. Pomological values of the Bacon cultivar

	Harvest	Harvesting time	Fruit weight (g)*	Fruit length (mm)*	Fruit width (mm)*	Edible portion (%)*	Seed portion (%)*	Edible portion/ seed ratio*
2010-2011	1	05.10.2010	204.10 d	90.88 d	65.51 f	66.23	21.69	3.08
	2	19.10.2010	224.85 cd	94.60 cd	67.99 df	65.68	21.76	3.03
	3	03.11.2010	224.34 cd	95.19 cd	67.40 ef	64.79	22.41	3.01
	4	23.11.2010	251.48 bc	100.16 bc	69.73 cde	66.05	22.32	2.96
	5	12.12.2010	250.26 bc	98.91 bc	69.91 cd	66.93	20.43	3.30
	6	29.12.2010	267.48 b	98.40 bc	72.10 bc	67.77	21.66	3.19
	7	13.01.2011	313.51 a	104.32 ab	76.31 a	63.46	23.46	2.83
	8	17.02.2011	273.13 b	100.88 bc	72.47 b	67.71	20.98	3.23
	9	10.03.2011	333.41 a	108.86 a	76.72 a	67.29	22.16	3.04
	10	23.03.2011	317.41 a	109.24 a	75.37 a	68.62	21.34	3.22
		LSD	34.24	6.42	2.49	6.40	4.77	0.87
2012-2013	1	08.10.2012	189.04 c	92.39 b	62.39 c	69.83	21.08	3.32
	2	05.11.2012	215.11 b	95.24 a	65.28 b	68.50	20.24	3.40
	3	21.11.2012	235.64 ab	97.82 ac	68.35 a	70.27	18.75	3.99
	4	12.12.2012	255.45 a	101.82 ab	69.55 a	71.68	18.13	4.03
	5	03.01.2013	247.52 a	100.19 ab	68.74 a	69.68	19.35	3.66
	6	24.01.2013	257.70 a	102.07 a	70.02 a	71.01	18.30	3.90
		LSD	24.49	6.60	2.60	5.04	4.78	1.38

* The differences between the averages indicated by different letters in the same column are statistically significant (p<0.05)

Table 3. Pomological values of the Zutano cultivar

	Harvest	Harvesting time	Fruit weight (g)*	Fruit length (mm)*	Fruit width (mm)*	Edible portion (%)*	Seed portion (%)*	Edible portion/ seed ratio*
2010-2011	1	05.10.2010	219.88 c	102.24 b	66.43 b	63.73 d	23.10 a	2.91 bc
	2	19.10.2010	235.23 bc	103.44 b	68.35 b	65.76 bd	22.40 a	2.97 bc
	3	03.11.2010	245.65 bc	104.66 b	68.87 b	67.95 ad	20.48 ab	3.42 ac
	4	23.11.2010	230.75 bc	105.22 b	67.63 b	68.53 ad	19.43 ab	3.54 ac
	5	12.12.2010	244.35 bc	101.37 b	70.42 b	64.43 cd	23.03 a	2.80 c
	6	29.12.2010	244.54 bc	105.56 b	69.08 b	71.06 ab	19.08 ab	3.80 ac
	7	13.01.2011	225.32 bc	104.37 b	66.90 b	67.73 ad	19.37 ab	3.54 ac
	8	17.02.2011	255.95 b	106.88 b	70.02 b	69.75 ac	18.16 ab	3.94 ab
	9	10.03.2011	336.42 a	117.69 a	77.99 a	69.71 ac	20.08 ab	3.50 ac
	10	23.03.2011	344.75 a	118.65 a	78.25 a	71.75 a	17.08 b	4.25 a
		LSD	34.07	5.73	4.04	5.39	5.24	1.07
2012-2013	1	08.10.2012	177.03 c	100.28 d	60.04 e	67.44 b	19.89	3.41
	2	05.11.2012	194.80 c	101.29 d	62.28 d	69.31 ab	20.26	3.44
	3	21.11.2012	219.34 b	106.96 c	64.47 c	73.33 a	17.29	4.65
	4	12.12.2012	231.68 b	108.33 bc	66.40 bc	68.70 ab	20.12	3.47
	5	03.01.2013	254.25 a	114.24 a	67.73 ab	71.07 ab	18.07	3.95
	6	24.01.2013	264.21 a	115.79 a	69.23 a	70.62 ab	18.41	3.84
	7	12.02.2013	257.30 a	112.68 ab	68.95 a	70.77 ab	17.98	3.95
		LSD	22.29	5.08	2.15	4.70	4.00	1.42

* The differences between the averages indicated by different letters in the same column are statistically significant (p<0.05)

