

EThermomechanical extraction and physico-chemical characterization of avocado oil (*Persea americana* Mill. cv.Hass)¹

Extracción termomecánica y caracterización fisicoquímica del aceite de aguacate (*Persea americana* Mill. cv. Hass)¹

Received: 23- 09 - 2016 Accepted: 25-05-2017

Diana Paola Yepes Betancur^{2*}
 Laura Sánchez Giraldo³
 Carlos Julio Márquez Cardozo⁴

¹ Physicochemical characterization of the avocado (*Persea americana* Mill. cv. Hass) and standardization of the oil extraction process. Completed in 2015. Executed and subsidized by the National Apprenticeship Service SENA, Textile Center and Industrial Management, Medellín, Antioquia and the National University of Colombia, Medellín.

² Colombian. Ph.D. (c). National Service of Learning SENA Leader SENNOVA SENA, Centro Textil y de Gestión Industrial. Medellín, Antioquia. * Author for correspondence. diayepesb@misena.edu.co

³ Colombian M.Sc. (c). National University of Colombia, Headquarters Medellín. Faculty of Agricultural Sciences. Fruits and Vegetables. Medellín Colombia. icsanche@unal.edu.co

⁴ Colombian. Ph.D. National University of Colombia, Headquarters Medellín. Faculty of Agricultural Sciences. Medellín Colombia. Associate professor. cjmarque@unal.edu.co

Abstract

The extraction of the oil from the fruit pulp of avocado (*Persea Americana* Mill. Cv. Hass) at maturity organoleptic treatment corresponding to the day harvested, being the day that presented greater concentration lipid ratio equivalent to 20 % ± 2. The extraction system used was a thermomechanical process, the response variable was the oil yield obtained in percentage and the control variable was the extraction temperature. The physicochemical characterization; index of iodine, index of acidity (%) expressed as acid oleic, index of saponification (mg KOH/g), index of refraction to 25 °C, index of peroxides (meq O₂/kg), index of peroxides (meq O₂/kg), point of merger (°C), point of smoke (°C), vitamin E, antioxidant capacity, total phenols and lipid profile of fatty acids, was carried out at oil obtained to temperature extraction of 55 °C for being this the highest yield percentage. Avocado oil obtained can be classified as extra virgin, high in ω3, ω6 fatty acids and vitamin e corresponding to 759.29 mg/100 g, 12862.30 mg/100g and 10.11 mg/100 g respectively, which positions the avocado oil as highly nutritious food and potentially functional what it means beneficial to health.

Keywords: Avocado oil; lipid concentration; physicochemical characteristics; lipid profile; extraction yield.

Introduction

The Avocado, for its nutritional quality, good taste, and culinary versatility, has been gaining importance in the diet of many countries, steadily increasing its production

and marketing worldwide. With the increase in its consumption and with the increase in the areas planted in all the countries that produce it, the avocado industrialization is an activity that depends on the remaining remnants of the production for fresh consumption, being said surpluses, necessarily, of good quality (Olaeta, 2003).

The avocado presents a variety of uses as industrialized products, which allow the use of surpluses and reduce post-harvest losses, among them oil, traditionally used for cosmetic purposes, although the production of extra virgin oil for culinary uses has increased, with great future potential due to its qualities that can replace olive oil (Reed, 2001). The avocado oil obtained from the pulp is relatively new in the gastronomic field. The predominant use of avocado oil has been in the cosmetic industry due to its stability and high level of vitamin E (α -tocopherol). The volume of avocado oil produced or traded is relatively small in comparison with other oils, which is around 2000 tons / year (Wong *et al.*, 2008).

Most of the processes applied in avocado oil extraction are done by relatively severe methods, high temperatures, and extraction by organic solvents, which are usually accompanied by standard measures of refining, such as bleaching and deodorization. The development of the cold pressing technique applied to the avocado pulp by using technologies similar to those used for the production of extra virgin olive oil was led by New Zealand (Ashton *et al.*, 2006; Wong *et al.*, 2008).). The release of oil from the pulp of the avocado is not as easy as it is shown in the tissue of other fruits, such as olives. For example, it was possible to observe the release of oil in ripe olives simply by crushing the fruit (Kiritsakis, Lenart, Willet, & Hernández, 1998). Since avocado pulp has relatively high water content, initial attempts to recover oil from the pulp by using hydraulic pressures or organic solvents require drying prior to extraction (Smith & Winter, 1970; Human, 1987;). Extraction by mechanical means leads to low oil yields, while the use of organic solvents such as petroleum ether, ethyl ether, or benzene results in the recovery of 60 % to 90 % of the total available oil. The extraction of the oil by centrifugation to obtain an oil free of impurities from the solvents and suitable for food use was developed in 1980, but the oil yields are significantly lower than with the solvent extraction, ranging from 30 % to 80 % of the total oil (Buenrostro & López-Munguía, 1986; Swisher, 1988; Werman & Neeman, 1987).

