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Food Chemistry 86 (2004) 79–83
Food Chemistry
www.elsevier.com/locate/foodchem

Changes in dry matter, oil content and fatty acids composition of avocado during harvesting time and post-harvesting ripening period

Feramuz Ozdemir *, Ayhan Topuz

Department of Food Engineering, Faculty of Agriculture, University of Akdeniz, 07070 Antalya, Turkey

Received 23 May 2003; accepted 14 August 2003

Abstract

Dry matter, oil content and fatty acid composition of avocado fruit (*Persea americana*, cv. Fuerte and Hass) were examined with respect to the harvesting and post-harvest ripening period. Fruits were harvested in November, December, and January at one-month intervals. Samples were kept for 8 days under ambient conditions to ripen. Dry matter and oil content of both cultivars increased significantly ($p < 0.05$) according to the length of time that the fruits remained on the tree. However, significant ($p < 0.05$) changes in the amount of dry matter and oil content of avocado were determined during the post-harvest ripening period. There were significant ($p < 0.05$) differences in the fatty acid compositions of Fuerte and Hass in each sampling time. Although oleic acid significantly ($p < 0.05$) increased with late harvest, other fatty acids decreased. In particular, palmitic acid notably underwent a 46.5% decrease from November to January. There were statistically significant ($p < 0.05$) differences in the fatty acid compositions during the post-harvest ripening period: however, these were too small numerically to be of significance, either biologically or nutritionally.

Keywords: Avocado (*Persea americana* Mill.); Fatty acid composition; Ripening period

1. Introduction

Vegetable oils are the major source of edible lipids which are consumed in the world. They are extracted either from the endosperm of the oil seeds or from the pericarp of oil fruits, mainly palm and olive. Another important oil fruit is avocado (*Persea americana* Mill.). Avocado is mainly grown in Mexico, the USA and Indonesia (Anon., 2000). However, the cultivation of avocado is expanding into some non-traditional localities, such as Sicily and Calabria in the Mediterranean area (Frega, Bocci, Lercker, & Bortolomeazzi, 1990). Avocado is also grown in Turkey, and plantations have rapidly expanded during the past decade.

From a nutritional point of view, avocado is an important and high caloric fruit. Indeed its high content of unsaturated fatty acids is one of its distinguishing characteristics. Moreover, avocado is rich in vitamin E, ascorbic acid, vitamin B_6, β-carotene, and potassium (Bergh, 1992; Gains, 1992). Unlike many other fruits, the ripening or softening of avocado does not occur during maturity on the tree, but takes place several days after the fruit has been picked. It seems that there is a flow of inhibitive components from the leaves to the fruit, preventing fruit from softening on the tree (Werman & Neeman, 1987). Avocado is also one of the most rapidly ripening of fruits, often completing ripening within 5–7 days following harvest (Seymour & Tucker, 1993). Fruit maturity and picking time are determined according to external markers (colour and size), or by measuring oil content in the flesh (Werman & Neeman, 1987). However, Martinez and Moreno (1995) reported that determining the commercial maturity of the avocado is

* Corresponding author. Tel.: +90-242-310-24-34; fax: +90-242-227-45-64.
E-mail address: feramuz@akdeniz.edu.tr (F. Ozdemir).

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doi:10.1016/j.foodchem.2003.08.012

difficult because the start of ripening is not accompanied by visible external changes.

The minimum oil content necessary for marketing avocado fruit is 8%. After maturation, values greater than 20% can occur. These values occur in the period between harvesting, when commercial maturity is reached and full maturation, when the oil content increases and change occurs in the oil composition. Concentrations of unsaturated fatty acids increase and those of saturated fatty acids decrease (Martinez & Moreno, 1995).