The fruit growth in the Fuerte, Bacon and Zutano cultivars increased rapidly throughout both harvest periods. During the 2010-11 harvest period (between October and March), the fruit weight values of these cultivars typically increased by over 50% from the first harvest to the final harvest, and the fruit width, fruit length and calculated fruit volume values

also increased considerably. Throughout the 2012-13 harvest period (between October and January), the fruit weight values of the Bacon and Zutano cultivars regularly increased by nearly 50%, and fruit width, fruit length and calculated fruit volume values rose significantly. The differences between mean values of the fruit weight, fruit size and fruit width were found to be statistically significant (p≤0, 05) throughout the harvest periods (Table 1-3). These differences, especially in the Fuerte cultivar, arose when fruit, still on the trees, was lost due to climatic events (cold, wind and rain etc.) occuring during January and February. These events reduced the fruit loads borne by each tree, in turn making it difficult to sample fruits of average and adequate size.In species with edible flesh, cell division usually occurs during the initial period of fruit set, with cell growth following cell division (Scora et al., 2002; Chanderbali et al., 2013). However, Schroeder (1953) states that avocados which remain on the tree experience simultaneous cell division and cell growth, although cell division occurs at a much reduced rate. In morphological and anatomical studies, fruit development of avocados was indicated at 6-12 months or more after fruit set, depending on the variety and the growing conditions (Scora et al., 2002; Chanderbali et al., 2013).

According to Barmore (1976), the fruit development curves of early maturing cultivars showed a vertical rise at the end of the harvest period, while the fruit development curves of late maturing cultivars followed a slower trend until commercial maturity is reached. In various studies on the fruit development of the avocado, it was emphasized that the fruit growth curve has a sigmoidal structure depending on an increase in fruit weight and fruit volume (Offer, 1986; Demirkol, 1997; Scora et al., 2002; Chanderbali et al., 2013). Demirkol (1997); fruit growth occurred very rapidly from mid-June to mid-August as temperatures began to be increase in Antalya. In September, when the weather became relatively cooler, the growth rate of fruit slowed but did not fully stop during this period. Similar results were also reported in another study examing the fruit development of the Fuerte, Bacon and Zutano cultivars from full bloom until harvest in Dortyol / Hatay (Ozdemir et al., 2009). Studies conducted on the Fuerte, Edranol and Hass cultivars in South Africa between March and October by McOnie and Wolstenholme (1982) reported that the fruit development increased rapidly between April and May, decreased dramatically between June and July, continued growing between August and September, and proceeded to slow in October.

The pomological values recorded in both harvest periods were found to be compatible with other studies made in California by Young and Lee (1978), in Israel by Zilkah and Klein (1987), in Chile by Undurraga et al. (1987) and Olaeta et al. (2007), in Serik/Antalya by Bayram and Aşkın (2006) and Bayram et al. (2016), and in Dortyol/Hatay by Ozdemir et al. (2009). The fruit weight, fruit width and fruit size of the Fuerte, Bacon and Zutano cultivars were typically greater in the last harvest when compared to the first harvest. The similar results were also obtained in another study conducted on the these three avocado cultivars (Bayram and Aşkın, 2006). As seen in Table 1-3, some statistically significant differences were found in the portion, seed portion and edible portion/seed ratio values of the three avocado cultivars during both harvest periods (only in the 2010-11 harvest period for Fuerte) but they were not consistent. Similar results were also obtained in another study conducted on the these three avocado cultivars (Bayram and Aşkın, 2006).

The appropriate harvest time for avocados is determined by the dry weight percentage and oil content of fruit flesh which are used as a maturity index in the development process. The values of the Fuerte cultivar for the 2010-11 harvest period are given in Table 4, while the values of the Bacon and Zutano cultivars are given for two harvest periods in Table 5-6, respectively. Also, fruit volume (ml) and fruit density (gml^{-1}) values of all the cultivars were calculated for the determination of the fruit development, and the values for the Fuerte, Bacon and Zutano cultivars are given in Table 4-6, respectively. According to Table 4-6; the percentages of dry weight and oil content of these cultivars generally increased throughout the harvest period. The dry weight and oil content of the Fuerte increased by 111.9% and 234.2%, respectively, between October 2010 and June 2011 (between October and May). While the dry weight and oil content of the Bacon increased by 44.7% and 180.7%, respectively, during the 2010-2011 harvest

period (between October and March), they increased by 51.0% and 174.1%, respectively, during the 2012-2013 harvest period (between October and January). While the dry weight and oil content of the Zutano increased by 47.4% and 200.0%, respectively, during the 2010-2011 harvest period (between October and March), they increased by 25.9% and 86.3%, respectively, during the 2012-2013 harvest period (between October and February). The dry weight and oil content of avocado fruits changes according to cultivars and harvesting times (Vakis et al., 1985; Hofman et al., 2002). Additionally, the dry weight and oil content increases throughout the fruit development process (Lee and Coggins, 1982; Undurraga et

