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Influence of different cultivars on oil quality and chemical characteristics of avocado fruit

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Abstract

The objective of this paper was to determine the chemical composition of the avocado fruit of cultivars Fortuna, Collinson, and Barker and to carry out a detailed analysis of the fatty acid composition of the pulp, seed, and peel oils. The saturated fatty acid (SFA) of the pulp oils accounted for around 22.3, 29.4, and 41.3% of the total fatty acids in the Fortuna, Collinson and Barker cultivars, respectively, and these values indicate better quality of pulp oil of Fortuna and Collinson cultivars than that of the Barker cultivar. There was very little variation in the content monounsaturated fatty acids of the peel oils between the cultivars. However, the seed oil of the Collinson cultivar was the best since it contained the lowest (30.8% of total fatty acids) content of SFA, but it had very high concentrations of 9,12-octadecadienoic (23.9 to 29.4% of total fatty acids) and 9,12,15-octadecatrienoic (9.9 to 18.3% of total fatty acids) acids.

Keywords: fatty acids; peel; avocado oil; pulp; seed.

1 Introduction

Among the tropical and subtropical fruits, the avocado (Persea americana, Mill.) fruit is very much appreciated, and it occupies a prominent place in the market due to its high nutritional value, especially fibers and lipids. In addition, it has soft flavor and low sugar content (about 10 g/kg of pulp) and is generally recommended for the diabetic suffering people since it is as high-energy food (Sinyinda & Gramshaw, 1998). The main characteristic of the edible pulp of the fruit is its high oil content, which varies depending on the cultivars, orchard location, and harvesting time (Gómez-López, 2000). The oil content in the avocado mesocarp is indicative of maturity and fruit quality, which is related to the firmness of the fruit. In addition, these fruits are often inexpensive, extremely rich in vitamins, and can be used in a wide range of food products (Pino et al., 2001).

Avocado fruit shows great variability in size, shape, weight, and chemical composition depending on the variety, the climate conditions, and the agricultural practices (Pino et al., 2004). The avocado fruit is classified into three races: West Indian, Mexican, and Guatemalan (Morton, 1987). The Collinson and Fortuna cultivars are Guatemalan x West Indian hybrids, which play an important role in the Florida avocado industry, while Barker is of West Indian race. The Collinson cultivar is a large fruit, ovoid to elliptical in shape, with smooth skin and shiny light green and yellow flesh of excellent flavor; its pulp contains about 13% of oil (Brasil, 1971; Medina, 1980; Morton, 1987). The Fortuna cultivar is a large fruit with dark green skin and yellow pulp, and it contains about 16% oil, while the Barker cultivar has a smooth skin, a sweet green-yellowish pulp, and an average oil content of 12% (Brasil, 1971; Medina, 1980).

In Brazil, the fruit is classified into two groups (Brasil, 1971): the fruits in the first group, which includes the Collinson and Barker cultivars, are suitable for long-distance transport and are commercialized as whole fruit, while the fruits in the second group, which includes the Fortuna cultivar, are delicate and have buttery consistency and soft pulp texture so that they are more suitable for oil extraction.

The avocado oil, which is similar in composition to olive oil, is highly digestible and consists mainly of unsaturated fatty acids, predominantly oleic acid (Gómez-López, 1998, 1999), which contributes to the consistency and the special taste of the fruit (Sinyinda & Gramshaw, 1998). The avocado oil content is used as a parameter to evaluate the maturation stage of the fruit for harvest purposes (Donadio, 1995). For this reason, the lipid fraction of the avocado fruit has been studied by several authors, focusing on the composition of its fatty acids (Bora et al., 2001; Frega et al., 1990; Freitas et al., 1993; Martinez Nieto et al., 1988; Ratovohery et al., 1988; Soares et al., 1991; Southwell et al., 1990). Gómez-López (2002) characterized the Collinson and Barker cultivars in terms of their high oil content (112.3 to 188.0 g/kg of pulp). Although several authors (Bora et al., 2001; Brasil, 1971; Gómez-López, 2002; Lozano et al., 1993; Martinez Nieto et al., 1988; Medina, 1980; Morton, 1987; Turatti & Canto, 1985) have studied the chemical composition of avocado pulp, only a few of them reported the oil and moisture content of the avocado pulp of the Fortuna (Brasil, 1971; Medina, 1980), Collinson (Brasil, 1971; Medina, 1980; Morton, 1987; Gómez-López, 2002) and Barker (Medina, 1980; Turatti & Canto, 1985; Gómez-López, 2002) cultivars. Moreover, all of these researchers studied the same compositional characteristics, such as proteins, fibers, ash, and carbohydrates of the avocado pulp of the Fortuna, Collinson, and Barker cultivars, and in their evaluation of lipid quality, only a very few fatty acids were reported. These studies focused on the pulp, while the seeds, which account for 100 to 300 g/kg of the fruit (Bora et al., 2001) and the peel, 50 to 220 g/kg (Freitas et al., 1993), have not been studied in detail in terms of their fatty acid profile.

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Nevertheless, no comparative study on the different portions (pulp, seed, and peel oils) of avocado fruits of the Fortuna, Collinson, and Barker cultivars has been published as yet. Thus, the aim of this study was to determine the chemical composition of the cultivars of the avocado fruits which are recommended by the Experimental Station of Itambé – IPA, located in the state of Pernambuco, Brazil. Furthermore, the purpose of this study was to obtain pulp, seed, and skin oils of the three Fortuna, Collinson, and Barker cultivars and to conduct a detailed study on their fatty acid composition.