Mexico and Chile are the Latin American countries where techniques for the extraction of avocado oil have been improved and applied (Velásquez, 2006). In Colombia, the

oil is little known and its extraction process has not been popularized yet. The objective of the present investigation consisted of the standardization of the extraction process of avocado oil, as well as its characterization based on the main physicochemical indices, the determination of the profile of fatty acids, antioxidant capacity and total phenols.

Materials y methods

Vegetal material

The research was carried out with avocado fruits (Persea Americana Mill. Cv. Hass) in physiological maturity, according to the specifications of the Colombian Technical Norm NTC 5209 (2003), harvested in a production farm located in the village El Cerro, from the municipality of El Carmen de Viboral, Antioquia (Colombia), located at 2,150 m.s.n.m. with an average temperature of 17 °C, the fruits were harvested in the main season corresponding to the month of July and were stored under laboratory conditions at 23 °C \pm 3 and 65 % RH \pm 5, for 12 days, during which time acquired organoleptic or consumer maturity, period in which it was processed.

Extraction of avocado oil

It was carried out by means of a thermomechanical process, heating and mechanical agitation were applied to aqueous emulsions of avocado pulp at consumer maturity.

The ripe fruits were washed with commercial soap and water, disinfected with sodium hypochlorite in 100 ppm solution and rinsed. Then they were conditioned to obtain the pulp.

The emulsions of avocado pulp and water were prepared at temperatures of 50 °C, 55 °C and 60 °C, then they were brought to homogenization for 10 minutes in an industrial equipment Javar® model LCT-15, capacity 20 L and 3,600 rpm. The lipid concentration of the emulsions prepared was between 3.0 % and 4.0 % as a function of the total lipid concentration of the pulp (20 % \pm 2) found in the previous analyzes (Márquez, Yepes, Sánchez & Osorio, 2014).

All procedures were performed at normal environmental laboratory conditions of 23 °C \pm 2, Relative Humidity of 65 % \pm 5 and an atmospheric pressure of 640 mm Hg.

The emulsion was passed through a 50-plate Westfalia AG Oelde / Westf® brand skimmer operated at 8070 rpm, which is recommended for the extraction of solutions with lipid content between 3.0 % to 4.0 % . Through this procedure, the lipid fraction was separated due to the lower density, as a consequence of having a chemical composition of organic apolar compounds that give it that characteristic. The procedure was performed in triplicate for each extraction temperature, using for each extraction 15 kg of which 3 kg were of participation of avocado pulp corresponding to 20 %, therefore with a lipid concentration in the emulsion of 4 % of total lipids in the emulsion, the extraction time was 5 min and the hydrosoluble fraction was again passed through the skimming equipment, for a total lipid fraction yield of 8 %, that is, 1.2 kg \pm 0.1 of lipid fraction were obtained, composed mostly by oil and other components. Subsequently, the lipid fraction obtained in the skimmer was centrifuged in a Hettich Universal 320R® brand equipment, operating at 3,500 rpm and room temperature of 23 °C for 15 min, where the solids and impurities were separated, and the oil was obtained pure extra virgin, which is expressed as a percentage in relation to the initial lipid concentration known for the pulp. A total of 9 extractions were made, 3 for each experimentation temperature.

The yield calculations of the oil extraction percentage were made with reference to the total lipid concentration of the pulp, it was determined by the Soxhlet method and it was equal to 20 % \pm 2 (Márquez, *et al.*, 2014).

The statistical design was used completely at random, with three treatments and three replications, as a response variable, the percentage of oil extraction was considered. The statistical analyses applied to the results obtained consisted of; multiple range test, chi square, calculation of means and standard error.

Avocado oil

The oil obtained was evaluated in accordance with the guidelines established in the Colombian Technical Standard NTC 241 (2014) and the vegetable oil standard CODEX STAN 210 (1999). The physicochemical indices were evaluated according to the procedures specified by the Association of Official Analytical Chemists (AOAC, 1984) and the American Oil Chemists Society (AOCS 1990, Bernal, 1993, Egan, Kirk & Sawyer, 1991).

Lipidic profile

A derivatization process was carried out to convert the fatty acids present in the avocado oil into non-polar low molecular weight substances, in order to improve the volatility and sensitivity in the detection. For this, 0.1 g of oil was weighed, 3 mL of ethyl ether was added, it was stirred and 1 mL of trimethyl ammonium hydroxyl was added, it was again subjected to agitation and the upper fraction of the container was extracted.

The fatty acids present in the oil and its concentration were evaluated according to the methodology proposed by Gómez-Coca, Moreda, and Pérez-Camino, (2012), for which a gas chromatograph coupled to an Agilent Technologies® mass spectrometer was used model 6890N, equipped with split / splitless injector and selective mass detector 5973N. A silica capillary column (5 % of 95 % diphenyl-dimethylpolysiloxane) was used. The temperatures for the injector and the detectors were 300 °C and 325 °C respectively, the carrier gas was Nitrogen with a flow rate of 1 mL / min. The temperature ramp was 80 °C, 1 min, then rose to 15 °C / min to 140 °C, and finally rose to 4.5 °C / min until reaching 335 °C, 16 min.

