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Determination of some physical and chemical changes in fruits of Hass avocado cultivar during harvesting time

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Abstract

Cultivation of avocado has increasingly attracted the attention of producers in Turkey recently. Hass is one of the most important avocado cultivars produced in the world and Turkey. The aim of this study was to determine the most suitable fruit maturity standards for Hass cultivar by analyzing some physical and chemical parameters. The study was conducted at the two harvest periods from October to June in 2010-11 and 2012-13 years with 15-20 days intervals. Fruit weights changed from 106.73 g to 196.50 g in 2010-11 and from 98.45 g to 157.81 g in 2012-13 harvest periods. Dry weight of fruits increased from 19.60% to 36.45% and from 19.23% to 38.28% and oil content increased from 6.43% to 22.06% and from 6.47% to 24.86% depending on the harvest period in 2010-11 and 2012-13 respectively. There was a very high positive relationship between dry weight and oil content of fruit, but a significant negative correlation was found between fruit flesh and seed weight. As a result of this study; the optimal harvest period of Hass cultivar was determined to be from January to June in terms of fruit dry weight and oil content in Antalya conditions.

Keywords: Avocado, Hass, Harvest period, Oil, Fruit weight

Hasat periyodu boyunca Hass avokado çeşidinin meyvelerinde bazı fiziksel ve kimyasal değişimlerin belirlenmesi

Öz

Avokado yetiştiriciliği, son yıllarda Türkiye'de üreticilerin giderek ilgisini çekmeye başlamıştır. Hass, Dünyada ve Türkiye'de üretilen en önemli avokado çeşitlerinden biridir. Bu çalışmada, bazı fiziksel ve kimyasal parametreler analiz edilerek, Hass çeşidi için en uygun meyve olgunluk standartların belirlenmesi amaçlanmıştır. Çalışma, 2010-2011 ve 2012-2013 yıllarında Ekim ayından Haziran ayına kadar iki hasat periyodunda, 15-20 gün aralıklarla yürütülmüştür. Meyve

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ağırlığı, 2010-11 hasat periyodu boyunca 106.73 g'dan 196.50 g'a ve 2012-13 hasat periyodu boyunca ise 98.45 g'dan 157.81 g'a kadar değişim göstermiştir. Kuru ağırlık 2010-11 ve 2012-2013 hasat periyodunda sırasıyla %19.60'dan %36.45'e ve %19.23'den %38.28'e kadar artmış ve yağ içeriği ise sırasıyla %6.43'den %22.06'a ve %6.47'den %24.86'ya kadar yükselmiştir. Denemede, kuru ağırlık ve meyvenin yağ içeriği arasında pozitif çok yakın bir ilişki bulunmuş, fakat meyve eti ve çekirdek ağırlığı arasında önemli bir negatif ilişki bulunmuştur. Bu çalışmanın sonucunda; Antalya koşullarında meyve kuru ağırlık ve yağ içeriğine göre Hass çeşidinin en uygun hasat döneminin Ocak-Haziran arası olduğu belirlenmiştir.

Anahtar kelimeler: Avokado, Hass, Hasat periyodu, Yağ, Meyve ağırlığı

1. Introduction

Avocados are evergreen subtropical species and grown in about 50 countries at the five continents of the world (Zentmyer, 1987; Knight, 2002). The world's total avocado production was 4 717 102 t and production area was 516 485 ha in 2013. Mexico, Indonesia, Brazil, Colombia, Dominican Republic, Spain and Chile are known to be largest producers in the world. (FAO, 2015).

Avocados are considered as an important alternative fruit for the producers interested in new fruit species, due to the limited growing area and higher prices in the market, with special nutritional values, and unique presence of taste (Bayram et al., 2006).

The first experiments were started in early 1970s in the province of Antalya, Turkey, with 4 important avocado cultivars including Fuerte, Hass, Bacon and Zutano, which were brought from California. The fruit and tree characteristics, blooming periods, maturity times and productivities of these cultivars with influences of climatic conditions on cultivars were investigated (Doğrular et al., 1983; Demirkol, 1995). It was stated that the Mediterranean coastal belt was suitable to grow avocado as well as some other subtropical fruits (Demirkol, 1995).