Oil content increases in the mesocarp a few weeks after the fruit sets and can be correlated, afterwards, with the age of fruit. As oil increases in the mesocarp, water content decreases by the same amount, so that the total percentage of oil and water remains constant during fruit life. Nevertheless, biosynthesis of triglycerides does not start at the beginning of the physiological life of the fruit (Gaydou, Lozano, & Ratovohery, 1987). The biochemistry of lipid metabolism in oil fruits has been recently reviewed (Salas et al., 2000). The all-important precursor for de novo fatty acid biosynthesis is acetyl-CoA. The necessary participation of a chloroplast acetyl-CoA carboxylase for the production of long chain fatty acids from [^{14}C]acetate in avocado tissues has been assessed. The products of fatty acid syntheses are mainly C16 or C18 saturated acyl chains. However, most vegetable oils are rich in certain types of unsaturated fatty acid, such as oleate and linoleate. This is due to plants having the necessary mechanisms to introduce double bonds into specific positions of the acyl chains yielded by the fatty acid synthesis reactions. So, in the plastid stroma, there is a very active stearoyl-ACP Δ9-desaturase. This means that, in most plant species, stearate does not accumulate and that oleate is the main product of de novo fatty acid formation. Further desaturation of oleate to produce polyunsaturated fatty acids can take place in the plastid or in the endoplasmic reticulum. Lipid biosynthesis is also affected by environmental factors. The general categories of environmental factors affecting lipid levels and metabolism are light, temperature, water stress, soil constituents, atmospheric constituents and other factors, such as physical damage and pest attack (Salas et al., 2000).

Fatty acid composition is the characteristic feature by which the quality and possible uses of a given oil can be directly delivered (Gaydou et al., 1987). Avocado oil is rich in oleate, which has a low content of saturated fatty acids, and this makes it appropriate for direct human consumption, as well as an excellent fat in diets designed to reduce cardiovascular disease (Gurr, 1992).

To our knowledge, there are no reports on fatty acid composition of avocado during the post-harvest ripening period. There are also no comparative studies on the different cultivars of avocado. The purpose of this study was to measure fatty acid composition in two common avocado cultivars (Fuerte and Hass) to determine whether, there was a change in the quality of oil during either the harvesting or the post-harvest ripening period.

2. Materials and methods

2.1. Materials

Two avocado varieties, Fuerte and Hass (*Persea americana* Mill.), were selected for this experiment. Avocados were harvested from the orchard of The Citrus and Greenhouse Crops Research Institute, Antalya, Turkey. Mature avocado fruits were picked up in the first week of November (Fuerte 215.7 + 14.49 g; Hass 161.1 + 7.05 g), December (Fuerte 298.1 + 7.88 g; Hass 178.0 + 3.01 g) and January (Fuerte 227.8 + 10.45 g; Hass 188.0 + 9.86 g). Sufficient fruits were hand-picked from the same side of visually similar trees, which had been treated by the same agricultural practices. Fruits from each variety were placed in single layer trays and transported to the laboratory within a few hours. Fruits were graded for appearance (i.e., free from damage and sunburn) and randomized for analyses. Fruits were put into commercial cardboard single layer trays and stored at ambient temperature (18–22 °C) in the laboratory for 8 days. Analyses were carried out on the 1st, 4th and 8th days of the post-harvest ripening period.

Methyl alcohol (Merck, Germany), sulphuric acid (Merck, Germany), 2,2-dimethoxypropane (Merck, Germany), *n*-heptane (Carlo Erba, Italy), petroleum ether (Carlo Erba, Italy), benzene (Carlo Erba, Italy) and fatty acid methyl ester standards (Sigma, Germany) were obtained commercially in Turkey.

2.2. Methods

Dry matter contents, at harvest and during ripening after harvest, were determined on the samples, prepared from 5 fruits. Each fruit was cut into quarters, and one-quarter was peeled, the seed coat removed, and the flesh from five fruits pooled and homogenized by a pestle. Dry matter was determined by drying 20 g sample at 70 °C to a constant mass. The other three quarters of the same fruits were treated by the same method, in order to analyse the oil content and composition. Oil content was determined by Soxhlet extraction, using petroleum ether as described by IUPAC (1979) method 1.122.