Determination of vitamin E (α Tocopherol). The official method AOAC 992.03 was used, saponifying the α tocopherol radical in the sample by means of organic solvents and with subsequent quantification by HPLC high-performance liquid chromatography, for which an Agilent Technologies® 1100 series chromatograph with autosampler system was used. , quaternary pump and diode array detector operating in the range between 190 and 1100 nm. A normal phase column Lichrosorb Si 60 (Merck) of particle size 5 μ m was used. The volume injection was 20 μ L, flow rate 1.0 mL / min. The mobile phase was 0.5% isopropanol in n-hexane (3:97) (Beltrán, *et al.*, 2010). Absorbance was measured at 295 nm. A Tocopherol was identified by comparing the retention time with the standard. The results were reported in mg / 100g of sample.

Determination of total phenols. They were quantified according to the reaction presented by the phenolic compounds with the Folin-Ciocalteu reagent, which is reduced in saturated sodium carbonate alkaline solution (Na₂CO₃), forming a blue color that is read at 760 nm. 50 μ L of sample was taken, 50 μ L of Na₂CO₃ of 20 % concentration (w / v), 800 μ L of distilled water and 100 μ L of the Folin-Ciocalteu reagent (Merck) were added, one hour was left at rest under conditions of laboratory (23 °C and 65 % RH), absorbance at 760 nm was read on a Jenway® model 6405

UV-Vis spectrophotometer. Tannic acid (C₇₆H₅₂O₄₆) was used for the reference curve, in a concentration of 5 avocado extracted at 55 °C. A solution of 2 % w / v sample was prepared with ethanol, filtered on Whatman No. 1 paper and centrifuged at 2000 rpm for 10 min at 23 °C in an Indulab® unit. The supernatant was recovered and used directly for the total antioxidant capacity test by the DPPH, ORAC method and to determine the total phenols.

Evaluación Evaluation of the total antioxidant activity by the method of capture of free radicals using the DPPH radical (1,1-diphenyl-2-picryl-hydroxyl). In order to quantify the free radical scavenging capacity of the samples, the degree of discoloration caused was determined its components to a methanolic solution of DPPH (1,1-diphenyl-2-picryl-hydroxyl). A stock solution of DPPH in methanol was prepared which was standardized at 517 nm. A solution was prepared with the sample, DPPH and methanol and a sample blank containing only methanol and sample. Finally, a reference blank was prepared with DPPH and solvent from the sample. It was incubated at room temperature for 30 min in the dark and the absorbance at 517 nm was measured in a Jenway® model 6405 UV-Vis spectrophotometer. The reaction consists of a change from violet to yellow in the presence of an antioxidant substance (Brand-Williams, Cuvelier, & Berset, 1995).

Evaluation of total antioxidant activity by ORAC method (Oxygen Radical Absorbance Capacity). The experimental procedure was carried out as described (Ou, Hampsch, & Prior, 2001), with some modifications. Trolox was used as standard at a temperature of 37 °C and pH 7.4. The readings were made at 493 nm and 515 nm. For the development of the technique, 1x10⁻² M fluorescein solutions were used in PBS (75 mM Sodium Phosphate Buffer) and 0.6 M AAPH in PBS (75 mM Sodium Phosphate Buffer). The process was determined using a spectrophotometer.

Determination of total phenols. They were quantified according to the reaction presented by the phenolic compounds with the Folin-Ciocalteu reagent, which is reduced in saturated sodium carbonate alkaline solution (Na₂CO₃), forming a blue color that is read at 760 nm. 50 µL of sample was taken, 50 µL of Na₂CO₃ of 20% concentration (w / v), 800 µL of distilled water and 100 µL of the Folin-Ciocalteu reagent (Merck) were added, one hour was left at rest under conditions of laboratory (23 °C and 65 % RH), absorbance at 760 nm was read on a Jenway® model 6405 UV-Vis spectrophotometer. Tannic acid (C₇₆H₅₂O₄₆) was used for the reference curve, in a

concentration of 5 at 100 mg * L, the content of total phenols was expressed how mg of tannic acid (C₇₆H₅₂O₄₆) per 100 g of sample (Adapted from Kalt, Forney, Martin & Prior, 1999).

Results and Discussion

By means of the thermomechanical process, a higher extraction yield was obtained for the process temperature of 55 °C, with an average oil result of 60.2 % with respect to the total lipid concentration of the pulp, which was 20 % ± 2. Figure 1 presents the percentages of extraction for the temperatures used.

