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Full Length Research Paper

The effects of physical and chemical changes on the optimum harvest maturity in some avocado cultivars

Ahmet Erhan Özdemir*, Elif Ertürk Çandır, Celil Toplu, Mustafa Kaplankıran, Turan Hakan Demirkeser and Ercan Yıldız

Mustafa Kemal University, Faculty of Agriculture, Department of Horticulture, 31034 Antakya, Hatay, Turkey.

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The aim of this study was to determine physical and chemical changes during fruit development and their relationship with optimum harvest maturity for Bacon, Fuerte and Zutano avocado cultivars grown under Dörtyol ecological condition. Fruits cv. Bacon, Fuerte and Zutano were obtained trees grafted on seedlings and planted 5 m x 6 m in Dörtyol Research Station of Faculty of Agriculture, Mustafa Kemal University. Fruit width and length, weight, skin and flesh color (L* and hue), total soluble solid (TSS), titratable acidity (TA), TSS/TA, fruit flesh firmness, juice pH, dry weight and oil content were measured on fruits samples collected from tagged trees from June drop to ripening at a 15 days interval during fruit development. Data indicated that oil and dry matter content, flesh firmness and fruit weight were important criteria in determining optimum harvest maturity. Based on the all criteria, the period from the end of November to middle of December was the optimum harvest time for these cultivars in order to deliver fruit at optimum commercial maturity and quality and to obtain adequate storage time.

Key words: Dörtyol, avocado, quality, harvest time.

INTRODUCTION

Avocado(*Persea americana* Mill.), which is a semitropical fruit variety, is grown on five continents and almost 50 countries around the world (Zentmeyer, 1987; Knight, 2002). Avocado production in Turkey is 524 t according to the data for the year of 2007 and highest production is obtained in Antalya City and Mersin City (Anonymous, 2005, 2007). Avocado is a fruit variety, which is being consumed more day by day in especially the countries with high economic level, due to its rich fruit Nutritious content and easily eatable characteristic by people also having certain health problems (Kaplankıran et al., 1994; Demirkol, 1997; Loeillet, 1997). Avocado, which is a fruit variety specific to semitropical climates, can be produced commercially in Mediterranean coastal stripe (Tuzcu et al., 1987; Kaplankıran et al., 1994; Demirkol, 1998; Toplu et al., 1998). Undesired eating quality and irregular maturity may occur in early harvested avocado fruits (Hofman et al., 2000). In case of late harvesting, cracks on its skin because the fruit keeping enlarges, and also, its flesh may spoil and darken as well as fall. Legal standards exist in many countries in which avocado production is intensive for determining fruit maturity and it is not preferred that the is introduced to the market before it reaches harvest maturity (Ranney et al., 1992; Hofman et al., 2000). Basically, determining fruit's oil content is very important in determining avocados' harvest maturity, and minimum 8% oil content was specified as standard (Lee et al., 1983; Kaiser et al.,1992; Demirkol and Pekmezci, 1999b; Knight, 2002). Correlation between dry weight and oil content or water content and oil as well as flavor test each is assessed as a criterion in determining optimum harvest maturity for avocados (Lee and Coggins,

*Corresponding author. E-mail: erhan@mku.edu.tr, aerhanozdemir@gmail.com. Tel: +90 326-245 5849. Fax: +90 326-245 5832.

1982; Lee and Young, 1983; Lee et al., 1983; Undurraga et al., 1987; Demirkol and Pekmezci, 1999a;b; Hofman et al., 2002). It was reported that correlation between dry weight ratio and oil content is used as a maturity index and minimum dry weight ratio should range between 19 and 25% in California (higher than 19% for Fuerte cultivar (Kader and Arpaia, 2006). Undurraga et al. (1987) reported that oil content rises rapidly after a certain period and keeps rising as long as the fruit stays on the tree; though at a low rate in their study in which they investigated seasonal oil contents. Toplu et al. (1998) found that, the highest fruit yield was obtained in Bacon cultivar and the lowest yield was obtained in Hass cultivar while Fuerte cultivar gave the biggest fruits and Hass cultivar produced the smallest fruits in their study performed under Iskenderun's ecological conditions. It was found that growth and development of avocado cultivars traced a sigmoid curve in a study (Demirkol and Pekmezci, 1999a). Similar results were found by various researchers in studies done on avocados (Morris and O'Brien, 1980; Bower and Cuttings, 1988). Demirkol and Pekmezci (1999a) reported that fruit size, dry weight and oil ratio may be used in determining optimal harvest maturity time for avocados grown under our country's conditions. Bayram and Aşkın (2006) reported that the most reliable method is to specify dry weight and oil content as a criteria for maturity and determine the earliest harvest time as the first week of November for Bacon and Fuerte cultivars and mid of November for Zutano cultivars under Antalya's conditions.

The aim of this study was to determine physical and chemical changes during fruit development and their relationship with optimum harvest maturity for Bacon, Fuerte and Zutano avocado cultivars.