Determination of minimum maturity standards is an economically important decision for avocados with climacteric feature and fruits of some varieties remaining up to 6 months or longer times on the tree in some cultivars. The growers want to benefit from the high price advantage for marketing at the beginning of the harvest season. However, marketing of the immature fruits in the early stages returns to producers as a disadvantage in the long term. This status is a big problem for avocado

which cannot be exactly determined maturity stage from outside (Young and Lee, 1978).

The legal standards of avocado fruit maturity have been determined in many countries (Ranney et al., 1992; Hofman et al., 2002) and avocado is undesirable to be delivered to the market before fruits reach to legal maturity. Also, the avocado producers want to benefit from the high price advantage in the marketing in early or late terms of the harvest period. Therefore, the definition of fruit maturity criteria of the avocado varieties is commercially very important (Hofman et al., 2000).The maturity standards of some avocado cultivars had already been determined in the conditions of Turkey (Kaplankıran and Tuzcu, 1994; Toplu et al., 1998; Toplu et al., 2003; Demirkol et al., 2004; Ozdemir et al., 2009). However, the few studies have been done on maturity standards of Hass variety during harvest period in Turkey.

The objective of this study was to determine the physical and chemical properties of the fruits at the various harvesting times and the most suitable standards for fruit maturity of the Hass cultivar during the period between October and June in Antalya province.

2. Material and Method

2.1. Material

This research was carried out at the Fruit Growing Department of Batı Akdeniz Agricultural Research Institute in Antalya between 2010 and 2013 years. The Hass cultivar, which was 20-year old trees, was used as the material of the study.

2.2. Method

The harvesting period studies of the first year were done from October-2010 to June-2011 and the second year studies conducted between October 2012 and June 2013. Due to frost damage and periodicity there were no works at the harvest periods in 2011-2012.

The experiment was carried out in completely randomized design (CRD) with three replications and two trees at each replication. Twelve fruit samples were taken from the four sides of 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 scale with 0.01 g precision.
-Fruit length (mm): Distance between the fruit stalk and the end of the flower was measured using the caliper with 0.01 mm precision.
-Fruit width (mm): It was identified with the caliper to 0.01 mm precision from the widest part of the fruit.
-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 (seed portion) (%): Seed weight divided by whole fruit weight and multiplied by 100.
-Fruit flesh/seed ratio: It 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 contents of flesh (%): It was determined using Soxhlet method using petroleum ether as extraction solvent (Lee, 1981).
-Fruit volume (ml): It was calculated with the following formula according to the method reported by 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 Hass cultivar (0.93)

-Fruit density (g/ml): 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 the cultivar Hass samples that were taken at different harvest times were analyzed using the JUMP software program and differences between means was determined by LSD test.

3. Results and Discussion

The pomological measurements performed in the Hass cultivar during 2010-2011 and 2012-2013 harvest periods are in Table 1.

Table 1. Pomological mean values of the Hass cultivar according to the harvest times in 2010-11 and 2012-13