The fatty acid methyl esters were prepared using a solution of methyl alcohol, benzene, 2,2-dimethoxypropane, sulphuric acid (37:20:5:2 v/v/v/v) and *n*-heptane was used for separation of methyl esters as described previously (Garces & Mancha, 1993). The analysis was performed on a Fison Inst. HRGC Mega 2 gas chromatography equipped with a 25 m $\times$ 0.25 mm ID fused silica capillary column. The flame ionization

detector (FID) and injector port were maintained at 260 °C. Column heating was performed, starting from 150 °C and increasing to 200 °C at 5 °C per minute. The flow rate of helium carrier gas was 1 ml/min, hydrogen 30 ml/min, and air 300 ml/min.

Free fatty acids were identified by comparison of retention time of the gas chromatographic peaks with those of commercial free fatty acid methyl ester standards. They were automatically computed as a percentage by the data processor (Chrom-card) from the ratio of individual peak area to the total peaks area of fatty acids.

2.3. Statistical analysis

Samples were studied in triplicate, analyses were carried out in parallel, and then the averages were calculated. Analysis of variance and Duncan's multiple range test were performed using SAS to evaluate the significance of differences between values at the level of $p < 0.05$.

3. Results and discussion

Table 1 shows that the dry matter and the oil content of both the Fuerte and Hass varieties of fruits increased from November to January. The dry matter content of flesh rapidly increased (22.3%) from November to December. This rate of increase dropped to 2.3% from December to January for the Fuerte. However, in the Hass, the dry matter content steadily increased from November to January. The total dry matter increase was higher in the Hass fruits (43.6%) than in the Fuerte fruits (25.1%). The increase in the dry matter contents was significantly ($p < 0.05$) important during all of the months for both varieties. The amount of oil and dry matter similarly increased in the Fuerte fruits from November to December. However, a rapid decrease was observed for the level of oil in January. In the Hass variety, the amount of oil increased throughout the entire sampling period. In the samples from the first week of November, the oil content of Hass fruits was less than the oil content of the Fuerte variety. The oil accumulation was higher in the Hass variety when the fruit remained on the tree longer, i.e., from the first to the third harvest periods. The oil content increased from November to January at the rates of 23.74% and 77.5% in Fuerte and Hass, respectively. Gaydou et al. (1987) reported that the moisture content of avocado mesocarp decreased steadily with increasing lipid content during the 12–39 weeks after flowering.

After harvesting, during the 8-day ripening period, dry matter decreased in the fruits of the Fuerte. That decrease was not observed to be similar in the Hass. Changes in dry matter were significantly ($p < 0.01$) different in both avocado varieties. As can be seen in Table 1, changes in lipid content were parallel to the changes in dry matter for both varieties. In both avocado varieties, the overall changes in dry matter and oil content during ripening after harvest, were much less when compared to the fruit which remained on the tree.

The fatty acid composition of avocado is given in Table 2. Palmitic, palmitoleic, oleic and linoleic acids were found to be major fatty acids in avocado. Arachidic acid was also determined to be in small amounts in both avocado cultivars. In January, stearic acid was not present for either variety, nor could linolenic acid be detected in the Hass variety.

In general, oleic acid was the only fatty acid which increased continuously from November to January in both varieties, with percentages ranging from 59.3% to 73.0% in the Fuerte, and from 47.2% to 59.5% in the Hass. Hulme (1971) noted that the proportion of oleic acid increases faster than the other fatty acids by retarding the harvest. Changes in the composition of fatty acids in each sampling period were significantly ($p < 0.01$) different from each other. Palmitic acid, in particular, showed a significant ($p < 0.05$) decrease in both cultivars at the end of the sampling period, when

Table 1
The dry matter and oil percentages of avocado (mean ± SE, $n = 9$)