Table 4. Chemical and physical values of fruits of the Fuerte cultivar

Harvest		Harvesting time	Oil contents of flesh (%)*	Dry weight (%)*	Fruit volume (ml)*	Fruit density (gml^{-1})*
2010-2011	1	05.10.2010	8.84 g	18.81 g	205.34 fg	1.07 bc
	2	19.10.2010	9.11 g	19.48 g	209.59 fg	1.07 bc
	3	03.11.2010	12.66 f	23.15 f	205.04 fg	1.09 ab
	4	23.11.2010	11.88 fg	24.70 ef	196.84 g	1.15 a
	5	12.12.2010	15.05 f	26.58 e	220.92 eg	1.10 bc
	6	29.12.2010	18.50 e	29.56 d	252.93 ce	1.07 bc
	7	13.01.2011	18.90 e	29.37 d	257.33 cd	1.08 bc
	8	17.02.2011	23.75 cd	34.40 c	251.53 de	1.07 bc
	9	10.03.2011	23.41 d	37.31 ab	340.96 a	1.03 c
	10	23.03.2011	24.51 cd	35.33 bc	305.17 b	1.05 bc
	11	08.04.2011	26.79 ac	37.22 ab	283.97 bc	1.06 bc
	12	25.04.2011	25.22 bd	36.69 bc	235.10 df	1.07 bc
	13	10.05.2011	28.18 ab	37.74 ab	264.33 cd	1.05 bc
	14	24.05.2011	29.54 a	39.86 a	260.30 cd	1.05 bc
		LSD	3.22	2.56	32.28	0.06

* The differences between the averages indicated by different letters in the same column are statistically significant ($p<0.05$)

Table 5. Chemical and physical values of fruits of the Bacon cultivar

Harvest		Harvesting time	Oil contents of flesh (%)*	Dry weight (%)*	Fruit volume (ml)*	Fruit density (gml^{-1})*
2010-2011	1	05.10.2010	6.49 e	19.22 c	202.24 e	1.01
	2	19.10.2010	9.60 de	19.84 c	227.34 ce	1.01
	3	03.11.2010	9.43 de	20.47 c	223.59 de	1.01
	4	23.11.2010	10.74 cd	21.65 c	252.56 bd	1.01
	5	12.12.2010	14.09 b	25.57 b	249.99 bd	1.00
	6	29.12.2010	13.97 bc	25.40 b	263.68 bc	1.00
	7	13.01.2011	16.86 ab	27.56 ab	315.38 a	1.00
	8	17.02.2011	17.74 a	27.47 ab	275.43 b	1.00
	9	10.03.2011	19.42 a	29.74 a	331.80 a	1.00
	10	23.03.2011	18.22 a	27.80 ab	319.74 a	0.99
		LSD	3.30	2.45	37.11	0.02
2012-2013	1	08.10.2012	6.88 d	18.48 d	185.89 c	1.02
	2	05.11.2012	11.62 c	22.53 c	211.14 bc	1.02
	3	21.11.2012	15.67 b	25.34 b	236.25 ab	1.00
	4	12.12.2012	14.20 bc	26.08 ab	254.80 a	1.01
	5	03.01.2013	15.17 b	26.33 ab	244.91 a	1.01
	6	24.01.2013	18.86 a	27.91 a	259.01 a	1.00
		LSD	3.11	2.16	29.74	0.03

* The differences between the averages indicated by different letters in the same column are statistically significant ($p<0.05$)

Table 6. Chemical and physical values of fruits of the Zutano cultivar

	Harvest	Harvesting time	Oil contents of flesh (%)*	Dry weight (%)*	Fruit volume (ml)*	Fruit density (gml^{-1})*
2010-2011	1	05.10.2010	5.47 f	16.78 g	217.13 b	1.01 ab
	2	19.10.2010	6.96 ef	17.34 fg	234.24 b	1.01 ab
	3	03.11.2010	8.00 de	18.34 ef	239.74 b	1.03 a
	4	23.11.2010	8.85 d	19.27 de	230.73 b	1.00 ab
	5	12.12.2010	10.58 c	20.38 cd	241.77 b	1.01 ab
	6	29.12.2010	10.52 c	21.72 bc	243.29 b	1.01 ab
	7	13.01.2011	11.83 c	22.11 b	224.94 b	1.00 ab
	8	17.02.2011	15.93 ab	25.32 a	254.32 b	1.01 ab
	9	10.03.2011	14.38 b	25.03 a	343.97 a	0.99 b
	10	23.03.2011	16.39 a	24.74 a	348.59 a	1.00 ab
		LSD	1.65	1.43	38.29	0.03
2012-2013	1	08.10.2012	6.93 d	17.24 d	173.15 d	1.03 a
	2	05.11.2012	10.63 bc	20.53 bc	189.92 d	1.02 ab
	3	21.11.2012	9.85 c	19.36 cd	214.65 c	1.02 ab
	4	12.12.2012	12.13 abc	22.66 ab	229.47 bc	1.01 abc
	5	03.01.2013	13.56 a	23.44 a	252.03 ab	1.01 abc
	6	24.01.2013	13.42 a	23.29 a	265.05 a	1.00 c
	7	12.02.2013	12.91 ab	21.71 abc	257.29 a	1.00 bc
		LSD	2.29	2.58	24.42	0.02

* The differences between the averages indicated by different letters in the same column are statistically significant ($p<0.05$)

al., 1987; Requejo-Tapia et al., 1999; Bayram and Aşkın, 2006; Osuna-Garcia et al., 2010; Magwaza and Tesfay, 2015). The avocado has a remarkable ability to synthesize fatty acid (Barmore, 1976) which can accumulate in high levels, reaching 30% of the fruit weight (Biale and Young, 1971; Barmore, 1976; Bizimana et al., 1993).