2 Materials and methods

2.1 Materials

Ripe fruits of the three cultivars, Fortuna, Collinson, and Barker, of avocado were obtained from the Experimental Station of Itambé (IPA - region in the Pernambuco Brazil). The fruits were transported to the laboratory in standard cardboard boxes used for export packaging, and no maturation inhibitor or accelerator was used. Fruits free from any apparent skin damage were selected for analysis. The pulp was manually removed and homogenized using a domestic blender, and the peel and seed were separated. The pulp was packaged in polyethylene bags and stored in a refrigerator (8±2°C) until analysis, which was conducted within 3 days. The pulp, peel, and seed were dried at 50°C for 24 h and triturated for lipid extraction. The solvents and authentic standard flavor compounds were of pure grade (purity >97.7%) and were obtained from Merck and Sigma/Aldrich, respectively.

2.2 Proximate analysis

Protein and lipid contents were determined according to the following methods (Instituto Adolfo Lutz, 2008): protein, method number 037/IV; lipid, method 032/IV; and ash, method 018/IV), while moisture and total dietary fiber were analyzed according to the methods described by Ranganna (1986). Three samples were analyzed in duplicate.

2.3 Physicochemical properties of oil

The oil of pulp, peel, and seed was extracted from dried powdered (about 50g) avocado samples using a Soxhlet extractor and hexane as solvent. Specific gravity and refractive index were determined at room temperature (28°C), according to AOCS methods (American Oil Chemists' Society, 1995 – Method number Cc 10a-25 for specific gravity and Method number Cd 7-25 for refractive index). For the determination of acid, peroxide, iodine, and saponification values, standard AOAC methods (Association of Official Analytical Chemists, 2000, Method number Cd 3a-63, Cd 8-53, Cd 1-25 and Cd 3-25, respectively) were used. Three samples were analyzed in duplicate.

2.4 Fatty acid composition of the oil extracted

Fatty acids were transformed into methyl esters (FAME) following the method of Hartman & Lago (1973) and were determined using an HP 5890 Series II gas chromatograph, (Hewlett Packard – Palo Alto, USA) equipped with a flame ionization detector (FID). A volume of 1.0μL of FAME was injected and chromatographic separation was carried out in an HP INNOwax capillary column (Hewlett Packard; 30m length, 0.25mm i.d. and 0.25μm film thickness). The carrier gas (ultra high purity helium – 99.999%) head pressure was maintained at 11.5 psi, and the column flow rate was 1mL/min. The oven temperature was held initially at 120°C for 1 min, whereafter it was increased at the rate of 8°C/min to 210°C, and then it was maintained at this temperature for 45 min. The temperatures of the injection port and the detector were 250 and 280°C, respectively. FAMEs were positively identified by comparing their retention time data and mass spectra with those of the FAME standards (Sigma/Aldrich; Nu-Chek-Prep, USA) under the same analytical conditions using a Gas Chromatograph coupled with mass spectrometer system (Varian – Walnut Creek, CA, USA; 4000 GC/MS). Three samples were analyzed in duplicate.

2.5 Statistical analysis

The results of the three samples analyzed in duplicate (n=6) were processed for the determination of mean and standard deviation values using the SAS software (SAS Institute, Cary, NC) Version 9.1.3. Significant differences between the mean values of different characteristics were determined by the Tukey´s test for multiple comparisons at the probability of 5% ($p \leq 0.05$).

3 Results and discussion

The data of the physical composition of the avocado fruits of the three cultivars are presented in Table 1. The fruits of the Fortuna cultivar were significantly bigger in size and heavier than the fruits of the other cultivars. There was a large variation (more than 20% in standard of deviation values) in the weight of fruits of the Collinson than those of the Fortuna and Barker cultivars. Medina (1980) reported an average weight of 718g for the Fortuna cultivar and 612g for the Collinson cultivar in fruits grown in the state of São Paulo, Brazil. Gómez-López (2002) reported an average weight of 364g for fruits of the Barker. The maximum pulp yield was also obtained for the Fortuna cultivar fruits, 757g/kg, compared to 735g/kg for Barker and around 700g/kg for the Collinson fruits. However, Medina (1980) reported higher (780g/kg) pulp content in fruits of the Collinson.

Table 2 presents the data on proximate composition of the avocado pulp, peel, and seed. The fruit pulp of the three cultivars, Barker, Collinson, and Fortuna, contained lipid concentrations of 11.9, 13.6, and 16.2 g/100g, respectively, and these values were significantly different ($p \leq 0.05$) between the cultivars. The highest lipid content (more than 16%) was found in the pulp of the Fortuna cultivar, and therefore this cultivar is more suitable for oil extraction. The lipid contents of the pulp of the Barker and Collinson cultivars, which varied between 12 to 14 g/100g, was similar to the data reported by other researchers (Gómez-Lopez, 2002; Morton, 1987; Turatti & Canto, 1985). Ozdemir & Topuz (2004) determined the lipid content of the cultivar Hass at different harvesting times. They reported higher lipid

Table 1. Physical characteristics (mean value ± standard deviation) of different cultivars of avocado fruits.