MATERIALS AND METHODS

Fruits cv. Bacon, Fuerte and Zutano, which were obtained from trees grafted on seedlings and planted 5 x 6 m in Dörtyol Research Station (36º 09' E, 36º 51' N, altitude 9 m) of Faculty of Agriculture, Mustafa Kemal University in 1998, were used as materials in 2006. Fruit samples were collected from the trees with full efficiency after June drop. Then, chemical and physical analy-ses were done on them. These analyses include: measuring dry weight of each sample after it was dried at 105ºC until fixed with petroleum ether in Soxholet instrument (Lee, 1981), fruit width weight (Lee and Coggins, 1982), oil content measurement through extracting fruit samples, which were dried until fixed weight ,and length (the distance between fruit stem and flower end) measurements in mm through digital compass (sensitivity: 0.01 mm) on the widest section of 5 fruits from 5 branches from 3 trees for each cultivar for each time. Samples were collected from fruits in similar size and fruit weight was measured in gram in laboratory with the help of a balance sensitive until 0.01 g. Skin and flesh color of the fruit was measured with the help of Minolta CR-300 Chromometer according to C.I.E. L*a*b* by reading on both sides in equator part of the fruit in L* and hue values (Abbott, 1999). TSS ratio was measured with the help of a handheld refractometer (Atago Model ATC-1E) as %. TA was measured by employing potentiometric method (Sadler, 1994). For measuring pH value, 5 ml of fruit juice was completed until 100 ml and titrated with 0.1 N NaOH until digital pH-meter showed the value of 8.1. The results were expressed in % malic acid ("g malic acid / 100 ml fruit juice"), TSS/TA, flesh firmness in kg-f (with the help of a penetrometer (Effegi model FT 444) having a drilling head at a length of 6 mm after removing the skin of the fruit with a diameter of approximately 1 cm on both sides of equator section of the fruit and the values were converted to N) and pH (with the help of a digital pH-meter).

Tests were based on completely randomized block design and the data acquired were analyzed through SAS software (SAS Institute, Cary, N.C.) (SAS, 1990) and Tukey test was employed for comparison.

RESULTS AND DISCUSSION

Full bloom time for all three cultivars was the third week of April. Fruit weight was 110.10 g on 80th day after full bloom (DAFB) for Bacon avocados and rose to 270.48 g on 245th DAFB. Fruit weight was 118.30 g on 80th DAFB for Fuerte avocados and rose to 247.44 g on 245th DAFB. Fruit weight was 116.73 g on 80th DAFB for Zutano avocados and rose to 275.20 g on 245th DAFB (Figure 1). Şengüler (1984) reported that, fruit cv. Fuerte was bigger than Zutano and Bacon was under Antalya conditions. Kaplankıran and Tuzcu (1994) reported that, the heaviest fruits were produced in Fuerte cultivar (234.17 g) under Adana conditions (Toplu et al., 1998). Fuerte (317.93 g) fruits were heavier than Zutano (289.04 g), Bacon (248.61 g) and Hass (169.68 g) under Iskenderun conditions. Toplu et al. (2003) produced the biggest fruits in Zutano (284.69 g) under Hatay-Dörtyol conditions. Bayram and Demirkol (2003) reported that, fruit weights ranged between 164.31 and 438.99 g under Antalya conditions. Bayram and Aşkın (2006) determined that, fruit weights reached 292, 289, 149 and 313 g for Bacon, Fuerte, Hass and Zutano cultivars respectively at mid-December. According to our findings, cultivars' fruit weight in harvest maturity time ranged between 247 and 275 g. Zutano and Bacon produced the biggest fruits. Fruit width was 51.60 mm on 80th DAFB for Bacon avocados and rose to 70.96 mm on 245th DAFB. Fruit width was 54.40 mm for Fuerte avocados on 80th DAFB and rose to 67.94 mm on 245th DAFB. Fruit width was 50.84 mm for Zutano avocados on 80th DAFB and rose to 68.67 mm on 245th DAFB (Figure 2). Toplu et al. (1998) reported that, fruit width was higher for Fuerte cv. (71.65 mm) compared with Zutano (71.56 mm), Bacon (67.60 mm) and Hass (61.82 mm) cultivars grown under Iskenderun conditions. Toplu et al. (2003) determined that, fruit width ranged between 70.86 mm (Zutano) and 58.08 mm (Hass) under Hatay-Dörtyol conditions. Bayram and Demirkol (2003) determined that, fruit width ranged between 60.86 and 86.55 mm under Antalya con-