The maturity of the avocado fruit depends on the oil contents of the fruit. This relationship has been known for a long time to have emerged as a natural result of an increase in the oil content of the fruit (Young and Lee, 1978; Osuna-Garcia et al., 2010; Magwaza and Tesfay, 2015). Avocados have a high oil content by the time the fruits have reached maximum maturity (Barmore, 1976; Osuna-Garcia et al., 2010; Blakey, 2011). However, there is not a comparable relationship between maturity and oil content for all cultivars of avocados. Depending on the variety and the growth conditions, the oil contents of avocado cultivars ranges from 8-30% (Quiñones-Islas et al., 2013).

Avocado cultivars consist of three different species all belonging to the Persea subgenus (West-Indian, Guatemalan and Mexican), and the fat contents of the various species' fruits is found to be at different levels. For example, the oil contents of West-Indian avocados ranged between 2.5-8% cultivars, while Guatemalan cultivars yield 10-13% and 15-25% in the Mexican cultivars. Fruits growing in cooler subtropical climates boast higher oil contents which continue to increase when harvest is delayed. Accordingly, oil contents of the Hass and Fuerte cultivars can increase up to 25-30% until the start of next season's blooming (Knight, 2002).

The percentages of the oil content and dry weight determined for the Fuerte, Bacon and Zutano cultivars in this study increased from the first harvest until the last harvest and statistically significant differences were found. These results are consistent with the other dry weight and oil content studies reported above.

The fruit develpoment curve of the avocado is a single sigmoid shaped structure (Offer, 1986; Demirkol, 1997; Undurraga et al., 1987; Scora et al., 2002). In a study of six different avocado cultivars in Chile, an increase in fruit volume depending on the fruit weight of the Fuerte, Bacon and Zutano cultivars was noted in observations made at 15-day intervals from anthesis to maturity (Undurraga et al., 1987). The fruit growth values of the Fuerte, Bacon

and Zutano cultivars were determined to increase from the time of small fruit spill until fruit harvesting time in similiar studies conducted in the Mediterranean regions of Turkey (Demirkol, 1997; Ozdemir et al., 2009). In another study conducted in California between 1994-1996, the fruit development of the Hass cultivar grafted onto Duke 7 clonal rootstocks was examined by Mickelbart et al. (2012). According to observations made up to 12-14 months after fruit set (130th day of the year), maximum fruit growth rate (fruit volume) was found during the time period ending around the middle of August (230th day of the year), then slowed down substantially from the middle of August to the harvest.

Fruit volume values of the Fuerte, Bacon and Zutano cultivars increased in statistically significant levels from the first harvest until the last harvest. When compared to other studies, similar results to this study were obtained, especially during in the 2012-13 harvest period, when the fruit volume increase occurred more markedly. The fruit density values of the Fuerte and Zutano cultivars were determined in statistically significant levels among the harvesting times, but these values were not consistent.

A correlation analysis was performed to determine the relations of the fruit maturity values of the different cultivars. The correlation coefficients (r) calculated for the Fuerte, Bacon and Zutano cultivars are given in Table 7-9, respectively. As seen in Tables; correlations between fruit length and fruit width along with fruit weight were found to be strong ($r \geq 0.90$) and the development of fruits in all cultivars continued as a whole. When the correlation coefficients (r) of the Fuerte cultivar were analyzed (Table 7), in the 2010-11 harvest period, a linear relationship emerged between harvest time and dry weight (0.80), dry weight and oil contents of flesh (0.76), and harvest time and oil contents of flesh (0.96). Moreover, a high degree of correlation between harvest time and oil contents of fruit flesh was noted. In addition, a high level of positive correlation between fruit length and fruit weight (0.96), fruit length and fruit width (0.92), and fruit width and fruit weight (0.96) was determined. However, a negative relationship between seed weight and fruit flesh (-0.90) was observed.

The Bacon cultivar, throughout the 2010-11 and 2012-13 harvest periods (Table 8), displayed a strong correlation between harvesting time and dry weight (respectively 0.91 and 0.88), dry weight and oil contents of flesh (respectively 0.97 and 0.96), and harvesting time and oil contents of flesh (respectively 0.92 and 0.85). Also, a positive linear relationship among these factors was determined. In addition, the study observed a high level of correlation between fruit length and fruit weight (respectively 0.95 and 0.91), fruit length and fruit width (respectively 0.89 and 0.84), and fruit width and fruit weight (0.98 in both periods). Again, a negative correlation was observed between seed weight and fruit flesh (respectively -0.93 and -0.94).