Characteristic	Fortuna	Collinson	Barker
Weight (g)	418.33 ± 10.26^{b}	280.89 ± 59.13^{a}	309.45 ± 27.89^{a}
Length (cm)	12.82 ± 0.08^{c}	9.20 ± 0.11^{a}	10.21 ± 0.10^{b}
Diameter (cm)	9.85 ± 0.16^{b}	7.11 ± 0.31^{a}	7.32 ± 0.31^{a}
Pulp (g/kg)	757.0 ± 1.42^{b}	695.7 ± 4.23^{a}	734.7 ± 1.52^{a}
Seed (g/kg)	151.4 ± 1.02^{a}	197.0 ± 2.59^{b}	161.1 ± 0.89^{a}
Peel (g/kg)	91.6 ± 0.44^{a}	107.3 ± 1.89^{b}	104.1 ± 0.96^{a,b}

Means in each row followed by different superscript letters are significantly different ($p \leq 0.05$) according to the Tukey test.

Table 2. Proximate composition (g/100g; mean value ± standard deviation) of pulp, seed, and peel of different cultivars of avocado fruit.

Constituents	Fortuna			Collinson			Barker		
	Pulp	Seed	Peel	Pulp	Seed	Peel	Pulp	Seed	Peel
Moisture	72.2 ± 0.85^{A,c}	31.9 ± 0.10^{B,a}	37.7 ± 0.40^{B,b}	76.4 ± 0.75^{B,c}	27.9 ± 1.23^{A,a}	36.5 ± 0.57^{A,B,b}	7.5 ±0.99^{A,B,c}	30.4 ±0.77^{A,B,a}	36.0 ± 0.06^{A,b}
Lipids	16.2 ± 0.13^{C,c}	1.8 ± 0.01^{A,b}	0.9 ± 0.04^{A,a}	13.6 ± 0.25^{B,c}	2.5 ± 0.01^{C,b}	1.7 ± 0.11^{C,a}	11.9 ± 0.62^{A,c}	2.1 ± 0.20^{B,b}	1.1 ± 0.05^{B,a}
Proteins	1.7 ± 0.02^{B,a}	3.6 ± 0.20^{A,b}	3.6 ± 0.09^{A,b}	2.1 ± 0.01^{C,a}	5.3 ± 0.66^{B,c}	3.9 ± 0.28^{A,b}	1.4 ± 0.06^{A,a}	4.0 ± 0.07^{A,B,b}	3.9 ± 0.05^{A,b}
Total dietary fiber	1.6 ± 0.07^{B,a}	1.7 ± 0.11^{A,a}	20.6 ± 0.03^{C,b}	1.3 ± 0.17^{A,B,a}	1.6 ± 0.38^{A,a}	17.7 ± 0.01^{A,b}	1.0 ± 0.02^{A,a}	1.7 ± 0.19^{A,b}	19.4 ± 0.44^{B,c}
Ash	0.6 ± 0.19^{A,a}	1.3 ± 0.07^{A,b}	2.0 ± 0.08^{A,c}	0.7 ± 0.00^{A,a}	1.8 ± 0.13^{B,b}	2.3 ± 0.01^{B,c}	0.7 ± 0.04^{A,a}	2.0 ± 0.01^{B,b}	2.5 ± 0.06^{C,c}

Mean values followed by different superscript letters are significantly different ($p \leq 0.05$) according to the Tukey test; small letters compare constituents (pulp, seed, peel) for the same cultivar and capital letters compare cultivars for the same constituent (pulp, seed, peel).

(19.57%) content in fruits harvested in the month of January than that of fruits harvested in November (11.02%), which could be due to pre-harvest factors. The protein content in the fruit pulp of the Barker, Fortuna, and Collinson cultivars was 1.4, 1.7, and 2.1 g/100g for, respectively, and these values were also significantly different ($p \leq 0.05$) between the cultivars. The ash content of different portions of the fruit varied; it was low in the pulp, medium in the seed, and high in the peel of the fruit and this trend was similar for all cultivars. The pulp of the three cultivars contained higher quantities of moisture and lipids than those of the peel and seed, while protein, ash, and total dietary fiber contents in the pulp were lower. In comparison to the pulp and peel, the seeds had higher amounts of proteins.

The pulp of the Fortuna cultivar contained higher content of total dietary fiber (1.6g/100g) than that of the Collinson and Barker cultivars. The total dietary fiber content of the avocado pulp in all cultivars was higher than the value of 0.4 g/100g reported by Moreno et al. (2003) and lower than the value of 6.3g/100g reported by Gondim et al. (2005). The Collinson cultivar had higher protein content (2.1g/100g), and this value was significantly different ($p \leq 0.05$) from those of the other cultivars. The protein content (1.4 to 2.1g/kg) found in the avocado pulp was similar to the data reported in other studies (Moreno et al., 2003; Gondim et al., 2005; Mooz et al., 2012).

Among all the cultivars studied, the lipid content (1.7%) in the peel of the fruits of the Collinson cultivar was higher, while its total dietary fiber content (17.6%) was lower, and these values were significantly different ($p \leq 0.05$), when compared those of the peel of fruits of the other cultivars. However, Medina (1980) reported lipid content of 4-7% in the avocado peel of some varieties, while Gondim et al. (2005) reported 11.0% lipid and 6.9% of total dietary fiber content.

The lipid (1.8g/100g), protein (3.6g/100g), and ash (1.3g/100g) contents in the seed of the fruits of the Fortuna cultivar were lower and significantly different ($p \leq 0.05$) than those of the Collinson and Barker cultivars. However, these values were similar to those reported in the seeds of the Fuerte cultivar by Bora et al. (2001).