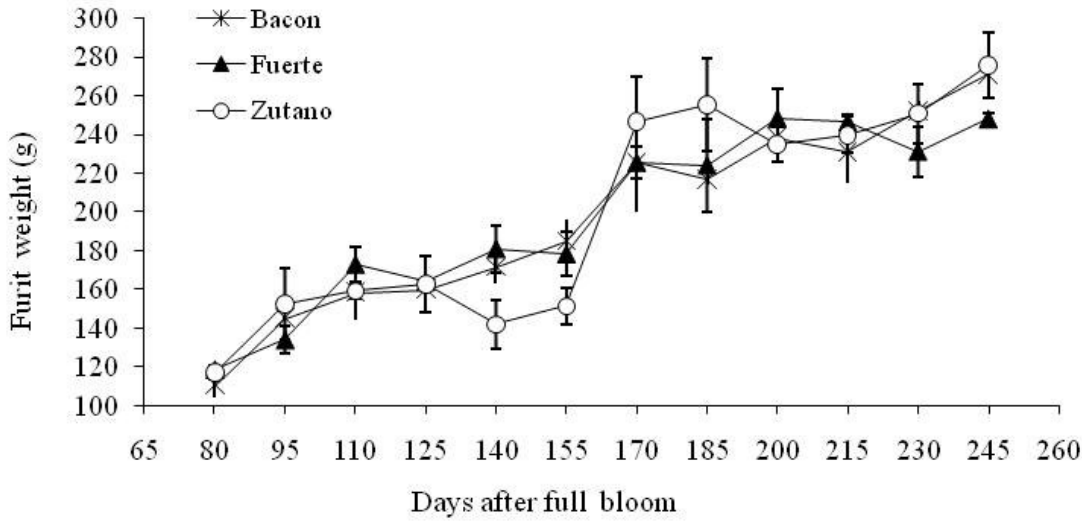

Figure 1. Variations determined in fruit weight during fruit development period for avocados grown under Dörtyol conditions

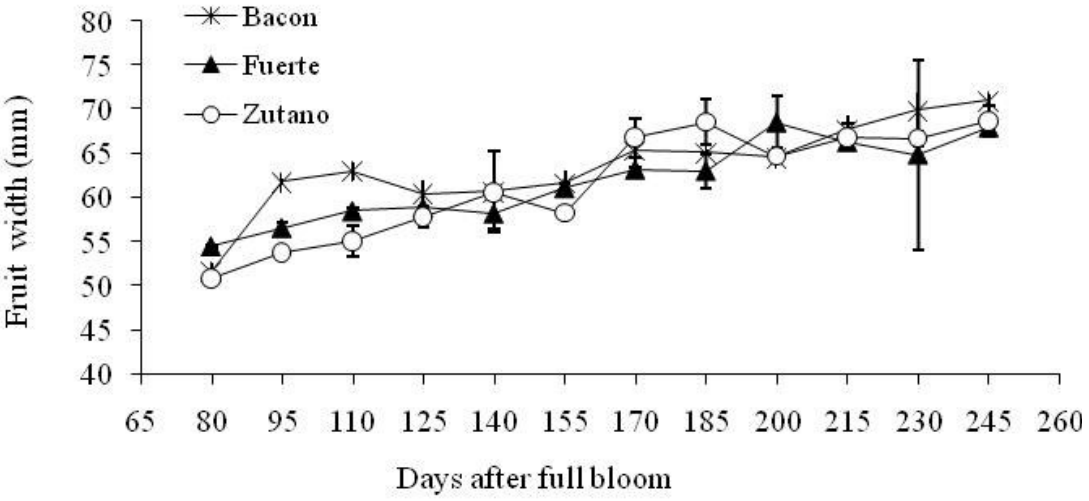

Figure 2. Variations determined in fruit width during fruit development period for avocados grown under Dörtyol conditions.

ditions and fruit width for Bacon cultivar was 69.14 mm, for Fuerte cultivar as 69.93 mm and for Zutano on 70.98 mm. Bayram and Aşkın (2006) found avocados on 80th DAFB and rose to 104.37 mm on 245th DAFB. Fruit length was 90.29 mm for Zutano avocados variations in 80th DAFB and rose to 116.98 mm on 245th DAFB (Figure 3). Kaplankıran and Tuzcu (1994), Toplu et al.cultivar as width between cultivars statistically (1998), Bayram and Demirkol (2003) and Bayram and Aşkın (2006) reported that the highest fruit length was obtained in Fuerte cultivar in their studies. According to our findings, fruit length ranged between 97 and 116 mm and the highest value was obtained in Zutano (116 mm) and Fuerte (104 mm) cultivars. It was reported that, avocado's fruit growth may take more than 12 months depending on cultivar and growth conditions (Scora et al., 2002). It was reported that, fruit growth and development follow a sigmoid curve as a result of variations occurred in its weight and volume (Morris and O'Brien, 1980; Bower and Cuttings, 1988; Demirkol, 1997; Demirkol and Pekmezci, 1999a; Scora et