	Dry matter		Lipid	
	Fuerte	Hass	Fuerte	Hass
Harvesting time				
November	$23.62^{c} \pm 0.571$	$21.64^{c} \pm 0.196$	$14.36^{c} \pm 0.405$	$11.02^{c} \pm 0.283$
December	$28.89^{b} \pm 0.373$	$24.26^{b} \pm 0.223$	$20.21^{a} \pm 0.225$	$13.44^{b} \pm 0.365$
January	$29.55^{a} \pm 1.322$	$31.09^{a} \pm 0.389$	$17.77^{b} \pm 1.218$	$19.57^{a} \pm 0.343$
Ripening stage				
1st Day	$28.25^{b} \pm 0.980$	$25.46^{b} \pm 1.582$	$18.55^{a} \pm 0.741$	$14.20^{b} \pm 1.567$
4th Day	$28.81^{a} \pm 1.243$	$25.08^{c} \pm 1.179$	$18.35^{a} \pm 0.980$	$14.40^{b} \pm 1.052$
8th Day	$25.00^{c} \pm 1.137$	$26.45^{a} \pm 1.473$	$15.43^{b} \pm 1.257$	$15.42^{a} \pm 1.233$

The means with different superscript letters within the same column between the lines are significantly different ($p < 0.05$ by Duncan's multiple range test).

Table 2
Changes in the fatty acid composition of avocado oil at three different harvesting times (means ± SE, $n = 9$)

Fatty acids	Cultivars	Harvesting time		
		November	December	January
Palimitic acid	Fuerte	$22.4^{a} \pm 0.693$	$17.7^{b} \pm 0.600$	$12.0^{c} \pm 0.740$
	Hass	$23.3^{a} \pm 0.256$	$21.2^{b} \pm 0.245$	$16.8^{c} \pm 0.508$
Palmitoleic acid	Fuerte	$6.17^{a} \pm 0.296$	$6.49^{a} \pm 0.298$	$4.22^{b} \pm 0.409$
	Hass	$11.2^{a} \pm 0.102$	$10.6^{b} \pm 0.158$	$9.44^{c} \pm 0.207$
Stearic acid	Fuerte	$0.32^{a} \pm 0.083$	$0.12^{b} \pm 0.058$	nd^{c}
	Hass	$0.38^{a} \pm 0.053$	$0.09^{b} \pm 0.037$	nd^{c}
Oleic acid	Fuerte	$59.3^{c} \pm 0.396$	$63.4^{b} \pm 0.926$	$73.0^{a} \pm 0.999$
	Hass	$47.2^{c} \pm 0.181$	$52.1^{b} \pm 0.321$	$59.5^{a} \pm 0.313$
Linoleic acid	Fuerte	$10.3^{b} \pm 0.761$	$11.5^{a} \pm 0.286$	$10.5^{b} \pm 0.390$
	Hass	$16.1^{a} \pm 0.229$	$15.0^{b} \pm 0.167$	$13.9^{c} \pm 0.400$
Linolenic acid	Fuerte	$0.17^{a} \pm 0.073$	$0.03^{b} \pm 0.014$	$0.02^{b} \pm 0.024$
	Hass	$0.44^{a} \pm 0.084$	$0.09^{b} \pm 0.042$	nd^{c}
Arachidic acid	Fuerte	$0.33^{b} \pm 0.063$	$0.53^{a} \pm 0.059$	$0.24^{b} \pm 0.045$
	Hass	$0.98^{a} \pm 0.042$	$0.81^{b} \pm 0.030$	$0.41^{c} \pm 0.027$

The means followed by the different superscript letters in the same line are significantly different ($p < 0.05$ by Duncan's multiple range test); nd, not detected.

compared with its initial value; however, there was a difference between the percentage decreases of the Fuerte and Hass. The percentage of palmitic acid decreased by 46.5% in the Fuerte from November to January; however, the proportion of palmitic acid in January for the Hass was 27.8% lower than its initial value.