Table 3 shows the data on some physical and physicochemical characteristics of pulp, peel, and seed oils. The oil obtained from peel (0.9292), seed (0.9339), and pulp (0.9275) of the fruits of the Collinson cultivar had the highest specific gravity among the cultivars studied The specific gravity values of the pulp oil were similar to those reported by Bora et al. (2001), Medina (1980) and Moreno et al. (2003). The refractive index values of the oils were not significantly different ($p \leq 0.05$) between the three cultivars for the same constituent of the fruit, and the values of the pulp oil obtained in the present study were similar to those previously reported (Bora et al., 2001; Brasil, 1971; Medina, 1980; Moreno et al., 2003; Soares et al., 1991).

The acid values, a measure of the amount of free fatty acids in the sample, of the pulp oil of the three cultivars did not show any significant difference ($p \leq 0.05$) between the cultivars. The values were 0.49, 0.51, and 0.54 for the pulp oil of the Fortuna, Collinson, and Barker cultivars, respectively, which are similar to the value of 0.50 (Brasil, 1971) and lower than the value of 1.23 reported for the Fuerte cultivar (Bora et al., 2001) and 1.46 reported for avocado grown in Mexico (Moreno et al., 2003).

The saponification value (119) of the pulp oils of the cultivar Fortuna was lower than other values reported in the literature, such as the values of 177 (American Oil Chemists' Society, 1995), 178 (Bora et al., 2001), 175-190 (Medina, 1980), 168-273 (Moreno et al., 2003), and 178 (Soares et al., 1991). The iodine values of the seed oil of the three cultivars were lower than those of the pulp and peel the oil. The iodine values of pulp oil of the three cultivars varied from 64 to 70, and these values are similar to those reported by Bora et al. (2001) and Medina (1980), but they are lower than the range of 82-95 reported by Moreno et al. (2003).

Table 3. Physicochemical characteristics (mean value ± standard deviation) of pulp, seed, and peel oils of different cultivars of avocado fruit.

Characteristic	Fortuna			Collinson			Barker		
	Pulp	Seed	Peel	Pulp	Seed	Peel	Pulp	Seed	Peel
Specific gravity	0.9054 ± 0.0014^{A,a}	0.9260 ± 0.0005^{A,c}	0.9116 ± 0.0004^{A,b}	0.9275 ± 0.0007^{B,a}	0.9339 ± 0.0019^{B,b}	0.9292 ± 0.0008^{B,a,b}	0.9104 ± 0.0018^{A,a}	0.9206 ± 0.0021^{A,b}	0.9265 ± 0.0006^{B,a}
Refractive index	1.4637 ± 0.00501^{A,c}	1.4212 ± 0.016^{A,a}	1.4467 ± 0.0022^{A,b}	1.4669 ± 0.0153^{A,a}	1.4335 ± 0.0311^{A,a}	1.4443 ± 0.0204^{A,a}	1.4662 ± 0.0124^{A,b}	1.3954 ± 0.0057^{A,a}	1.4062 ± 0.0087^{A,a}
Acid value	0.49 ± 0.03^{A,a}	1.19 ± 0.01^{A,b}	1.06 ± 0.23^{A,B,b}	0.51 ± 0.01^{A,a}	2.23 ± 0.10^{C,c}	1.61 ± 0.02^{B,b}	0.54 ± 0.13^{A,a}	1.47 ± 0.01^{B,c}	0.98 ± 0.03^{A,b}
Saponification value	119.5 ± 8.92^{A,a}	206.7 ± 1.61^{A,b}	200.5 ± 3.92^{A,b}	173.7 ± 4.45^{B,a}	232.0 ± 2.95^{B,c}	210.4 ± 1.77^{A,b}	175.0 ± 3.67^{B,a}	261.5 ± 3.17^{C,c}	200.9 ± 1.74^{A,b}
Iodine value	70.40 ± 0.69^{B,a}	68.53 ± 1.92^{B,a}	71.63 ± 0.30^{A,a}	68.24 ± 1.05^{B,b}	62.09 ± 0.35^{A,a}	71.06 ± 0.14^{A,c}	64.40 ± 0.49^{A,a}	63.16 ± 1.35^{A,B,a}	70.00 ± 1.24^{A,b}
Peroxide value	2.60 ± 0.05^{A,c}	1.41 ± 0.04^{B,a}	1.70 ± 0.04^{B,b}	2.30 ± 0.28^{A,c}	1.26 ± 0.01^{A,B,a}	1.48 ± 0.02^{A,b}	2.05 ± 0.78^{A,a}	1.22 ± 0.05^{A,a}	1.63 ± 0.05^{A,B,a}

Mean values followed by different superscript letters are significantly different ($p \leq 0.05$) according to the Tukey test; small letters compare constituents (pulp, seed, peel) for the same cultivar and capital letters compare cultivars for the same constituent (pulp, seed, peel).

The peroxide value of the pulp oil of the Barker cultivar was lower (2.05) than that of the pulp oil of the other cultivars studied in this study, but these values were not significantly different. Similar peroxide values of the pulp oil were found by other researchers, such as 2.5 by Soares et al. (1991), but a lower value (1.4) was reported by Bora et al. (2001) and much higher values, varying from 3.7 to 12.74, were reported by Moreno et al. (2003). Bora et al. (2001) found a peroxide value of 1.37 for avocado seed oil, which is similar to values found (1.2 to 1.4) in the present study. These differences may be due to fruit production in different places, climate, and soil composition.