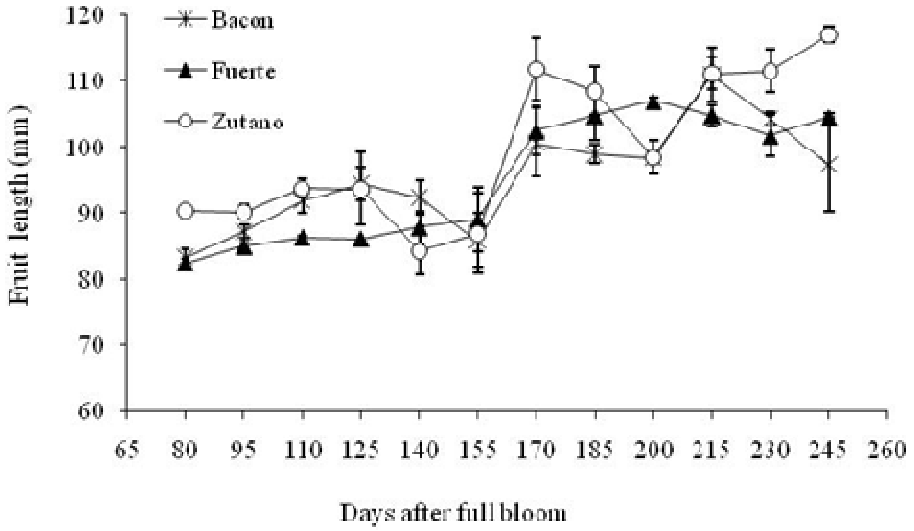

Figure 3. Variations determined in fruit length during fruit development period for avocados grown under Dörtyol conditions.

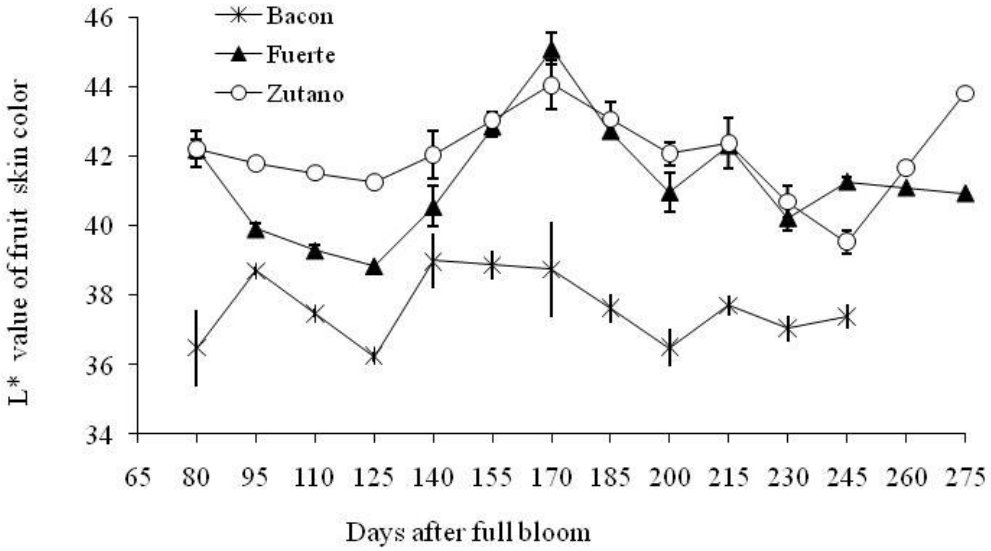

Figure 4. Variations determined in L* value of fruit skin color during fruit development period for avocados grown under Dörtyol conditions

al., 2002). Similarly, fruit weight, width and length intended to increase until 245th DAFB on which final samples were collected for all three cultivars used in our study. Fruit skin color L* value was 36.47 on the 80th DAFB for Bacon avocados. It increased and decreased. It increased although not much and reached 37.37 on the 245th DAFB. Fruit skin color L* value was 42.19 on the 80th DAFB for Fuerte avocados. It increased and decreased. Then, it decreased to 41.27 on the 245th DAFB and 40.94 on the 275th DAFB. Like Bacon avocados, decreases and increases occurred in case of Zutano avocados. While its skin color L* value was 42.20 on the 80th DAFB, it decreased to 39.51 on the 245th day and became 43.82 on the 275th DAFB (Figure 4). Hue (hº) value for skin color of Bacon avocados was 125.82 on the 80th DAFB and decreases and increases occurred in it. It decreased to 123.10 on the 245th DAFB. In Fuerte avocados, hº value of skin color was 122.60 on the 80th

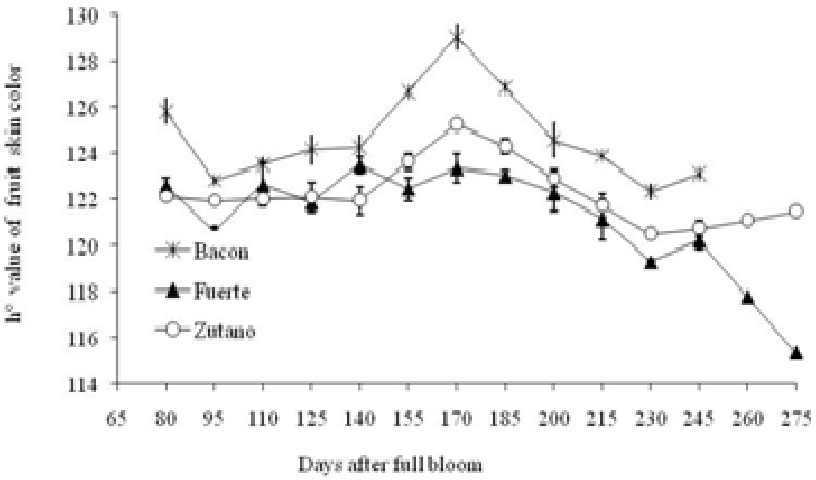

Figure 5. Variations determined in hº value of fruit skin color during fruit development period for avocados grown under Dörtyol conditions.