Harvest Years/Number of 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	106.73 h	78.75 g	51.74 k	64.99 bd	12.15 ab	5.42 ac
	2	19.10.2010	113.69 gh	80.43 fg	53.32 j	67.42 ad	11.68 ab	6.88 ac
	3	03.11.2010	131.01 ef	84.83 ef	56.97 eg	68.79 ac	10.73 ab	7.36 ac
	4	23.11.2010	118.74 fh	82.16 fg	53.91 ıj	64.31 bd	13.59 ab	4.88 ac
	5	12.12.2010	129.89 ef	83.12 eg	57.13 ef	65.85 ad	13.87 ab	4.75 bc
	6	29.12.2010	120.04 fg	81.89 fg	54.93 hı	64.28 bd	16.15 a	3.98 c
	7	13.01.2011	125.98 eg	83.60 ef	55.48 gh	63.82 cd	13.37 ab	4.91 ac
	8	17.02.2011	136.93 e	86.84 de	57.50 de	66.84 ad	12.65 ab	5.35 ac
	9	10.03.2011	196.50 a	97.10 a	66.15 a	63.68 d	15.47 ab	4.12 c
	10	23.03.2011	164.36 c	90.89 bd	61.42 c	66.61 ad	14.16 ab	4.81 ac
	11	08.04.2011	152.02 d	90.17 cd	58.65 d	69.07 ab	11.53 ab	8.56 ab
	12	25.04.2011	129.35 ef	84.44 ef	55.93 fh	70.09 a	9.55 b	9.13 a
	13	10.05.2011	183.24 b	96.51 a	62.85 bc	64.78 bd	13.01 ab	5.36 ac
	14	24.05.2011	169.39 c	91.68 bc	61.96 c	66.30 ad	13.86 ab	4.82 ac
	15	13.06.2011	187.94 ab	95.06 ab	64.31 b	70.24 a	12.70 ab	5.88 ac
	LSD		12.29	4.50	1.50	4.99	5.67	4.35
2012-2013	1	08.10.2012	98.45 d	76.57 d	50.99 e	65.37 ad	12.56 bc	5.43 ac
	2	05.11.2012	106.08 d	78.00 cd	52.12 de	63.48 ad	17.96 ab	3.57 ac
	3	21.11.2012	104.89 d	78.85 cd	51.78 de	65.72 ad	15.57 ac	4.23 ac
	4	12.12.2012	112.77 cd	79.84 cd	53.02 de	58.90 d	18.89 a	3.29 c
	5	03.01.2013	132.94 ac	81.43 bd	57.23 ab	62.73 bd	17.18 ac	3.65 ac
	6	24.01.2013	119.45 ac	80.36 cd	54.24 cd	60.76 cd	18.05 ab	3.37 bc
	7	12.02.2013	114.59 bd	80.74 cd	52.82 de	67.96 ab	12.23 c	5.97 a
	8	06.03.2013	141.51 ab	88.82 ab	56.69 bc	65.97 ac	14.14 ac	4.66 ac
	9	28.03.2013	133.21 ac	81.45 bd	57.70 ab	62.38 bd	17.65 ac	3.55 ac
	10	17.04.2013	148.40 a	85.48 ac	59.25 ab	64.83 ad	15.93 ac	4.07 ac
	11	14.05.2013	157.81 a	89.62 a	59.49 ab	70.08 a	12.61 bc	5.82 ab
	12	04.06.2013	154.03 a	86.01 abc	60.20 a	64.02 ad	16.39 ac	3.93 ac
	LSD		25.23	8.05	3.14	6.88	5.59	2.46

* The differences between the averages indicated by the same letters in the same column were not statistically significant ($p>0.05$).

In the first year of the trial, it was usually observed an increase from the first harvest to ninth harvest (March 10, 2011) in the fruit weight, fruit length and fruit width. A general increasing trend continued at the second year of the study during the harvest period (Table 1).

At the pomological studies of the both periods, the differences between means of fruit weight, fruit length and fruit width were found statistically significant ($p\leq0.05$) throughout the harvest periods (Table 1). These differences are thought to be because of the climatic events (cold, wind and rain e.g.) during January and February, and fruit losses.

In species eaten fruit flesh, cell division usually occurs in the first period of fruit set and cell growth follows cell division (Scora et al., 2002). However, it is stated that cell division continues together with cell growth as long as fruit remains on the tree for avocado, even if it is slower (Schroeder, 1953).

Barmore (1976) states that the fruit development curves of late maturing varieties followed a slower trend until it reaches commercial maturity while fruit development curves of early maturing varieties showed vertical rise in the end of harvest period. In the different researches on the development of the avocado fruit, it was emphasized that the fruit growth curve had a sigmoidal structure depending on increase in fruit weight and fruit volume (Offer, 1986; Demirkol, 1997; Scora et al., 2002).