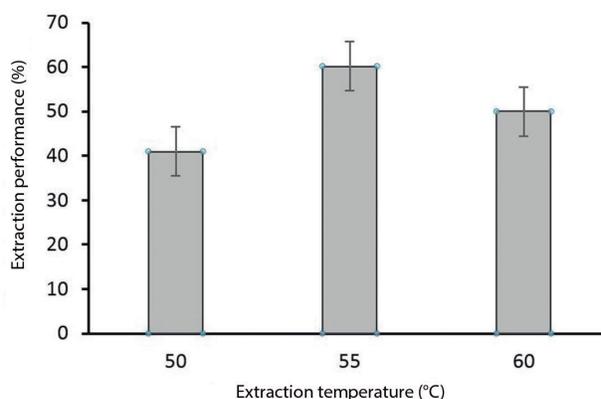


Figure 1. Percentage of oil yield extracted from avocado (Persea Americana Mill. Cv Hass). The bars represent the mean and the vertical lines the values ± of the standard error for n = 3

Other extraction methods such as enzymatic have reported yields of 80 % (Costa, 2001), treatment with microwaves and organic solvents yielded results between 80 % and 90 % (Jiménez, Aguilar, Zambrano & Kolar, 2001). In the application of the thermomechanical method, lower yields than those reported by other researchers were found, although the applied technology is considered relatively simple, economical and easy to transfer to the avocado agroindustrial sector. In particular, it is an oil extraction process that is considered healthier for potential consumers by not using organic solvents. Figures 2A and 2B show the procedure of thermomechanical extraction of the lipid fraction of the avocado pulp emulsions and the oil purification process by centrifugation, respectively.

Table 1 shows the quality indexes of the avocado oil extracted at 55 °C.

According to Table 1, an iodine index of 80.98 was



Figure 2. Thermomechanical extraction of the lipid fraction of avocado emulsions (2nd) and purification of avocado oil by centrifugation

Table 1. Avocado oil quality indexes
(Persea Americana Mill. Cv Hass)

Physicochemical analysis Result	
Iodine index	80.98
Acidity index (%) expressed as oleic acid	0.38
Melting point (° C)	22-24
Saponification index (mg KOH / g)	195.55
Refractive index at 25 ° C	1.4686
Peroxide value (meq O ₂ / Kg)	5.56
Smoke point (° C)	210
Vitamin E (α tocopherol. in mg / 100g sample)	10.11

found, which is relatively high, an aspect that may be related to a high percentage of unsaturated fatty acids, this value is higher than that reported by Costa (2001). Other oils, such as palm oil, have an average value of 53 for the iodine index (Rincón & Martínez 2009). According to NTC 258 (1996), for olive oil an average iodine index of 85 is required, therefore the index found for avocado oil is very close to this value.

The acidity index of 0.38 % for the extracted avocado oil is a low value, according to the NTC 199, which allows classifying the oil as extra virgin, since its acidity is less than 0.8 %. Jiménez, *et al.* (2001) report different values depending on the extraction method, however they are in a range of 0.50 % to 1.50 %. Corner and Martínez (2009), reports values of 2.40 % for African palm oil. With the found values of acidity, the avocado oil obtained could be classified as excellent quality, due to the low content of free fatty acids.

The found saponification index of 195.55 mg KOH / g coincides with that obtained by Costa (2001) and by that required by NTC 258 (1196), for olive oil, while for oils

such as coconut, whose Average molecular weight is higher because of its content of saturated fatty acids, the saponification index required by Codex (1999) is 250 mg KOH / g.

The peroxide index for an oil in optimum conditions should below, the result found of 5.56 meq O₂ / kg is higher than the one reported by Bora, Narain, Rocha, and Queiroz Paulo, (2001) of 3.78 meq O₂ / kg obtained for Milpesos palm oil, this is probably due to some oxidation process during storage, however it is within the values specified by NTC 258 (1996).

The refractive index found at 25 °C, of 1.4686, coincides with that obtained by Human (1987) and Jiménez, *et al.* (2001), indicating the quality and purity of the oil.

The melting point, between 22 °C and 24 °C indicates that this oil is liquid at room temperature, which is also valid for oils such as olive and soy, which can be stored at room temperature; unlike African palm oil that has a melting point between 34 °C to 40 °C (Rincón & Martínez, 2009), an aspect that involves implementing heating systems during transport and storage to keep it liquid.

The smoke point of 210 °C for avocado oil is a little lower than that found by Human (1987) for crude oil of the same fruit; other oils such as soy and corn have smoke points of 257 °C and 246 °C respectively, which gives them greater resistance to high treatment temperatures; while for olive oil it is 191 °C (Rincón. & Martínez, 2009); This indicates that avocado oil has greater resistance to high temperatures than olive oil, so it could be more suitable for use in frying.