The fatty acid composition of the pulp, seed, and peel oils is presented in Table 4. The total values of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA), in addition to the MUFA/SFA, PUFA/SFA, and UFA/SFA ratios are presented in Table 5. About 20 FAMEs were identified in the pulp oils of the Fortuna cultivar, followed by 17 fatty acids in Collinson and 14 fatty acids in the Barker cultivars.

The fatty acid *n*-heptanoic was found in trace amounts (less than 0.01% of total fatty acids) in the pulp oils of the Fortuna cultivar, and *n*-heptanoic and n-tridecanoic acids were found in trace amounts in the pulp oils of the Collinson cultivar. The presence of very few fatty acids was reported in earlier reports on avocado pulp oils (Brasil, 1971; Bora et al., 2001; Frega et al., 1990; Martinez Nieto et al., 1988; Medina, 1980; Ratovohery et al., 1988; Soares et al., 1991; Tango et al., 1972, 2004; Villa-Rodríguez et al., 2011; Dreher & Davenport, 2013); the maximum value found was only twelve. The pulp oil quality of Fortuna and Collinson cultivars was found to be better since the SFA values in these pulp oils were 22.3 and 29.4% of the total fatty acids, respectively, when compared with the pulp oil of Barker cultivar, which had higher SFA content, 41.3% of the total fatty acids. Hexadecanoic acid was the major SFA in the three cultivars.

The total contents of MUFA in the pulp oils were 56.9% for the Collinson and 60.8% for the Fortuna cultivar, while the pulp oil content for the Barker cultivar was quite low (37.5%). 9-Octadecenoic acid was the major fatty acid, representing about 86% of the total MUFA in all cultivars. Among the PUFA, 9,12-octadecadienoic acid was present in higher concentrations, and it varied from 13.0 to 19.3% of total fatty acids in three cultivars.

The oleic acid was the principal fatty acid in the pulp oils, followed by palmitic, linolenic, and palmitoleic acids. The contents of oleic and linoleic acids were 51.4 and 16.0% in the pulp oil of the cultivar Fortuna, 51.3 and 13.0% for the Collinson cultivar, and 32.7 and 19.3% for the Barker cultivar. Another essential fatty acid identified in this study was the linolenic acid, which was around 1.0% of total fatty acids in the pulp of the Fortuna cultivar, 0.7% for the Collinson cultivar and 2.0% for the Barker cultivar. Based on the linoleic and linolenic acid contents in the pulp of the three avocado cultivars, it can be concluded that these cultivars are rich sources of these ω-3 and ω-6 fatty acids, which could contribute towards the daily needs of an adult (around 0.8 to 4.0g (World Health Organization & Food and Agriculture Organization, 2003). Other researchers (Brasil, 1971; Bora et al., 2001; Frega et al., 1990; Martinez Nieto et al., 1988; Medina, 1980; Moreno et al., 2003; Ratovohery et al., 1988; Salgado et al., 2008; Tango et al., 1972, 2004; Villa-Rodríguez et al., 2011; Dreher & Davenport, 2013) have also reported oleic acid as the major fatty acid, followed by palmitic, linolenic, and palmitoleic acids in the pulp of Collinson, Barker, Fortuna, Lula, Bacon, Fuerte, Zutano, Hass, and Margarida cultivars of avocado fruit.

A total of 21 fatty acids were identified in the seed oils of the Fortuna and Collinson cultivars, while 22 fatty acids were identified in the seed oil of the Barker cultivar. The only exception was the 13-docosenoic acid, which was found at high levels, 0.6% of total fatty acids in the seed oil of the Barker cultivar. SFA accounted for around 43.9, 30.8, and 36.8% of total fatty acids in the seed oils of the Fortuna, Collinson, and Barker cultivars, respectively, and these values were significantly ($p \leq 0.05\%$) different between the cultivars. The hexadecanoic acid was the major SFA in the seed oil for all cultivars, and it varied from 12.7 to 22.4% of total fatty acids. These values were also significantly different between the varieties. Other researchers (Bora et al., 2001; Medina, 1980)

Table 4. Fatty acid composition (% total fatty acids; mean value ± standard deviation) of pulp, seed and peel oils obtained from different cultivars of avocado fruit.