According to the pomological values; fruit weight, fruit width and fruit length of the cultivar Hass usually increased until the last harvest from the first harvest in both periods, which were compatibly with the works of Young and Lee (1978) in California, Zilkah and Klein (1987) in Israel, Undurraga et al. (1987) and Olaeta et al. (2007) in Chile, Bayram and Aşkın (2006) in Antalya/Turkey and Ozdemir et al. (2009) in Hatay/Turkey.

As seen from Table 1, edible portion, seed portion and edible portion to seed ratio ranged from 63.68% to 70.24%, from 9.55% to 16.15% and from 3.98 to 9.13, respectively, between the first harvest and the last harvest in the 2010-2011 period. As for the 2012-2013 period; edible portion, seed portion and edible portion to seed ratio were found to be between 58.90-70.08%, 12.23-18.89% and 3.29-5.97, respectively. Even though statistically significant differences were found in terms of edible portion, seed portion and edible portion /seed ratio until the last harvest from the first harvest in periods, increment and decrement were not consistent within the observed traits. The similar results were obtained at the studies conducted on the cultivar Hass (Bayram and Aşkın, 2006) and on the other cultivars (Ozdemir et al., 2009).

Oil contents of flesh and dry weight percentages are used as a maturity index for determination of avocado harvest time. The percentages of dry weight and oil content values of the Hass cultivar are given in Table 2 in 2010-2011 and 2012-2013 harvest periods. Also, fruit volume (ml) and fruit density (g ml^{-1}) values, used to calculate fruit development are given in Table 2. The differences between the harvest times with regard to dry weight (%) and oil content (%) values of the Hass cultivar were found statistically significant in harvest periods of 2010-2011 and 2012-2013.

Table 2. Some chemical and physical mean values in percent of fruits of the Hass cultivar according to the harvest times in 2010-11 and 2012-13.

Harvest Years/Number of harvest		Harvesting time	Oil contents of flesh (%)*	Dry weight (%)*	Fruit volume (ml)*	Fruit density (gml^{-1})*
2010-2011	1	05.10.2010	6.43 ı	19.77 g	104.92 ı	1.02 a
	2	19.10.2010	7.85 hı	19.60 g	112.97 hı	1.01 ab
	3	03.11.2010	9.29 gh	21.57 fg	135.40ef	0.97 de
	4	23.11.2010	9.90 gh	23.12 ef	117.64 gı	1.02 ab
	5	12.12.2010	11.32 fg	24.37 ef	134.24 ef	0.97 ce
	6	29.12.2010	11.52 fg	24.43 ef	122.41 fh	0.98 ce
	7	13.01.2011	13.69 ef	26.20 de	129.34 eg	0.98 ce
	8	17.02.2011	16.03 def	27.77 cd	141.85 de	0.96 de
	9	10.03.2011	18.75 c	31.84 b	207.98 a	0.96 e
	10	23.03.2011	18.46 cd	30.68 bc	169.26 c	0.97ce
	11	08.04.2011	19.56 bc	30.94 bc	152.63 d	1.00 ac
	12	25.04.2011	20.71 ac	33.39 ab	130.91 ef	0.99 bd
	13	10.05.2011	20.83 ac	33.17 ab	186.71 b	0.98 ce
	14	24.05.2011	21.99 ab	35.24 a	173.26 c	0.98 ce
	15	13.06.2011	22.06 a	36.45 a	193.32 b	0.97 ce
	LSD		2.45	3.32	13.16	0.03
2012-2013	1	08.10.2012	6.47 f	19.23 f	97.23 d	1.02
	2	05.11.2012	10.23 e	22.48 ef	104.37 d	1.02
	3	21.11.2012	10.59 e	23.14 ef	103.96d	1.02
	4	12.12.2012	10.84 e	24.94 de	111.08 cd	1.02
	5	03.01.2013	14.89 d	25.78 ce	130.80 ac	1.02
	6	24.01.2013	15.66 d	28.38 cd	116.58 bd	1.03
	7	12.02.2013	15.94 d	30.20 bc	111.83 cd	1.03
	8	06.03.2013	21.14 bc	33.90 ab	140.41 ab	1.01
	9	28.03.2013	21.94 ac	34.35 ab	132.93 ac	1.00
	10	17.04.2013	20.28 c	34.21 ab	147.68 a	1.01
	11	14.05.2013	24.07 ab	38.15 a	156.16 a	1.01
	12	04.06.2013	24.86 a	38.28 a	152.82 a	1.01
	LSD		3.38	4.67	26.04	0.03