The concentration of vitamin E (α tocopherol) of 10.11 mg / 100 g indicates that the avocado oil naturally has a protective agent to oxidation, in addition to the nutritional contribution. Savage, Webster, and Plows, (1994) argue that the content of tocopherol in the oil of Avocado can be up to 3,700 ppm while in olive oil it varies from 12 to 150 ppm. The levels of tocopherol in avocado oil and in the fruit vary depending on the degree of maturity. Lozano, Dhuique, Bannon, & Gaydou, (1993) reported lower levels of tocopherol in the oil extracted from the mature fruit (5.7 to 10.3 mg / 100 g oil) than in the immature fruits that showed concentrations of (20 , 1 to 45.6 mg / 100 g of oil).

Vitamin E helps to prolong the useful life of avocado oil since it destroys free radicals produced during oxidation reactions by the presence of hydroperoxides (Coppen, 1994). Tocopherols are unstable and sensitive to light, therefore low levels of oxygen and light are recommended during the oil extraction process. The situation that was not applied in the present investigation, therefore the low levels of tocopherol could be due to not controlling the light and oxygen variables during the experimentation.

Table 2 presents the lipid profile of the fatty acids of avocado oil and clearly indicates the large proportion of unsaturated fatty acids in relation to the number of saturated ones. Palmitic acid was the main saturated acid, with a concentration of 21.52 %, almost the total of saturated fat, this agrees with that found by Bora, *et al.* (2001). The most representative unsaturated fatty acid was oleic acid, with 53.25 %, lower than that found by Human (1987) of 70.54 % and by Costa (2001) of 75.12 %. The percentage of polyunsaturated fatty acids was 13.62 %, higher than that reported by Parra (2005) of 12.1 %, but coincides with that reported by Pérez, Villanueva, and Cosio, (2005). It can also be observed that it does not contain cholesterol, instead, it has essential fatty acids omega 3 and omega 6, essential in the diet.

Other vegetable oils have an average palmitic acid content of 43 % and 40 % oleic acid, while according to NTC 258 (1996), olive oil must have a percentage of oleic acid between 55 % to 83 %; soybean oil, on the other hand, has the highest amounts of linoleic acid and linolenic acid, 48.60%, and 10.85% respectively, as well as commercial canola oil that has high percentages of these acids (Osuna, Judis, Avallone, & Romero, 2009). The specifications indicated for commercial avocado oil in California indicate that palmitic acid (C16: 0) should fluctuate between 5 % and 25 %, a maximum of 3.0 % stearic acid (C18: 0) and a range of oleic acid between 50 % and 74 % (Parra, 2005).

Table 2. Fatty acid lipid profile of avocado oil (*Persea Americana* Mill.cv. Hass)

Lipid profile of fatty acids	Results
Saturated fat (%)	22.1059
Unsaturated fat (%)	77.377
Monounsaturated fat (%)	63.7555
Polyunsaturated fat (%)	13.6216
Palmitic acid (%)	21.5194
Oleic acid (%)	53.2511
Linoleic acid (%)	12.8726
Linoleic acid (%)	0.7599
Stearic acid (%)	0.4806
Omega 3 (mg/100g)	759.292
Omega 6 (mg/100g)	12862.302
Omega 9 (mg/100g)	53208.499

The avocado oil obtained in the present study is within the indicated ranges. It is important to note the low percentage of stearic acid (C18: 0) and in general of saturated fatty acids and the high percentage of monounsaturated fatty acids. Bergh (1992) points out that although monounsaturated and polyunsaturated acids are related to the reduction of cholesterol in the blood, only monounsaturates influence the reduction of blood pressure.

The importance of the bioavailability of oleic and linoleic unsaturated fatty acids lies in the fact that they are hypocholesterolemic, which is why LDL (low density lipoprotein) cholesterol levels drop in the arteries and potentiate the beneficial actions of HDL cholesterol (high density lipoprotein) (Stanley, 2008). For these reasons avocado oil complies with the nutritional recommendations and is also considered a functional food by the contribution of substances known to contribute to the good health of consumers. The differences found in this work with respect to other investigations, in the physicochemical indices and the lipid profile of the avocado oil, are probably due to the techniques used in the extraction, to the environmental conditions in which the fruit was grown, to the variety and to the state of maturity.

According to Table 3 it can be seen how the inhibition percentages of the DPPH radical were very low, in an order of 6.15 % for the pulp and 3.4 % for the extracted oil, this indicates that both the pulp and the oil are not good radical scavengers by technique DPPH, since a large part of the radical remains unstable. A sample with good antioxidant activity by DPPH is in the order of a percentage

of inhibition greater than 50 % (Corral, Yahia, Carrillo, & González, 2008). The antioxidant activity of the oil by the ORAC method was also low 518 μM Trolox / 100 g oil, compared with the antioxidant activity of the small berries, for strawberry for example a value of 3600 μM Trolox / 100 g (Fraternale, Giamperi, Bucchini, & Ricci, 2009; Wang, Bostic, & Gu, 2010), evaluated in the pulp, skin and seed of avocado (*Persea Americana Mill. Cv Hass*) the antioxidant capacity by DPPH and ORAC methods, finding very low values in the pulp of 1.3 μM TE / g and 11.6 μM Trolox / g respectively, compared to that found in the seed of 428.8 μM Trolox / g.