Table 7. The correlation coefficients (r) of the Fuerte cultivar

Variables		Correlation coefficients (r)
X	Y	2010-11 harvest period
Fruit length (mm)	Fruit weight (g)	0.96
Fruit width (mm)	Fruit weight (g)	0.96
Fruit width (mm)	Fruit length (mm)	0.92
Oil contents of flesh (%)	Harvest time	0.96
Oil contents of flesh (%)	Fruit width (mm)	0.71
Dry weight (%)	Harvesting time	0.80
Dry weight (%)	Fruit weight (g)	0.72
Dry weight (%)	Fruit width (mm)	0.74
Dry weight (%)	Oil contents of flesh (%)	0.76
Fruit volume (ml)	Fruit weight (g)	0.97
Fruit volume (ml)	Fruit length (mm)	0.96
Fruit volume (ml)	Fruit width (mm)	0.98
Seed weight (%)	Fruit flesh (%)	-0.90
Fruit flesh / seed ratio (%)	Fruit flesh (%)	0.92
Fruit flesh / seed ratio (%)	Seed weight (%)	-0.98

Table 8. The correlation coefficients (r) of the Bacon cultivar

Variables		Correlation coefficients (r)	
X	Y	2010-11 harvest period	2012-13 harvest period
Fruit weight (g)	Harvest time	0.85	0.81
Fruit length (mm)	Harvest time	0.79	0.69
Fruit length (mm)	Fruit weight (g)	0.95	0.91
Fruit width (mm)	Harvest time	0.87	0.79
Fruit width (mm)	Fruit weight (g)	0.98	0.98
Fruit width (mm)	Fruit length (mm)	0.89	0.84
Oil contents of flesh (%)	Harvest time	0.92	0.85
Oil contents of flesh (%)	Fruit weight (g)	0.86	0.74
Oil contents of flesh (%)	Fruit length (mm)	0.80	0.57
Oil contents of flesh (%)	Fruit width (mm)	0.87	0.77
Dry weight (%)	Harvest time	0.91	0.88
Dry weight (%)	Fruit weight (g)	0.86	0.86
Dry weight (%)	Fruit length (mm)	0.79	0.70
Dry weight (%)	Fruit width (mm)	0.87	0.88
Dry weight (%)	Oil contents of flesh (%)	0.97	0.96
Fruit volume (ml)	Harvest time	0.84	0.77
Fruit volume (ml)	Fruit weight (g)	1.00	0.99
Fruit volume (ml)	Fruit length (mm)	0.96	0.94
Fruit volume (ml)	Fruit width (mm)	0.98	0.97
Fruit volume (ml)	Oil Contents of flesh (%)	0.85	0.71
Fruit volume (ml)	Dry weight (%)	0.85	0.83
Seed weight (%)	Fruit flesh ratio (%)	-0.93	-0.94
Fruit flesh / seed ratio (%)	Fruit flesh ratio (%)	0.94	0.94
Fruit flesh / seed ratio (%)	Seed weight (%)	-0.99	-0.99
Fruit density (gml^{-1})	Fruit length (mm)	0.36	-0.76

Table 9. The correlation coefficients (r) of the Zutano cultivar

Variables		Correlation coefficients (r)	
X	Y	2010-11 harvest period	2012-13 harvest period
Fruit weight (g)	Harvest time	0.65	0.85
Fruit length (mm)	Harvest time	0.64	0.79
Fruit length (mm)	Fruit weight (g)	0.94	0.97
Fruit width (mm)	Harvest time	0.60	0.86
Fruit width (mm)	Fruit weight (g)	0.98	0.99
Fruit width (mm)	Fruit length (mm)	0.88	0.95
Oil contents of flesh (%)	Harvest time	0.96	0.80
Oil contents of flesh (%)	Fruit weight (g)	0.61	0.73
Oil contents of flesh (%)	Fruit width (mm)	0.58	0.73
Dry weight (%)	Harvest time	0.93	0.68
Dry weight (%)	Oil contents of flesh (%)	0.96	0.95
Fruit volume (ml)	Harvest time	0.64	0.84
Fruit volume (ml)	Fruit weight (g)	1.00	1.00
Fruit volume (ml)	Fruit length (mm)	0.94	0.98
Fruit volume (ml)	Fruit width (mm)	0.98	0.99
Fruit volume (ml)	Oil contents of flesh (%)	0.60	0.71
Fruit density (gml^{-1})	Fruit weight (g)	-0.56	-0.74
Fruit density (gml^{-1})	Fruit length (mm)	-0.60	-0.78
Fruit density (gml^{-1})	Fruit width (mm)	-0.61	-0.78
Fruit density (gml^{-1})	Fruit volume (ml)	-0.63	-0.78
Seed weight (%)	Fruit flesh (%)	-0.92	-0.93
Fruit flesh / seed ratio (%)	Fruit flesh (%)	0.91	0.97
Fruit flesh / seed ratio (%)	Seed weight (%)	-0.98	-0.95