* The differences between the averages indicated by the same letters in the same column were not statistically significant ($p>0.05$).

While the percent of dry weight for the first harvest and the last harvest increased from 19.77% to 36.45% in 2010-11 and from 19.23% to 38.28% in 2012-13, similarly oil content increased from 6.43% to 22.06% in 2010-11 and from 6.47% to 24.86% in 2012-13 at the same period (Table 2). Dry weight and oil content of avocado fruit varied according to the variety and harvesting time (Vakis et al., 1985; Hofman et al., 2002) and increased throughout the fruit development (Lee and Coggins, 1982; Undurraga et al., 1987; Requejo-Tapia et al., 1999; Bayram and Aşkın, 2006; Ozdemir et al., 2009). Avocado with a remarkable ability to synthesize fatty acid (Barmore, 1976) had fat accumulation in the high levels reaching

up to 30% of fruit weight (Biale and Young, 1971; Barmore, 1976; Bizimana et al., 1993).

The fruit maturity of avocado has been known to occur as a natural consequence of increase in its oil content for a long time and this relationship was shown to have high oil content when fruit reaches a maximum maturity (Barmore, 1976). However, there were not comparable relationships between fruit maturity and fruit oil content for all cultivars when fruits reached maturity. The oil content of avocado cultivars ranged from 15 to 30%. Fruit consisted of further oil content in the cool subtropical climate conditions and it continued to increase when harvest was delayed. As a result, oil contents of the cultivars like Hass and Fuerte could increase up to 25-30% until the start of next season's bloom (Knight, 2002).

Increases of oil content and dry weight throughout harvest periods of this study and significant differences between these values were consistent with other studies reported above.

Fruit development curve of the avocado had a single sigmoid shaped structure (Offer, 1986; Demirkol, 1997; Scora et al., 2002). It was stated that increasing of fruit volume was observed depending on the fruit weight for both the Hass cultivar and the other 6 avocado cultivars, which were observed at 15-day intervals from anthesis to maturity in Chile (Undurraga et al., 1987).

In another study conducted in 1994-96 years in California; fruit development of the cultivar Hass grafted on Duke 7 clonal rootstock was examined by Mickelbart et al. (2012). On observations until 12-14 months by beginning from fruit set (130^{th} day of the year); while maximum fruit growth rate (fruit volume) was determining until the middle of August (230^{th} day of the year), it was quite slow from the middle of August to harvest.

Fruit volume values of the cultivar Hass increased significantly ($P<0.05$) from the first harvest until the last harvest and compared with the other studies, similar results was obtained from this study. Although, for the fruit density, there were statistically significant differences among the harvest times only for the 2010-11 harvest period, there was no consistent changing for this value. While the fruit density values changed between 0.96 g ml^{-1} and 1.02 g ml^{-1} in the 2010-11 harvest period, they varied between 1.00 g ml^{-1} and 1.03 g ml^{-1} in the 2012-13 harvest period.

The correlation analysis was performed for the physical and chemical properties of fruits to determine the fruit maturity index for the Hass cultivar. The correlation coefficients (r) calculated for each harvest periods are given in Table 3.