Table 3. Antioxidant capacity of avocado oil and pulp (*Persea Americana Mill. Cv Hass*)

Method	Pulp	Oil
DPPH (% of inhibition)	6.15 \pm 0.45	3.4 \pm 0.22
ORAC (μM Trolox/100 g oil)	---	518 \pm 14

In vegetable oils, is normal to find low values with the application of different techniques since during the extraction process many compounds of antioxidant activity are usually lost, probably due to exposure to heat, light, and oxygen. In addition, it is important to mention that some antioxidants are polar, so to evaluate the antioxidant capacity it is important to obtain hydrophilic and lipophilic extracts of both the fruit and the oil and thus determine the antioxidant capacity in each extract since the different antioxidant compounds are distributed from according to their affinity with the environment (Cheng, Moore, & Yu, 2006, Villa, Molina, Ayala, Oliva, & González, 2011).

So far, the majority of the studies carried out on the antioxidant activity of avocado have focused mainly on the evaluation of hydrophilic compounds, such as ascorbic acid and phenolic compounds, because they are usually closely related to the important antioxidant activity in fruits and vegetables (Wang, *et al.*, 2010; Corral, *et al.*, 2008) reported lower antioxidant capacity in lipophilic extracts than in the hydrophilic extracts of several tropical fruits such as mango, papaya and avocado measured by DPPH and expressed as TEAC.

The lipophilic phytochemicals contribute to the total antioxidant activity of the avocado, (Richard, Kefi, Barbe, Bausero, & Visiolo, 2008) have reported that the acids unsaturated fatty acids can act as antioxidants depending on their degree of saturation, however it is necessary to take into account the possible synergistic and / or antagonistic effects of these compounds since in making specific

analyzes these behaviors can not be evaluated (Hidalgo, Sánchez, & Pascual, 2010).

Table 4 presents the values of total phenols for the pulp and oil, which are low, when compared to other fruits such as papaya in which a value of 57.8 mg GAE / 100 g, the medlar with 56 was found , 9 mg GAE / 100 g and the fig with 61 mg GAE / 100 g (Pande & Akoh, 2010). The values found coincide with the total content of phenols found in eight different avocado cultivars; the pulp and seeds of the cv. Hass with 4.9 mg GAE / g and 51.6 mg GAE / g respectively, was the highest compared to the other cultivars (Wang, *et al.*, 2010; Wong, *et al.*, 2009) point out that until now Phenolic compounds are not found in high concentrations in avocado oils, since the nature and concentration of the phenols present in it depend on the composition of the fruit and the extraction conditions, these compounds being easily modified by oxidation.

Tabla 4. Total phenols in avocado oil and pulp (*Persea Americana Mill.cv. Hass*)

Sample	Total phenols (mg tannic acid / g sample)
Pulp	0.38 \pm 0.01
Oil	0.17 \pm 0.01

The low values found in the antioxidant capacity and in the total phenols in the pulp and avocado oil could be related to the proposed by Jayaprakasha, and Patil, (2007) who demonstrated a causal relationship between the content of total phenols and the antioxidant activity.

Conclusions

The thermomechanical extraction of avocado oil represents a good technological alternative for the agroindustrial sector of this crop, as it is a simple and affordable procedure, providing a final product of excellent quality and with high agroindustrial potential. The optimum oil extraction temperature for this process was 55 °C, with a yield of 60.2 %, without causing deterioration to the quality of the oil. According to the NTC 199 standard, avocado oil obtained can be classified as an extra virgin product with In addition, a content of $\omega 3$, $\omega 6$ unsaturated fatty acids of 759.292 mg / 100 g, 12862.302 mg / 100 g respectively and Vitamin E of 10.11 mg / 100 g, respectively, was found. which makes avocado oil a highly nutritious and functional food.

Acknowledgments

The authors thank in a special way the technician of the fruit and vegetable laboratory, Engineer Fernando Arenas Gil, in addition to the personnel of the laboratories of Food Quality Control, Instrumental Analysis and Dairy Plant of the *Universidad Nacional de Colombia*, Medellín Headquarters, the support provided during the experimental stage of this work, likewise, to the *Servicio Nacional de Aprendizaje* SENA, Textile Center and Industrial Management, for the co-financing of the research.