In the Zutano cultivar (Table 9); in the 2010-2011 and 2012-13 harvest periods, a high level of correlation between dry weight and harvesting time (respectively 0.93 and 0.63), dry weight and oil contents of flesh (respectively 0.96 and 0.95), and harvesting time and oil contents of flesh (respectively 0.96 and 0.80) was found. Furthermore, a strong correlation was found between fruit length and fruit weight (respectively 0.94 and 0.97), fruit width and fruit weight (respectively 0.98 and 0.99), and fruit length and fruit width (respectively 0.88 and 0.95). These pairs exhibited positive linear relationships and during harvest periods. However, a negative relationship between seed weight and fruit flesh was noted (respectively -0.92 and -0.93).The oil and dry weight ratios of fruit flesh that are used as maturity indices for the different avocado cultivars are calculated according to typical values of the cultivars and harvesting time (Vakis et al., 1985; Hofman et al., 2002; Magwaza and Tesfay, 2015). The close relationship between the oil content and the dry weight ratios of the avocado increases during the fruit development process (Lee and Coggins, 1982; Undurraga et al., 1987; Requejo-Tapia et al., 1999; Carvalho et al., 2014; Magwaza and Tesfay, 2015). This data supports the findings obtained from this study. Also, these results were compatible with other studies that reported relationships between harvesting time and characteristic pomological values (Offer, 1986; Demirkol, 1997; Scora et al., 2002; Pak et al., 2003) and between the dry weight ratio of fruit flesh and several aspects of fruit quality (Pak et al., 2003; Gamble et al., 2010). They stated that fruit volume increased during harvest periods.

4. Conclusions

In this study, the physical and chemical properties of the fruits of Fuerte, Bacon and Zutano avocado cultivars which are intensively grown in the Mediterranean region were analyzed throughout their respective harvest periods. Certain relationships between the physical and chemical properties of the avocados became evident during the course of this study.

As a result; the fruit development of the Fuerte, Bacon and Zutano cultivars continued up until a certain point during the harvest period while the fruit weight increased, on average, by over 50% from the time of the first harvest. Fruit development decreased when harvest times were delayed.

The dry weight and oil content of the Fuerte cultivar increased by 200.3% and 288.8%, respectively, between October and June of the 2010-2011 harvest period. While the dry weight and oil content of the Bacon cultivar increased by 144.7% and 317.3%, respectively, between October and April of the 2010-2011 harvest period, they also increased by 151.0% and 274.1%, respectively, between October and January of the 2012-2013 harvest period. However, while the dry weight and oil content of the Zutano cultivar increased by 151.9% and 301.5%, respectively, between October and April of the 2010-2011 harvest period, they increased by 125.9% and 186.3%, respectively, between October and February of the 2012-2013 harvest period.

In the Fuerte, Bacon and Zutano cultivars very strong positive correlations were found between some pomological properties used as maturity index in avocado fruits. However, a strong negative correlation between fruit flesh and seed weight was also determined. While a quite strong correlation (r=0.76) between dry weight and oil content in the Fuerte cultivar was noted, this correlation was found to be at a much higher level (r ≥ 95) in the Bacon and Zutano cultivars.

As a result of this study; in terms of fruit dry weight and oil content in the Antalya region, while the optimal harvest time of the Fuerte cultivar is determined to be the period between November and May, the optimal harvest time of the Bacon and Zutano cultivars is determined to be the period between November and January.

References

Anonymous. (2000). Growing avocados in ventura county. A Reference Handbook-University of California Cooperative Extension, pp. 45–47.

Barmore, C.R. (1976). Avocado fruit maturity. Proceedings of the I. International Tropical Fruit Short Course: The Avocado. pp. 103–109. Gainesville: Fruit Crops Dept., Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences, University of Florida.

Bayram, S., & Aşkın, M. A. (2006). Bazı avokado çeşitlerinde harvest zamanının belirlenmesinde yağ ve kuru ağırlık parametrelerinin kullanımı.

Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 1(2):38-48.

Bayram, S., Tepe, S., & Toker, R. (2016). Determination of some physical and chemical changes in fruits of hass avocado cultivar during harvesting time. *Derim*; 33 (1): 14-26.

Blakey, R.J. (2011). Management of avocado postharvest physiology. Doctorate Thesis, pp. 5-16. Disipline of Horticultural Science School of Agricultural Sciences and Agribusiness Faculty of Science and Agriculture University of KwaZulu-Natal Pietermaritzburg South Africa.

Biale, J.B., & Young, R.E. (1971). The avocado pear. pp. 1-60. In: Biale, A.C. (Ed.), The Biochemistry of Fruits ve Thei Products. Academic Press, London.

Bizimana, V., Breene, W.M., & Csallany, A.S. (1993). Avocado oil extraction with appropriate technology for developing countries. Journal of the American Oil Chemists' Society, 70(8): 821-822.

Bower, J. P., & Cutting, J. G. (1988). Avocado fruit development and ripening physiology. In: J. Janick (Ed.), *Horticultural Reviews*, 10: 229–271.