Table 3. The correlation coefficients (r) found between pomological properties in 2010-2011 and 2012-2013 harvest periods

Variables		Correlation coefficients (r)	
X	Y	2010-2011 Harvest period	2012-2013 Harvest period
Fruit weight (g)	Harvesting time	0.73	0.86
Fruit length (mm)	Harvesting time	0.72	0.73
Fruit length (mm)	Fruit weight (g)	0.96	0.89
Fruit width (mm)	Harvesting time	0.71	0.85
Fruit width (mm)	Fruit weight (g)	0.98	0.96
Fruit width (mm)	Fruit length (mm)	0.92	0.75
Oil contents of flesh (%)	Harvesting time	0.96	0.96
Oil contents of flesh (%)	Fruit weight (g)	0.77	0.83
Oil contents of flesh (%)	Fruit length (mm)	0.76	0.71
Oil contents of flesh (%)	Fruit width (mm)	0.75	0.83
Dry weight (%)	Harvesting time	0.94	0.96
Dry weight (%)	Fruit weight (g)	0.78	0.80
Dry weight (%)	Fruit length (mm)	0.77	0.70
Dry weight (%)	Fruit width (mm)	0.76	0.78
Dry weight (%)	Oil contents of flesh (%)	0.98	0.98
Fruit volume (ml)	Harvesting time	0.71	0.85
Fruit volume (ml)	Fruit weight (g)	0.99	1.00
Fruit volume (ml)	Fruit length (mm)	0.96	0.89
Fruit volume (ml)	Fruit width (mm)	0.99	0.97
Fruit volume (ml)	Oil contents of flesh (%)	0.76	0.82
Fruit volume (ml)	Dry weight (%)	0.77	0.78
Seed weight (%)	Fruit flesh (%)	-0.85	-0.88
Fruit flesh/seed ratio	Fruit flesh (%)	0.85	0.88
Fruit flesh/seed ratio	Seed weight (%)	-0.93	-0.96

As seen in Table 3, in the 2010-11 harvest period, it was found to be linear and high positive relationships between dry weight and harvest time (r=0.94), between dry weight and oil content (r=0.98), and between oil content and harvest time (r=0.96). In addition, there were linear and high positive correlations between fruit length and fruit weight (r=0.96), between the fruit width and fruit weight (r=0.98), and between fruit length and fruit width (r=0.92). A negative relationship was found between seed weight and fruit flesh (r=-0.85).

For the 2012-13 harvest period; similar results with the 2010-11 season were found between dry weight and harvest time (r=0.96), between dry weight and oil content (r=0.98) and between oil content and harvest

time (r=0.96). Also, it was determined linear and high positive relationships between fruit length and fruit weight (r=0.89), between fruit width and fruit weight (r=0.96) and between fruit length and fruit width (r=0.75). It was found a negative relationship between seed weight and fruit flesh (r=-0.88).

Lee and Coggins (1982), Undurraga et al. (1987) and Requejo-Tapia et al. (1999) reported that avocado had a very close relationship between oil content and dry weight during the fruit development. The studies mentioned above confirmed the findings obtained from this study. In addition, an increase was detected on fruit volume from first harvest to last harvest, it was compatible with some other researches, stating the relationship between harvest time and fruit growth (Offer, 1986; Demirkol, 1997; Scora et al., 2002).

4. Conclusion

In this study carried out in Serik, Antalya conditions, it was aimed to investigate some fruit quality criteria for Hass cultivar, which was one of most important commercial avocado cultivars grown in Turkey. Analyses of dry weight and oil content with pomological observations in the Hass cultivar were made during the harvest periods of the 2010-11 and 2012-13.

In the pomological observations; fruit weight, fruit length and fruit width increased 60-85%, 15-20% and 20-25%, respectively, during the harvest periods (between October and June). Additionally, oil contents of flesh, fruit dry weight and fruit volume were observed to increase up to 250-300%, 85-100% and 60-100%, respectively, during the harvest periods.

According to the physical and chemical analyses in fruits; it was found that fruit weight was highly correlated with fruit width, fruit length and fruit volume (r>0.90) during the harvest period. In addition, a very close relationship (r=0.98) was found between dry weight and oil contents of flesh. As a result of this study; the optimal harvest period of Hass cultivar was determined to be from January to June in terms of fruit dry weight and oil content in Antalya conditions.

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