Fatty acid	Fortuna			Collinson			Barker		
	Pulp	Seed	Peel	Pulp	Seed	Peel	Pulp	Seed	Peel
Saturated Fatty acids (SFA)	22.28	43.91	32.04	29.44	30.75	23.35	41.25	36.81	28.40
n-Heptanoic acid C7:0	Tr	$0.28 \pm 0.04^{B,b}$	$0.06 \pm 0.01^{A,a}$	Tr	$0.08 \pm 0.01^{A,a}$	Tr	$0.07 \pm 0.01^{A,a}$	$0.19 \pm 0.06^{A,B,a}$	$0.74 \pm 0.02^{B,b}$
n-Octanoic acidC8:0	$0.01 \pm 0.00^{A,a}$	$0.08 \pm 0.01^{B,b}$	$0.13 \pm 0.01^{A,c}$	–	$0.24 \pm 0.01^{B,b}$	$0.16 \pm 0.04^{A,B,b}$	$0.24 \pm 0.01^{B,b}$	$0.12 \pm 0.01^{A,a}$	$0.24 \pm 0.01^{B,b}$
n-Nonanoic acidC9:0	$0.01 \pm 0.00^{A,a}$	Tr	–	$0.01 \pm 0.00^{A,a}$	$0.09 \pm 0.01^{A,b}$	–	$0.09 \pm 0.01^{B,a}$	$0.24 \pm 0.04^{B,b}$	–
n-Decanoic acidC10:0	$0.01 \pm 0.00^{A,a}$	–	$0.20 \pm 0.02^{B,b}$	–		Tr	–	–	$0.07 \pm 0.02^{A,a}$
n-Dodecanoic acid C12:0	$0.01 \pm 0.00^{A,a}$	$0.04 \pm 0.01^{A,a}$	$0.64 \pm 0.04^{B,b}$	$0.02 \pm 0.00^{B,a}$	$0.30 \pm 0.01^{B,b}$	$0.04 \pm 0.01^{A,a}$	–	$0.32 \pm 0.04^{B,b}$	$0.14 \pm 0.03^{A,a}$
n-Tridecanoic acidC13:0	$0.06 \pm 0.00^{A,a}$	Tr	–	Tr	Tr	–	–	$0.81 \pm 0.04^{A,a}$	–
n-Tetradecanoic acidC14:0	$0.05 \pm 0.00^{A,a}$	$0.14 \pm 0.02^{A,b}$	$0.45 \pm 0.01^{A,c}$	$0.07 \pm 0.02^{A,a}$	Tr	$0.49 \pm 0.02^{A,b}$	$0.31 \pm 0.13^{B,a}$	$0.51 \pm 0.05^{B,b}$	$0.53 \pm 0.03^{A,b}$
n-Pentadecanoic acidC15:0	$0.05 \pm 0.01^{A,a}$	$7.30 \pm 0.28^{B,b}$	$0.58 \pm 0.04^{B,a}$	$0.17 \pm 0.02^{B,a}$	$5.45 \pm 0.05^{A,b}$	Tr	$0.38 \pm 0.04^{C,a}$	$5.28 \pm 0.16^{A,b}$	$0.39 \pm 0.05^{A,a}$
n-Hexadecanoic acidC16:0	$20.51 \pm 0.07^{A,a}$	$22.41 \pm 1.19^{C,a}$	$28.93 \pm 0.39^{C,b}$	$27.47 \pm 0.91^{A,c}$	$12.64 \pm 0.66^{A,a}$	$19.79 \pm 0.76^{A,b}$	$36.39 \pm 3.49^{B,b}$	$17.87 \pm 0.27^{B,a}$	$24.25 \pm 0.94^{B,a}$
n-Heptadecanoic acidC17:0	$0.03 \pm 0.01^{A,a}$	$5.88 \pm 0.13^{A,b}$	–	$0.05 \pm 0.00^{A,a}$	$7.06 \pm 0.16^{B,b}$	–	$1.29 \pm 0.06^{B,a}$	$6.85 \pm 0.13B^{b}$	–
n-Octadecanoic acidC18:0	$0.53 \pm 0.02^{B,a}$	$2.66 \pm 0.04^{C,c}$	$0.94 \pm 0.03^{A,b}$	$1.06 \pm 0.03^{B,a}$	$1.85 \pm 0.01^{B,b}$	$2.56 \pm 0.19^{C,c}$	$2.25 \pm 0.30^{A,b}$	$1.17 \pm 0.11^{A,a}$	$1.76 \pm 0.07^{B,a,b}$
n-Nonadecanoic acidC19:0	$0.96 \pm 0.01^{A,b}$	–	–	–		–	–	–	–
n-Eicosanoic acidC20:0	$0.07 \pm 0.01^{A,a}$	$0.94 \pm 0.04^{A,b}$	–	$0.14 \pm 0.01^{B,a}$	$1.30 \pm 0.04^{A,b}$	$0.23 \pm 0.03^{A,a}$	$0.25 \pm 0.01^{C,a}$	$2.00 \pm 0.17^{B,b}$	$0.30 \pm 0.02^{A,a}$
n-Doeicosanoic acidC22:0	–	$2.24 \pm 0.16^{B,b}$	$0.15 \pm 0.02^{B,a}$	$0.45 \pm 0.04^{A,b}$	$1.09 \pm 0.09^{A,c}$	$0.07 \pm 0.01^{A,a}$	–	Tr	Tr
n-Tetraeicosanoic acidC24:0	–	$1.96 \pm 0.02^{C,a}$	–	–	$0.64 \pm 0.04^{A,a}$	–	–	1.45 ± 0.11^{Ba}	–
Mono-unsaturated fatty acids (MUFA)	60.79	16.80	48.52	56.91	27.05	51.03	37.48	24.94	50.40
9-Tetradecenoic acidC14:1	$0.01 \pm 0.00^{A,a}$	$0.76 \pm 0.01^{B,b}$	$1.01 \pm 0.04^{A,c}$	–	$0.64 \pm 0.03^{A,a}$	$1.01 \pm 0.04^{A,b}$	–	$0.63 \pm 0.04^{A,b}$	$0.93 \pm 0.08^{A,c}$
10-Pentadecenoic acidC15:1	–	$0.30 \pm 0.02^{B,a}$	–	–	$0.08 \pm 0.03^{A,a}$	–	–	$0.43 \pm 0.03^{C,a}$	–
9-Hexadecenoic acidC16:1	$9.15 \pm 0.16^{B,d}$	$4.45 \pm 0.11^{A,a}$	$6.75 \pm 0.18^{B,c}$	$5.34 \pm 0.86^{B,a,b}$	$4.25 \pm 0.13^{A,a}$	$5.83 \pm 0.19^{B,b}$	$4.30 \pm 0.47^{A,a}$	$6.42 \pm 0.27^{B,c}$	$6.08 \pm 0.27^{B,b,c}$
10-Heptadecenoic acidC17:1	$0.08 \pm 0.01^{A,a}$	$0.42 \pm 0.09^{A,b}$	$0.91 \pm 0.02^{B,c}$	$0.10 \pm 0.01^{A,a}$	$1.90 \pm 0.26^{B,b}$	$0.51 \pm 0.02^{A,a}$	–	$0.76 \pm 0.03^{A,a}$	Tr
9-Octadecenoic acidC18:1	$51.40 \pm 0.45^{B,c}$	$10.88 \pm 0.98^{A,a}$	$39.85 \pm 0.24^{A,b}$	$51.26 \pm 0.86^{B,c}$	$17.59 \pm 0.10^{B,a}$	$43.01 \pm 0.20^{B,a}$	$32.66 \pm 1.12^{A,b}$	$16.09 \pm 0.09^{B,a}$	$42.87 \pm 0.91^{B,C}$
11-Eicosenoic acidC20:1	$0.15 \pm 0.01^{A,a}$	Tr	–	$0.21 \pm 0.03^{A,a}$	$2.59 \pm 0.03^{A,c}$	$0.68 \pm 0.04^{B,b}$	$0.53 \pm 0.08^{B,b}$	Tr	$0.31 \pm 0.08^{A,a}$
13-Docosenoic acidC22:1	–	–	–	–	–	–	–	$0.61 \pm 0.08^{A,b}$	$0.21 \pm 0.04^{A,a}$
Poly-unsaturated fatty acids (PUFA)	16.93	39.31	19.45	13.67	42.22	26.38	21.27	38.27	21.22
9,12-Octadecadienoic acidC18:2	$15.97 \pm 0.39^{A,B,a}$	$29.38 \pm 0.32^{C,c}$	$17.54 \pm 0.33^{A,b}$	$12.98 \pm 0.87^{A,b}$	$23.95 \pm 0.23^{A,a}$	$22.60 \pm 0.06^{B,a}$	$19.25 \pm 1.88^{B,a}$	$25.77 \pm 0.03^{B,b}$	$17.99 \pm 0.11^{A,a}$
9,12,15-Octadecatrienoic acid C18:3	$0.97 \pm 0.01^{A,a}$	$9.93 \pm 0.03^{A,c}$	$1.91 \pm 0.04^{A,b}$	$0.70 \pm 0.04^{A,a}$	$18.27 \pm 0.04^{C,c}$	$3.78 \pm 0.18^{C,b}$	$2.02 \pm 0.55^{A,a}$	$11.72 \pm 0.16^{B,b}$	$3.06 \pm 0.18^{B,a}$
11,14,17-Eicosatrienoic acidC20:3	–	–	–	–	–	–	–	0.78 ± 0.08^{b}	0.17 ± 0.02^{a}