References

- Ashton, O., Wong, M., McGhie, T., Vather, R., Wang, Y., Requejo-Jackman, C., Ramankutty P., Woolf, A. (2006). Pigments in Avocado Tissue and Oil. *J. Agric. Food Chem.*, 54 (26), pp 10151–10158. doi: <https://doi.org/10.1021/jf061809j>
- Association Of Official Analytical Chemist. (A.O.A.C.). (1984). Official methods on analysis of Association of Official Analytical Chemist. 14th ed. Virginia, U.S.A.
- Association Of Official Analytical Chemist. (A.O.A.C.). (1990). Official methods on analysis of Association of Official Analytical Chemist. 15th ed. U.S.A.
- Beltrán, G., Jiménez, A., Del Rio, C., Sánchez, S., Martínez, L., Uceda, M., Aguilera, M. (2010). Variability of vitamin E in virgin olive oil by agronomical and genetic factors. *Journal of Food Composition and Analysis* 23(6), 633–639. doi: <https://doi.org/10.1016/j.jfca.2010.03.003>
- Bergh, B. (1992). The avocado an human nutrition. Avocados and your heart. Proceedings of the second world avocado congress. University of California, Riverside. California. 25-35 p.
- Bernal, I. (1993). *Análisis de Alimentos*. Universidad Nacional de Colombia, Bogotá D.C, 127 pp.
- Bora, P., Narain, N., Rocha, R., & Queiroz, P.M. (2001). Characterization of the oils from the pulp and seeds of avocado (cultivar: Fuerte) fruits. *Grasas Y Aceites*, 52(3-4). doi: <https://doi.org/10.3989/gya.2001.v52.i3-4.353>
- Brand-Williams, W. Cuvelier, M. E. & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT Food Science and Technology*, 28(1), 25–30. doi: [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)
- Buenrostro, M. & López-Munguia, A.C. (1986). Enzymatic extraction of avocado oil. *Biotechnology Letters*, 8, 505–506. doi: <https://doi.org/10.1007/BF01025210>
- Cheng, Z., Moore, J. & Yu, L. (2006). High-throughput relative DPPH radical scavenging capacity assay. *Agricultural and Food Chemistry*, 54, 7429–7436. doi: <https://doi.org/10.1021/jf0611668>
- Codex Stan 210. (1999). Norma del Codex para aceites vegetales especificados.
- Coppen, P. (1994). *Rancidity in Food. The use of antioxidants*. London: Blackie Academic & Professional. 84-103.
- Corral, R., Yahia, E., Carrillo, A., & González, G. (2008). Correlation between some nutritional components and the total antioxidant capacity measured with six different assays in eight horticultural crops. *Journal of Agricultural and Food Chemistry*, 56(22), 498–504.
- Costa, V. (2001). *Undergraduate thesis Enzymatic extraction and characterization of avocado oil (Persea americana Mill)*. Faculty of Agricultural Sciences, University of Chile, Santiago, Chile.
- Egan, H., Kirk, R. & Sawyer, R. (1991). *Chemical analysis of Pearson's food*. Editorial Continental, S.A. Mexico, 520 pp.
- Fraternale, D., Giamperi, L., Bucchini, A. & Ricci, (2009). Antioxidant activity of prunus spinosa L. fruit juice. *Food Sci.*, 21, 337–346.
- Gómez-Coca, R., Moreda, W., & Pérez-Camino, M. (2012). Fatty acid alkyl esters presence in olive oil vs. organoleptic assessment. *Food Chemistry*, 135, 1205–1209. doi: <https://doi.org/10.1016/j.foodchem.2012.05.053>