Carvalho, C. P., Velásquez, M. A., & Rooyen, Z. V. (2014). Determination of the minimum dry matter index for the optimum harvest of 'Hass' avocado fruits in Colombia. *Agronomía Colombiana*, 32(3):399-406.

Chanderbali, A.S., Soltis, D.E, Soltis, P.S., & Wolstenholme, B.N. (2013). Taxonomy and botany. 3: pp. 44. In: Schaffer, B., Whiley, A.W. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production And Uses; 2nd Edition, Cabi Publishing.

Demirkol, A. (1997). Antalya koşullarında yetiştirilen bazı önemli avokado çeşitleri üzerinde biyolojik, morfolojik ve fizyolojik araştırmalar. Doktora Tezi, Akdeniz Üniversitesi Fen Bilimleri Enstitüsü, Bahçe Bitkileri Ana Bilim Dalı, (in Turkish).

Demirkol, A. (1998). Avocado growing in Turkey. Procedings, pp. 451–456. *World Avocado Congress III, 22–27 October, Tel-Aviv, Israel*.

Demirkol, A., Bayram, S., & Baktır, I. (2004). Adaptation and performance of 15 avocado cultivars grown in Antalya province in southern Turkey. *Proceeding XXVI, IHC-Citrus; Subtropical and Tropical Fruit Crops*. Acta Hort, 632; 45-52.

Doğrular, H.A, Tuncay, M., & Şengüler, A. (1983). Adaptation of avocado varieties in Antalya and Alanya conditions (Interim Report).Turunçgil Research Institute, Antalya, Unpublished .

Flitsanov, U. Mizrach, A., Liberzon, A., Akerman, M., Zauberman, G. (2000). Measurement of avocado softening at various temperatures using ultrasound. *Postharvest Biology and Technology*, 20: 279–286.

FAO (2018). Agricultural production data. http://www.fao.org/faostat/en/#data/QC. Access date: October 3, 2018.

Gamble, J., Harker, F. R., Jaeger, S. R., White, A., Bava, C., Beresford, M., Stubbings, B., Wohlers, M., Hofman, P. J., Marques, R., & Woolf, A. (2010). The impact of dry matter, ripeness and internal defects on consumer perceptions of avocado quality and intentions to purchase. *Postharvest Biology and Technology*, 57: 35–43.

Hernández, I., Fuentealba, C., Olaeta, J.A., Lurie, S., Defilippi, B.G., Vargas, R.C., & Pedreschi, R. (2016). Factors associated with postharvest ripening heterogeneity of 'Hass' avocados (*Persea americana* Mill). Fruits, Cirad / EDP Sciences, 71(5): 259–268

Hofman, P.J., Jobin-Décor, M., & Giles, J. (2000). Percentage of dry matter and oil content are not reliable indicators of fruit maturity or quality in late-harvested 'Hass' avocado. *HortScience*, 35 (4): 694–695.

Hofman, P.J., Fuchs, Y., & Milne, D.L. (2002). Harvesting, Packing, Postharvest Tecnology, Transport and Processing. 14, pp. 363–390. In: Whiley, A.W., Schaffer, B. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production and Uses; Cabi Publishing.

Hofman, P.J., Bower, J., & Woolf, A. (2013). Harvesting, packing, postharvest tecnology, transport and processing. 15: 494. In: Schaffer, B., Whiley, A.W. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production and Uses; 2nd Edition, Cabi Publishing.

Kaplankıran, M., & Tuzcu, Ö (1994). Characteristics of some avocado cultivars emerged under adana conditions. Çukurova University Agric. Faculty Journal, 9 (2): 103-112, (In Turkish).

Knight, Jr. R.J. (2002). History, distribution and uses. 1: pp. 10. In: Whiley, A.W., Schaffer, B. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production and Uses; Cabi Publishing.

Lee, S.K. (1981). Methods for percent oil analysis of avocado fruit. *California Avocado Society Yearbook*, 65:133-141.

Lee, S.K., Coggins, & Jr. C.W. (1982). Dry weight method for determination of avocado fruit maturity. *California Avocado Society Yearbook*, 66: 67–70.

Magwaza, L.S., & Tesfay, S. Z. (2015). A review of destructive and non-destructive methods for determining avocado fruit maturity. *Food and Bioprocess Technology*,Vol 8, Issue 10: 1995–2011.

McOnie, A.J., & Wolstenholme, B.N. (1982). Avocado fruit growth and maturity in two Natal localities. *South African Avocado Grower' Association Yearbook*, 5: 76-77.

Mickelbart, M.V., Robinson, P.W., Witney, G., & Arpaia, M.L. (2012). 'Hass' avocado tree growth on four rootstocks in California. I. Yield and Flowering. *Scientia Horticulturae*, 143:184-188.

Offer, R.A. (1986). Maturation and ripening of avocado fruit (summary). Thesis submitted for the degree of M.Sc. (agric.), The Faculty of

Agriculture of the Hebrew University, Jerusalem, Israel. http://www.avocadosource.com/papers /Israeli_Papers.htm. Access date: October 3, 2018.