NI – Not identified; *Tr stands for trace level (less than 0.01% of total fatty acids); mean values followed by different superscript letters are significantly different ($p \leq 0.05$) according to the Tukey test; small letters compare constituents (pulp, seed, peel) for the same cultivar and capital letters compare cultivars for the same constituent (pulp, seed, peel).

Table 5. Saturated (SFA), monounsaturated (MUFA), polyunsaturated fatty acids (PUFA) profile (% of total fatty acids; mean value ± standard deviation) of pulp, seed and peel oils obtained from different cultivars of avocado fruit.

Fatty acids	Fortuna			Collinson			Barker		
	Pulp	Seed	Peel	Pulp	Seed	Peel	Pulp	Seed	Peel
SFA	$22.28 \pm 0.07^{A,a}$	$43.91 \pm 1.51^{C,c}$	$32.04 \pm 0.33^{C,b}$	$29.44 \pm 0.93^{A,b}$	$30.75 \pm 0.74^{A,b}$	$23.35 \pm 0.86^{A,a}$	$41.25 \pm 3.17^{B,b}$	$36.81 \pm 0.37^{B,b}$	$28.40 \pm 0.88^{B,a}$
MUFA	$60.79 \pm 0.31^{C,c}$	$16.80 \pm 1.16^{A,a}$	$48.52 \pm 0.04^{A,b}$	$56.91 \pm 0.02^{B,c}$	$27.05 \pm 0.47^{B,a}$	$51.03 \pm 0.05^{B,b}$	$37.48 \pm 0.74^{A,b}$	$24.94 \pm 0.41^{B,a}$	$50.40 \pm 0.98^{A,B,c}$
PUFA	$16.93 \pm 0.38^{A,B,a}$	$39.31 \pm 0.35^{A,c}$	$19.45 \pm 0.36^{A,b}$	$13.67 \pm 0.91^{A,a}$	$42.22 \pm 0.27^{B,c}$	$26.38 \pm 0.12^{B,b}$	$21.27 \pm 2.43^{B,a}$	$38.27 \pm 0.04^{A,b}$	$21.22 \pm 0.09^{A,B,a}$
MUFA/SFA	$2.73 \pm 0.01^{C,c}$	$0.38 \pm 0.04^{A,a}$	$1.51 \pm 0.01^{A,b}$	$1.93 \pm 0.06^{B,b}$	$0.88 \pm 0.04^{C,a}$	$2.19 \pm 0.08^{C,b}$	$0.91 \pm 0.09^{A,a}$	$0.68 \pm 0.02^{B,a}$	$1.78 \pm 0.09^{B,b}$
PUFA/SFA	$0.76 \pm 0.02^{B,b}$	$0.90 \pm 0.04^{A,c}$	$0.61 \pm 0.02^{A,a}$	$0.47 \pm 0.05^{A,a}$	$1.37 \pm 0.04^{C,c}$	$1.13 \pm 0.04^{C,b}$	$0.52 \pm 0.10^{A,a}$	$1.04 \pm 0.01^{B,b}$	$0.75 \pm 0.02^{B,a}$
UFA/SFA	$3.49 \pm 0.01^{C,c}$	$1.28 \pm 0.08^{A,a}$	$2.12 \pm 0.03^{A,b}$	$2.40 \pm 0.11^{B,a}$	$2.25 \pm 0.08^{C,a}$	$3.32 \pm 0.11^{C,b}$	$1.43 \pm 0.19^{A,a}$	$1.72 \ 0.03^{B,a}$	$2.53 \pm 0.11^{B,b}$