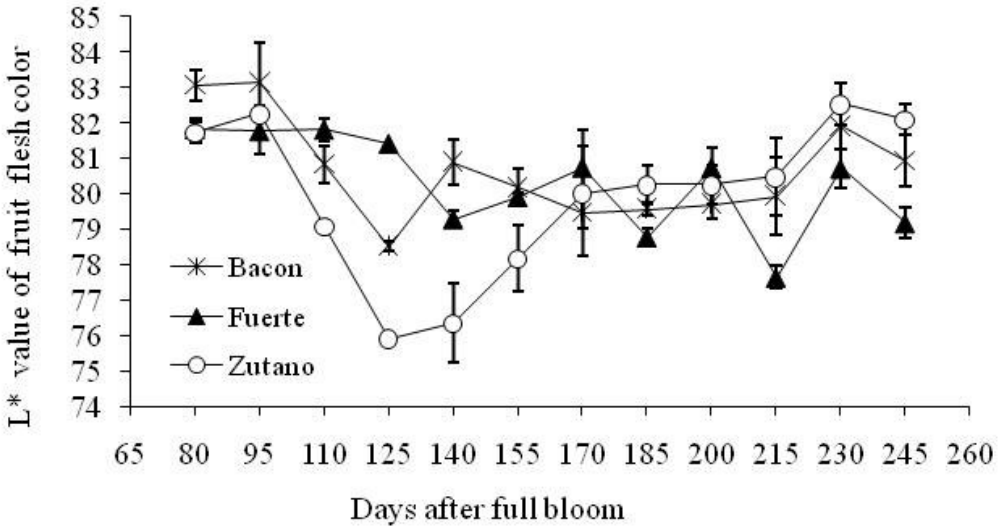

Figure 6. Variations determined in L* value of fruit flesh color during fruit development period for avocados grown under Dörtyol conditions.

DAFB and decreases and increases occurred in it. It decreased to 120.21 on the 245th DAFB and to 115.33 on the 275th DAFB. Similar increases and decreases were seen in Zutano avocados also. While hº value of skin color was 122.11 on the 80th DAFB, it decreased to 120.74 on the 245th DAFB and became 121.47 on the 275th DAFB (Figure 5). In Bacon avocados, flesh color L* value was 83.06 on the 80th DAFB and it decreased to 80.92 on the 245th DAFB. In Fuerte avocados, flesh color L* value was 81.81 on the 80th DAFB and it decreased to 79.17 on the 245th DAFB. In Zutano avocados, flesh color L* value was 81.73 on the 80th DAFB. Decreases and increases occurred in it. It increased to 82.09 on the 245th DAFB (Figure 6). hº value for flesh color of Bacon avocados was 103.80 on the 80th DAFB. It decreased to 98.67 on the 245th DAFB. hº value for flesh color of Fuerte avocados was 104.79 on the 80th DAFB. It decreased to 98.53 on the 245th DAFB. hº value for flesh color of Zutano avocados was 102.86 on the 80th DAFB. It decreased to 99.03 on the 245th DAFB (Figure 7) .In

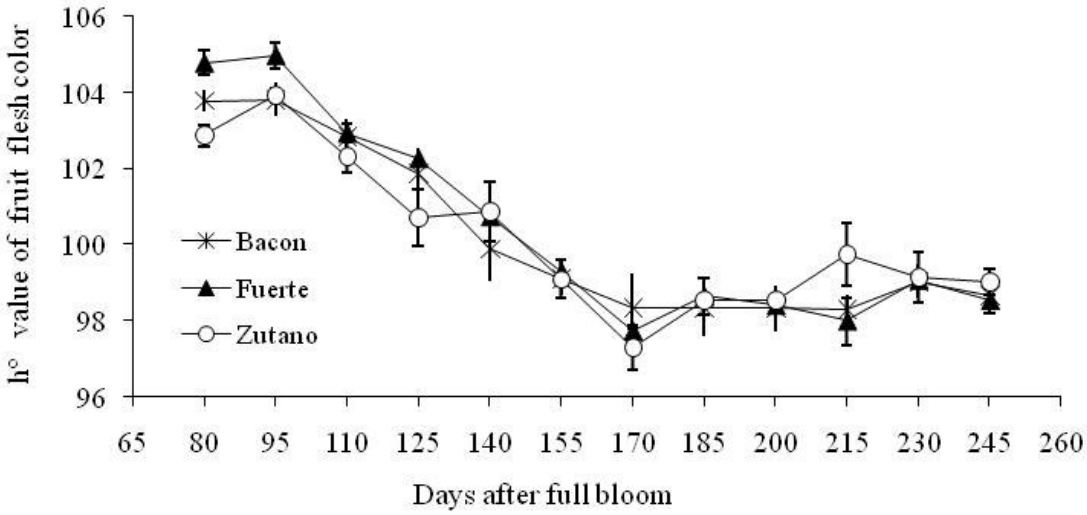

Figure 7. Variations determined in hº value of fruit flesh color during fruit development period for avocados grown under Dörtyol conditions.