A regular decrease was shown for other fatty acids, except linoleic acid. There was a small increase in the percentage of linoleic acid for the Fuerte from November to December and then a slight decrease was observed in January. However, in January, the value of linoleic acid in the Fuerte was not significantly ($p > 0.05$) higher than its value in November. In contrast, linoleic acid steadily decreased from November to January in the fruits of the Hass. The total loss reached 14.2% in January. It has been previously reported that, as the fruits developed, the contents of fatty acids and triglycerides increased (Gaydou et al., 1987).

After harvesting, during a ripening time within 8 days, the proportion of some fatty acids showed a statistically significant ($p < 0.05$) change. In contrast, there were no significant ($p > 0.05$) differences in the proportion of other fatty acids, such as oleic acid, and there were no numerically important changes in terms of nutrition value (Table 3). No literature reports exist on variations in the fatty acid composition of avocado fruit during the post-harvest ripening period. For this reason, these present results could not be compared to existing literature.

The present data show that the oil content and the fatty acid composition of the oil change differently with the avocado varieties, harvesting time and post-harvest ripening period. The data are important in providing information about the oil and fatty acid composition of avocado fruit during maturation to decide the proper harvesting time. The present study also indicates that

Table 3
Changes in the fatty acid composition of avocado oil at three different post-harvest ripening stages (means ± SE, $n = 9$)

Fatty acids	Cultivars	Post-harvest ripening stages		
		1st Day	4th Day	8th Day
Palimitic acid	Fuerte	$17.4^{ab} \pm 1.76$	$18.7^{a} \pm 1.57$	$16.1^{b} \pm 1.49$
	Hass	$21.3^{a} \pm 0.926$	$20.3^{b} \pm 0.991$	$19.8^{b} \pm 1.05$
Palmitoleic acid	Fuerte	$5.60^{ab} \pm 0.548$	$6.00^{a} \pm 0.254$	$5.28^{b} \pm 0.568$
	Hass	$10.2^{b} \pm 0.351$	$10.3^{b} \pm 0.304$	$10.7^{a} \pm 0.192$
Stearic acid	*Fuerte*	$0.07^{b} \pm 0.052$	$0.22^{a} \pm 0.091$	$0.15^{ab} \pm 0.066$
	Hass	$0.23^{a} \pm 0.080$	$0.16^{ab} \pm 0.055$	$0.08^{b} \pm 0.056$
Oleic acid	Fuerte	$65.7^{a} \pm 2.54$	$65.1^{a} \pm 1.49$	$65.0^{a} \pm 2.35$
	Hass	$52.8^{a} \pm 1.93$	$53.1^{a} \pm 1.71$	$53.0^{a} \pm 1.77$
Linoleic acid	Fuerte	$10.7^{b} \pm 0.397$	$9.54^{c} \pm 0.484$	$12.13^{a} \pm 0.318$
	Hass	$14.6^{b} \pm 0.539$	$14.9^{ab} \pm 0.338$	$15.41^{a} \pm 0.356$
Linolenic acid	Fuerte	$0.04^{b} \pm 0.023$	$0.03^{b} \pm 0.024$	$0.16^{a} \pm 0.075$
	Hass	$0.12^{b} \pm 0.041$	$0.16^{b} \pm 0.078$	$0.25^{a} \pm 0.118$
Arachidic acid	Fuerte	$0.35^{b} \pm 0.072$	$0.28^{b} \pm 0.079$	$0.47^{a} \pm 0.036$
	Hass	$0.69^{a} \pm 0.098$	$0.73^{a} \pm 0.066$	$0.77^{a} \pm 0.103$

The means followed by the different superscript letters in the same line are significantly different ($p < 0.05$ by Duncan's multiple range test).

there are no significant changes in oil content of the fruit within the first four days during the post-harvesting ripening period; however, there were statistically significant but not nutritionally important changes in fatty acid composition of the avocado oil.

Acknowledgements

This study was supported by the Research Fund of Akdeniz University Project No: 98.01.0104.06. The authors thank Dr. Ali Ozturk, the director of The Citrus and Greenhouse Crops Research Institute, Antalya, Turkey for collaboration.

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