Means values followed by different superscript letters are significantly different ($p \leq 0.05$) according to the Tukey test; small letters compare constituent (pulp, seed, peel) for the same cultivar and capital letters compare cultivars for the same constituent (pulp, seed, peel).

also reported hexadecanoic acid as the major SFA in seed oil. The 9-octadecenoic acid was the major MUFA in the seed oil in the Fortuna (10.9%), Collinson (17.6%), and Barker (16.1%) cultivars, followed by 9-hexadecenoic acid (1.2% in Fortuna; 1.5% in Collinson, and 2.4% in Barker cultivars). Among the PUFA in seed oils, 9,12-octadecadienoic acid was the major fatty acid accounting for about 29.4% in Fortuna, 24.0% in Collinson, and 25.8% in the Barker cultivars. Similar values were found by Bora et al. (2001) and Medina (1980) for avocado seed oil.

Avocado seed oils contain high concentration of 9,12-octadecadienoic (23.9 to 29.4%) and 9,12,15-octadecatrienoic (9.9 to 18.3%) acids. Higher values of C18:2/C18:3 fatty acid ratio of avocado seed oil could possibly be responsible for the reduction in the triglycerides and HDL in blood plasma, as reported by Werman et al. (1991) on a nutritional study carried out with rats fed diets containing 10% (w/w) of avocado seed oil. Moreover, the concentrations of 9,12-octadecadienoic and 9,12,15-octadecatrienoic acids and their ratio has been suggested to detect adulteration of avocado pulp oil with seed oil (Bora et al., 2001; Flores et al., 2014).

The fatty acid profile of the peel oils showed the presence of a maximum number (19) of FAMEs in the Barker cultivar, followed by Collinson (17) and Fortuna (15) cultivars. Medina (1980) reported the presence of only 9 FAMEs in the peel oil of the Collinson and Barker cultivars. The SFA of the peel oil accounted for about 23.4, 28.4, and 32.0% of total fatty acids for the fruits of the Collinson, Barker, and Fortuna cultivars, respectively. The major SFAs in the peel oil of all cultivars were hexadecanoic and octadecanoic acids. MUFA in peel oils represented about 48.5 (Fortuna), 51.0 (Collinson), and 50.4% (Barker) of total fatty acid composition, and the 9-octadecenoic acid was the major fatty acid present in the peel oil. Medina (1980) also found the presence of this acid as the most prominent in avocado peel oil.

It is known that some UFAs produce specific effects on living microorganisms and unlike others, it cannot be synthesized by humans; therefore, these fatty acids need to be supplemented in diets. Among these fatty acids are ω-3 and ω-6 fatty acids, which are represented by linoleic acid (C18:2ω6) and linolenic acid (C18:3ω3), respectively, which were present in relatively high levels in the pulp oils of the 3 cultivars studied (Ariffin et al., 2009; Chow, 2008; Uauya et al., 2000).

SFA with an odd number of carbon atoms such as pentadecanoic and heptadecanoic acids are quite rare, and they are found mostly in small levels in microorganisms plants and animals. In the present study, the presence of pentadecanoic acid was detected in the seed oil of all cultivars, and heptadecanoic acid was found in all oils, except for the pulp oil of Barker cultivar.

Wood et al. (2003) reported the importance of high ratio of PUFA/SFA to reduce cardiovascular diseases, and they recommended a minimum value of 0.4. Thus, higher values of this index in almost all oils extracted from the pulp, seed, and peel of the avocado three cultivars, except for that of the pulp oil of the Collinson cultivar, show the high quality of the oils of the Barker, Collinson, and Fortuna cultivars.

4 Conclusions

This study aimed to characterize and evaluate the oil quality of pulp, seed and peel of the Barker, Collinson and Fortuna cultivars of the avocado fruit. The higher pulp yield and lipid concentrations found in the Fortuna cultivar make this fruit to be more suitable for pulp oil extraction, while lipid, protein and ash contents in the seed of this cultivar were lower and significantly different than those of the other cultivars.

A variety of fatty acids was detected in the pulp, seed, and peel oils of the three avocado cultivars in the present study. Relatively high contents of linoleic and linolenic acids present in the avocado pulp oil reveal that the Barker, Collinson, and Fortuna cultivars are rich sources of ω-6 and ω-9 fatty acids.

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