Olaeta, J.A., Undurraga, P., & Jaque, R. (2007). Effect of size and height of fruit within the tree on content of oil in Hass and Fuerte avocados (*Persea americana* Mill.). *Proceeding VI World Avocado Congress (Actas VI Congreso Mundial Del Aguacate)*, 12-16 November, Viña Del Mar, Chile, pp: 1-10.

Osuna-García, J.A., Doyon, G., Salazar-García, S., Goenaga, R., & González-Durán I.J.L. (2010). Effect of harvest date and ripening degree on quality and shelf life of Hass avocado in Mexico. *Fruits*, 65: 367–375.

Ozdemir, A.E., Çandır, E.E., Toplu, C., Kaplankıran, M., Demirkeser, T.H., & Yıldız, E. (2009). The effects of physical and chemical changes on the optimum harvest maturity in some avocado cultivars. *African Journal of Biotechnology* 8 (9): 1878-1886.

Quiñones-Islas, N., Meza-Márquez, O G., Osorio-Revilla, G., & Gallardo-Velazquez, T. (2013). Detection of adulterants in avocado oil by mid-FTIR spectroscopy and multivariate analysis. *Food Research International*, 51: 148.

Pak, H.A., Dixon, J., & Cutting, J.G.M. (2003). Influence of early season maturity on fruit quality in New Zealand Hass avocados. Proceedings V World Avocado Congress, 19-24 October, Malaga, Spain, pp: 635-640.

Ranney, C.A., Gillette, G., Brydon, A, McIntyre, S., Rivers, O., Vasquez, C.A., & Wilson, E. (1992). Physiological maturity and percent dry matter of California avocado. *Proc. of Second World Avocado Congress*, pp. 379–385.

Requejo-Tapia, L.C. Woolf, A.B. Roughan, G. Schroeder, R. Young, H., & White, A. (1999). Avocado postharvest research: 1998/99: seasonal changes in lipid content and fatty acid composition of 'Hass' avocados. pp. 1-25. HortResearch Client Report No. 2000/1 Contract No.5262, Report to the NZ Avocado Industry Council, New Zeland.

Schroeder, C.A. (1953). Growth and development of the Fuerte avocado fruit. *Proceedings of the American Society for Hortıcultural Science*, 61:103–109.

Scora, R.W., Wolstenholme, B.N., & Lavi, U. (2002). Taxonomy and botany. 2: pp. 15. In: Whiley, A.W., Schaffer, B. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production and Uses; Cabi Publishing.

Toplu, C., Demirkeser, T.H., Kaplankıran, M., Demirkol, A., Baturay, S.G., & Yanar, M. (1998). The yield, quality and growth parameters of some avocado cultivars grown in Iskenderun. *Derim*, 15 (2): 50-57, (in Turkish).

Toplu, C., Kaplankıran, M., Demirkeser, T.H., Yıldız, E., & Temiz, S. (2003). Pomolojical characteristics seen in some avocado cultivars grown under Hatay-Dörtyol. *IV. National Horticulture Congress, Antalya*, pp. 185-187, (in Turkish)

Undurraga, P., Oleata, J., & Gardiazabal, F. (1987). Seasonal changes on chemical and physical parameters in six avocado (*Persea americana* Mill) cultivars grown in Chile. *South African Avocado Growers Association Yearbook*, 10: 138–140.

Vakis, N.J., Gregoriou, C., & Papademetriou, M. (1985). Maturity and picking dates of avocados under Cyprus conditions. *California Avocado Society Yearbook*, 69: 81–88.

Whiley, A.W. (2002). Crop management. 10: pp. 231–254. In: Whiley, A.W., Schaffer, B. and Wolstenholme, B.N. (Eds), The Avocado: Botany, Production and Uses; Cabi Publishing.

Whiley, A.W., Wolstenholme, B.N., & Faber, B. (2013). Crop Management. 12: pp. 363.In: B.Schaffer, A.W. Whiley, and B.N. Wolstenholme (Eds), The Avocado: Botany, Production And Uses; 2nd Edition, Cabi Publishing.

Woolf, A.B., White A., Arpaia M.L., & Gross K.C. (2016). Avocado. pp. 217. In: Gross K., Wang C. and Salveit M (Eds.), Agriculture Handbook 66: The storage of fruits, vegetables and florist and nursery stocks, USDA, USA. https://www.ars.usda.gov/is/np/CommercialStorage/CommercialStorage.pdf. Accessed date: September 25, 2018.

Young, R. E., & Lee, S. K. (1978). Avocado fruit maturity. *California Avocado Society Yearbook*, 62: 51–57.

Zentmyer, G.A. (1987). Avocados around the World. *Avocado Society Yearbook*, 71: 63–77.

Zilkah, S., & Klein, I. (1987). Growth kinetics and determination of shape and length of small and large avocado fruits cultivars 'Hass' on the tree. *Scientia Horticulturae*, 32: 195-202.