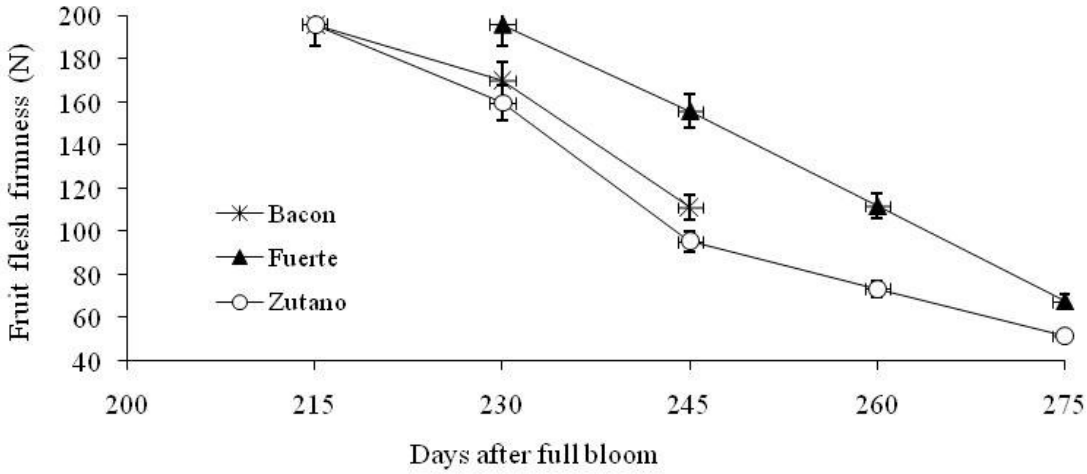

Figure 8. Variations determined in fruit flesh firmness during fruit development period for avocados grown under Dörtyol conditions.

Bacon avocados, Fruit Flesh Firmness (FFF) was over 196.13 N on the 200th DAFB and was 196.13 N on the 215th DAFB. Then, it decreased to 170.24 N on the 230th DAFB and to 111.40 N on the 245th DAFB. In Fuerte avocados, FFF was over 196.13 N on the 215th DAFB and was 196.13 N on the 230th DAFB. Then, it decreased to 156.02 N on the 245th DAFB and to 67.66 N on the 275th DAFB. In Zutano avocados, FFF was over 196.13 N on the 200th DAFB and was 196.13 N on the 215th DAFB. Then, it decreased to 159.85 N on the 230th DAFB, to 95.52 N on the 245th DAFB and to 51.58 N on the 275th DAFB (Figure 8).Oil content of Bacon avocados was 8.64% on the 125th DAFB. Then, it increased to 14.34% on the 245th DAFB. Oil content of Fuerto avocados was 13.84% on the 125th DAFB. Then, it increased to 15.84% on the 245th DAFB. Oil content of Zutano avocados was 12.85% on the 125th DAFB. Then, it increased to 13.95% on the 245th DAFB (Figure 9). Dry weight ratio of Bacon avocados was 19.07% on the 125th DAFB. Then, it increased to 28.56% on the 245th DAFB. Dry weight ratio of Fuerto avocados was 20.50% on the 125th DAFB. Then, it increased to 29.45% on the 245th DAFB. Dry weight ratio of Zutano avocados was 18.97% on the 125th DAFB. Then, it increased to 21.92% on the 245th DAFB