- Hidalgo, M., Sánchez, C. & Pascual, T. (2010). Flavonoid-flavonoid interaction and its effect on their antioxidant activity. *Food Chemistry*, 691–696. doi: <https://doi.org/10.1016/j.foodchem.2009.12.097>
- Human, T. P. (1987). *Oil as a byproduct of avocado*. South African Avocado Growers' Assoc. Yearbook, 10, 159–162.
- Jayaprakasha, G. K. & Patil, B. S. (2007). In vitro evaluation of the antioxidant activities in fruit extracts from citron and blood orange. *Food Chemistry*, 101, 410–418. doi: <https://doi.org/10.1016/j.foodchem.2005.12.038>
- Jiménez, M.E., Aguilar, M., Zambrano, M., Kolar, (2001). Physical and chemical properties of avocado oil obtained from dehydrated puree by microwaves. *Journal of the Mexican Chemical Society*, 45 (2), 89–92. Recovered from: <http://www.redalyc.org/articulo.oa?id=47545209>
- Kalt, W., Forney, C., Martin, A., & Prior, R. (1999). Antioxidant Capacity, Vitamin C, Phenolics, and Anthocyanins after Fresh Storage of Small Fruits. *J. Agric. Food Chem*, 47(11), 4638–4644. doi: <https://doi.org/10.1016/j.foodchem.2005.12.038>
- Kiritsakis, A.P., Lenart, E.B., Willet, W.C. & Hernandez, R.J (1998). Olive Oil: From the Tree to the Table. *Food & Nutrition Press*, cop. 2nd ed, 348.
- Lozano, Y., Dhuique, C., Bannon, E. & Gaydou, E. (1993). Unsaponifiable matter, total sterol and tocopherol contents of avocado oil varieties. *Journal of the American Oil Chemists' Society*, 70(6), 561–565. doi: <https://doi.org/10.1007/BF02545319>
- Yepes, D., Sánchez, L. & Osorio, J.A. (2014). Physico-chemical changes of the avocado (*Persea americana* Mill. Cv. "Hass") in post-harvest for two municipalities of Antioquia. *Agrarian Issues*, 19 (1), 34–49. doi: <https://doi.org/10.21897/rta.v19i1.723>
- Colombian Technical Standard NTC 258. (nineteen ninety six). Vegetable and animal edible fats and oils. Olive oil. Colombian Technical Standard. Edited by the Colombian Institute of Technical Standards ICONTEC
- Colombian Technical Standard NTC 5209. (2003). Fresh fruits. Avocado. Improved varieties. Specifications. Colombian Technical Standard. Edited by the Colombian Institute of Technical Standards ICONTEC
- Colombian Technical Standard NTC 241 .. (2014). Vegetable and animal edible fats and oils. Margarines, esparcibles and minarinas for use in table and kitchen. Edited by the Colombian Institute of Technical Standards ICONTEC
- Olaeta, J.A. (2003). Avocado industrialization: Current status and future perspectives. Minutes V World Avocado Congress. Granada, Malaga, Spain, 749–754.
- Osuna, M., Judis, M., Avallone, C., and Romero, A. (2009). Analysis of the lipid profile of functional flours and oils for the preparation of fortified breads. Scientific and technological communications. National University of the Northeast, Argentina.
- Ou, B., Hampsch, M., & Prior, R., (2001). Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe. *J. Agric. Food Chem*, 49(10), 4619–4626. doi: <https://doi.org/10.1021/jf010586o>
- Pande, G. & Akoh, C. (2010). Organic acids, antioxidant capacity, phenolic content and lipid characterisation of Georgia- grown underutilized fruit crops. *Food Chemistry*. 120, 1067–1075. doi: <https://doi.org/10.1016/j.foodchem.2009.11.054>
- Parra, J. (2005). *Pulp and oil yield and quality in nine selections of avocado* (*Persea americana* Mill.) In Chile. Undergraduate thesis Fac. Of Agronomic Sciences, University of Chile, Santiago, Chile.
- Pérez, R., Villanueva, S. & Cosio, S. (2005). Avocado oil and its nutritional properties. *Journal e-Gnosis*, University of Guadalajara, Guadalajara, Mexico.

- Reed. (2001) Avocados: The new wonder oil ?. *Food New Zealand*, 31 (1) 20-25.
- Richard, D., Kefi, K., Barbe, T., Bausero, P. & Visiolo, F. (2008). Polyunsaturated fatty acids as antioxidants. *Pharmacological Research*, 57(6), 451-455. doi: <https://doi.org/10.1016/j.phrs.2008.05.002>
- Rincón, S. & Martínez, D., (2009). Analysis of the properties of palm oil in the development of its industry. *Palmas Magazine* 30 (2), 11-23.
- Savage, G., Webster, G., & Plows, E. (1994). The advantages of increasing olive oil in the diet: Proceedings of a Continuing Education Seminar. Oils & Fats Specialist Group of the NZ Institute of Chemistry.
- Smith, L. M. & Winter, F. H. (1970). Research on avocado processing at the University of California Davis. *California Avocado Soc. Yearbook*, 54, 79-84.
- Stanley, J. (2008). The nutritional reputation of palm oil. *Lipid technology*, 20(5), 2. doi: <https://doi.org/10.1002/lite.200800024>
- Swisher, H. E. (1988). Avocado oil- from food use to skin care. *J. Am. Oil Chem. Soc.*, 65, 1704-1706.
- Velásquez, J. (2006). *Identification of the avocado as an important item of great commercial opportunities, according to the integration agreements, the new trade treaties and the globalized world trade.* Secretary of Productivity and Competitiveness. Government of Antioquia.
- Villa, J., Molina, F., Ayala, J., Oliva, G. & González, G. (2011). Effect of maturity stage on the content of fatty acids and antioxidant activity of 'Hass' avocado. *Food Research International*, 44, 1231-1237. doi: <https://doi.org/10.1016/j.foodres.2010.11.012>
- Wang, W., Bostic, T. & Gu, L. (2010). Antioxidant capacities, procyanidins and pigments in avocados of different strains and cultivars. *Food Chemistry*, 122, 1193-1198. doi: <https://doi.org/10.1016/j.foodchem.2010.03.114>
- Werman, M. J. & Neeman, I. (1987). Avocado oil production and chemical characteristics. *J. Am. Oil Chem. Soc.*, 64, 229-232. doi: <https://doi.org/10.1007/BF02542007>
- Wong, M., Ashton, O., Requejo-Jackman, C., McGhie, T., White, A., Eyres, L., Sherpa, N., and Woolf, A. (June, 2008). Avocado Oil: The Color of Quality, Color Quality of Fresh and Processed Foods. Simposio dirigido por American Chemical Society, Vol. 983. Washington DC.