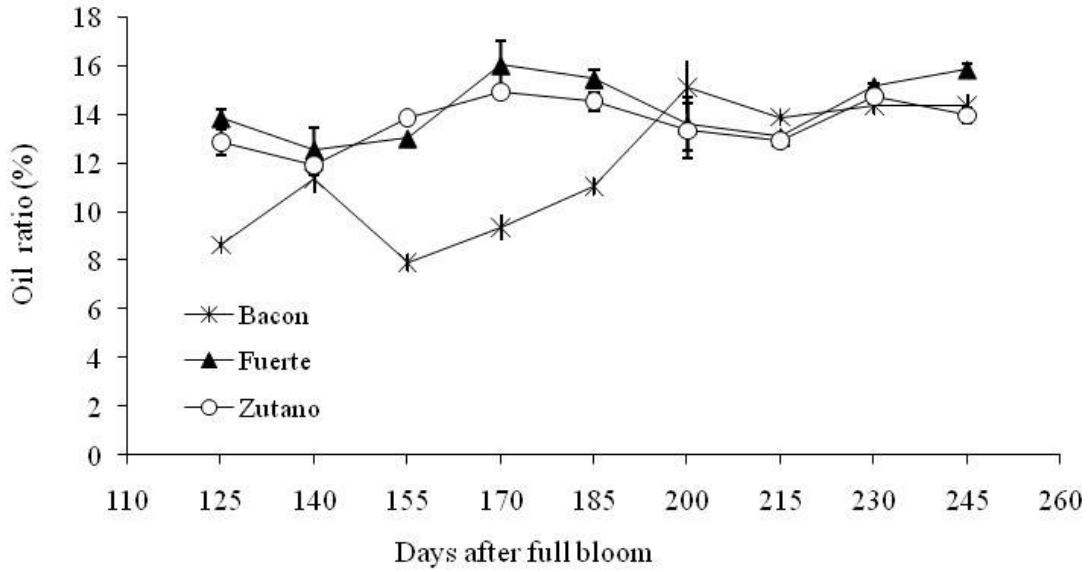

Figure 9. Variations determined in oil ratio during fruit development period for avocados grown under Dörtyol conditions.

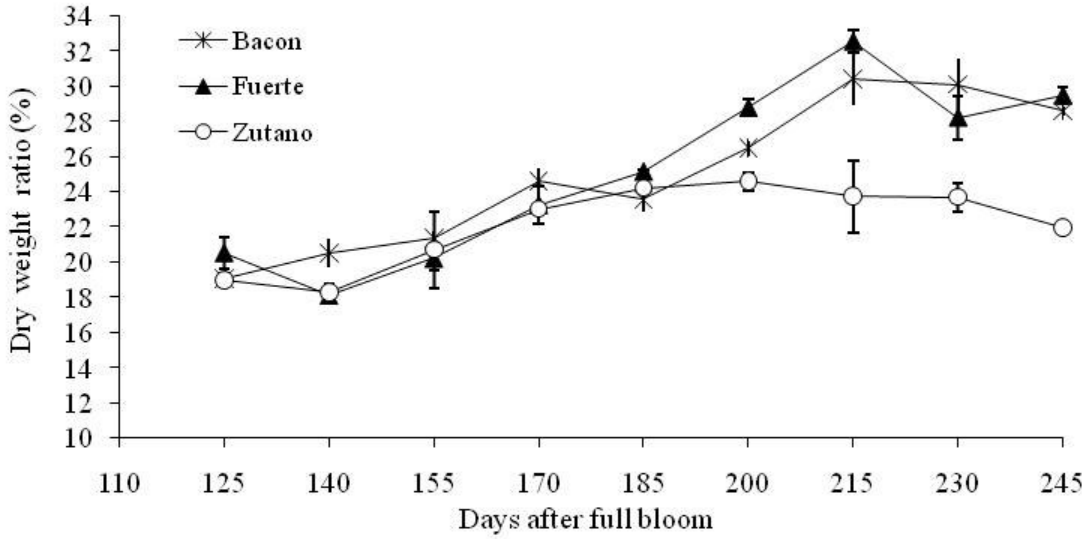

Figure 10. Variations determined in dry weight ratio during fruit development period for avocados grown under Dörtyol conditions.

(Figure 10). Oil and dry weight contents vary depending on cultivars' characteristics and harvest time. Like the studies done previously, oil and dry weight contents intended to increase for three cultivars in our study (Demirkol and Pekmezci, 1999a; Hofman et al., 2002; Bayram and Aşkın, 2006). According to our findings, dry weight ratio increased by 33.23% for Bacon cultivar, 30.39% for Fuerte cultivar and 13.46% for Zutano cultivar between first and last sampling. Oil ratio also increased by 39.75% for Bacon cultivar, 12.63% for Fuerte cultivar and 7.88% for Zutano cultivar between first and last sampling. Although oil ratio variea depending on cultivar,

it was reported that it ranges between 2 and 8% in Americana supsp. cultivars, 10 and 13% in Guatemalensis supspcultivars and 15 and 25% in Dyrimifolia supspcultivars. Oil ratio increases in cool subtropical climates and it reaches 25-30% in Fuerte and Hass cultivars if harvest is delayed (Knight, 2002).In Bacon avocados, total soluble solid (TSS) content was 9.60% on the 80th DAFB and it increased to 10.73% on the 125th DAFB. Then, it decreased and became 7.33% on the 245th DAFB. In Fuerte avocados, TSS content was 8.00% on the 80th DAFB and it increased to 10.07% on the 155th DAFB. Then, it decreased and became 7.20% on the 245th DAFB. Then, it became 7.67% on the 275th DAFB. In Zutano avocados, TSS content was 8.80% on the 80th DAFB and it increased to 10.27% on the 125th DAFB. Then, it decreased and became 7.93% on the 245th DAFB. Then, it became 8.07% on the 275th DAFB (Data no shown). Kaplankıran and Tuzcu (1994) determined that, TSS contents of cultivars grown under Adana conditions ranged between 6.0 and 8.1%. Toplu et al. (1998) determined that TSS content of Fuerte cv (7.36%) was higher compared with those for Bacon (7.05%), Zutano (6.91%) and Hass (6.40%) cv grown under Iskenderun conditions. According to our findings, TSS contents of cultivars at harvest maturity time ranged between 7.33 and 8.10%. Unlike findings of Toplu et al. (1998), the highest TSS content was found in Zutano cultivar (8.10%) while the lowest one was found in Fuerte cv (7.33%).In Bacon avocados, titratable acidity (TA) content was 0.19% on the 80th DAFB. Then, decreases and increases occurred. Then, it decreased and finally became 0.18% on the 245th DAFB. In Fuerte avocados, TA content was 0.22% on the 80th DAFB. Then, decreases and increases occurred. Then, it increased to 0.24% on the 245th DAFB. It finally became 0.21% on the 275th DAFB. In Zutano avocados, TA content was 0.19% on the 80th DAFB. Then, decreases and increases occurred. Then, it decreased to 0.17% on the 245th DAFB and finally became 0.18% on the 275th DAFB (Data no shown). In Bacon avocados, pH value was 5.90 on the 80th DAFB and increased to 6.16 on the 245th DAFB. In Fuerte avocados, pH value was 5.80 on the 80th DAFB, then, increased to 6.20 on the 245th DAFB and finally, became 6.30 on the 275th DAFB. In Zutano avocados, pH value was 5.68 on the 80th DAFB, then, increased to 6.17 on the 245th DAFB and finally, became 6.16 on the 275th DAFB (Data no shown). In Bacon avocados, TSS/TA ratio in water was 52.07 on the 80th DAFB and then decreased to 41.74 on the 245th DAFB. In Fuerte avocados, TSS/TA ratio in water was 36.21 on the 80th DAFB, then, decreased to 30.14 on the 245th DAFB and finally, became 37.25 on the 275th DAFB. In Zutano avocados, TSS/TA ratio in water was 47.28 on the 80th DAFB, then, decreased to 46.99 on the 245th DAFB and finally, became 45.69 on the 275th DAFB (Data no shown).

In conclusion, according to the findings, since Kader and Arpaia (2006) reported dry weight ratio to be over 21%, dry weight ratio was 24.59% of Bacon over 19 avocados grown in Dörtyol in our study at the beginning of October (170th DAFB). Also, oil ratio was 11.02% at mid-October and became 14.35% at the end of November. Fruit flesh firmness (FFF) kept over 196.13 N until the end of October (200th DAFB). Then, it started to decrease. However, the end of November (the 230th DAFB) was determined as the most optimal harvest maturity time for this cultivar from the point of view of commercial maturity and quality desired by the market at which FFF starts to decrease below 196.13 N, skin color L* value ranges between 35 and 40 and hue value ranges between approximately 120 and 125, fruit flesh color L* value is around 80 and hue value between 90 and 100 indicating green-yellow color, oil ratio is around 14% and dry weight ratio is higher than 25%. Similarly, Kader and Arpaia (2006) reported that dry weight ratio should be higher than 19% and Lee et al. (1983) and Demirkol and Pekmezci (1999a) reported that dry weight ratio should be higher than 21% for Fuerte cultivar for achieving the desired flavor. Dry weight ratio reached 23.23% at the beginning of October (170th DAFB) in Fuerte avocados grown under Dörtyol conditions. Also, Demirkol and Pekmezci (1999a) found oil ratio as 11% at the beginning of November in their study while we found it as 13.07% at mid-November and 15.16% at the end of November. FFF was higher than 196.13 N until the end of November (the 230th DAFB) and then, started to decrease. However, around mid-December (the 245th DAFB) was determined as the most optimal harvest maturity time for this cultivar from the point of view of commercial maturity and quality desired by the market at which FFF starts to decrease below 196.13 N, skin color L* value is higher than 40 and hue value is approximately 120, fruit flesh color L* value is around 80 and hue value between 90 and 100 indicating green-yellow color, oil ratio is around 15% and dry weight ratio is higher than grown in Dörtyol in our study at the beginning of October 25%. Dry weight ratio was 22.99% of Zutano avocados (170th DAFB). Fruit flesh firmness (FFF) kept over 196.13 N until the end of October (200th DAFB). Then, it started to decrease. However, the end of November (the 230th DAFB) was determined as the most optimal harvest maturity time for this cultivar from the point of view of commercial maturity and quality desired by the market at which FFF starts to decrease below 196.13 N, skin color L* value ranges between 40 and 45 and hue value is around 120, fruit flesh color L* value is ranges between 80 and 85 and hue value between 90 and 100 indicating green-yellow color, oil ratio is around 14% and dry weight ratio is higher than 21%. According to results, any significant variation in pH, TSS, TA and TSS/TA ratios did not occur in case of all three cultivars.

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