Chapter 9

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Avocado and Its By-products: Natural Sources of Nutrients, Phytochemical Compounds and Functional Properties

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ABSTRACT

Avocado (*Persea americana* Mill.) is a tropical and subtropical fruit that is native to Mexico and Central America. This fruit is gaining increasing worldwide acceptance and has received extensive marketing and a wide distribution due to its relevant nutritional benefits for human health. This work presents relevant information on the production, composition and application of avocado, with an emphasis on its by-products, focusing on the proper use of waste and the possibility of monetizing waste for nutritional and environmental purposes. The entire avocado is rich in bioactive compounds (pulp, peel and seed) and presents several health benefits, such as antimicrobial, antioxidant and anticancer activities, as well as dermatological uses and others. Therefore, several food grade ingredients can be obtained from avocado wastes, particularly premium-grade fats or extracts with a high functional power. Studies should continue to identify the profiles and phytochemicals available to the business sector, which can also be implemented to valorize the nutritional and functional potential of avocado seeds and peels.

Keywords: Avocado fruit; by-products; nutritional composition; bioactive compounds; antioxidant activity.

1. INTRODUCTION

Persea americana, commonly known as avocado fruit, has recently achieved significant popularity and is often marketed as a “superfood” because of its unique nutritional composition, phytochemical content, and health benefits. *P. americana* is native to Mexico and Central America, being a member of the flowering plant family Lauraceae [1]. Apart from its use as food, the avocado is traditionally used for several medicinal purposes including hypotensive, hypoglycemic, anti-viral and anti-diarrheal and cardiovascular diseases [2-8]. Thus, to these fruits are equally attributed analgesic, anti-inflammatory and antifungal properties [9] and their pulp is also used in several dermatological formulations namely, emulsions for the treatment of dry skin, protective agents against ultraviolet radiation, and anti-aging agents [10,11]. A large variety of phytochemicals commonly consumed in human diet, promove health benefits and may contribute to the prevention of many diseases. However, it is still difficult to make nutritional recommendations for these bioactive compounds. Current studies of phytochemicals are generally focused on specific compounds and their effects on a limited number of markers. New approaches are needed to take into account both the diversity of phytochemicals found in these fruits and the complexity of their biological effects. Firstly, it is necessary to mention that there are three major races with different growing conditions and characteristics: Mexican race (*P. americana* var. “drymifolia), Guatemalan race (*P. nubigena* var. “guatamalensis”) and West Indian race (*P. americana* var. “Americana”). Thus, hybrid forms exist among all three types or races. Despite the pre-established morphological differences and botanical

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characterization, all varieties are known to contain, besides fat (monounsaturated (oleic acid), and polyunsaturated fatty acids (linoleic acid and linolenic acid), protein (highest among fruits), sugars (sucrose and D-mannoheptulose), natural pigments, pholyphenols, phytoestrogens, and fiber [12]. Besides their association with biological factors, avocados have also been studied for their nutritional profile and phytochemical contents, revealing great variability among species and sometimes even within the same species. The reported differences are often modulated by soil and climatic conditions, besides being influenced by the avocado tree regeneration processes.

2. AVOCADO FRUIT AND AVOCADO BY-PRODUCTS

Different varieties of avocado are cultivated worldwide, and Hass and Fuerte are among the most consumed ones. Avocado industrial processing generates large quantities of agro-industrial by-products, mainly peel and seed, ranging from 18% to 23% of fruit dry weight [13]. Thus, it is interesting to reuse these by-products both to reduce their negative impact on the environment and to add value to them, in as much as they are sources of important phytochemical compounds.

2.1 Fruit Pulp

Avocado is a low sugar fruit with high contents of protein, fibre and vitamins (A, B, C and E). It is an excellent source of potassium and phosphorus, and contains mono-unsaturated fatty acids which effectively reduces the levels of low density lipoproteins, in the blood helping in the prevention of coronary heart diseases [14]. Thus, avocado pulp is recognized to present high phenolic compounds content of different chemical classes from simple phenolic acids such as gallic acid to larger flavonoids, anthocyanidins, and tocopherols with significant antioxidant, neuroprotective and cardioprotective activities [15-18]. Also, a natural compound (2 R,4 R)-1,2,4-trihydroxyheptadec-16-yne, extracted from the unripe pulp, may inhibit dengue virus replication [19].

2.2 Fruit By-products

Avocado seeds (an industrial by-product) can be used to prevent and treat gastric disorder due to its anti-inflammatory, antioxidant and antimicrobial properties [20]. *P. americana* leaves and seeds exhibited anti-cholinesterases and antioxidant activities [21].

Given the variety of uses that are assigned to ethnobotanical species of *P. americana* several studies have been conducted in order to unveil their biological activity [22,23]. In fact, avocado is currently considered “superfood” because of its uniquenutritional and phytochemical composition compared to other fruits [12]. The characterization of phenolic components and antioxidant activity of hydroethanolic extracts of the avocado skin and seed revealed a predominance of compounds belonging to the group of flavonoids, proanthocyanidins, and hydrocinnamic acids [5]. Phenolic compounds, such as gallic acid, 3,4-dihydroxyphenylacetic acid, 4-hydroxybenzoic acid, vanillic acid, *p*-coumaric acid, ferulic acid and quercetin, existing in avocado pulp, are associated with antioxidant properties [18]. Ortega-Arellano et al. [17] conclued that avocado peels var. Colinred showed the highest total phenolic content, and specifically B-type procyanidins and epicatechin, as well antioxidant activity, when compared with seeds. These authors also showed that peel extract can protect transgenic parkin Drosophila melanogaster fly against paraquat-induced oxidative stress, movement impairment and lipid peroxidation, as model of Parkinson's disease. Segovia et al. [1] also demonstrated that antiradical activity is mainly due to polyphenols (+)-catechin, (−)-epicatechin, 3-*O*-caffeoylquinic acid (chlorogenic acid isomer), and three compounds of the flavonoid family. Flavonoids was one of the most representative group in seed and seed coat avocado, being quercetin, (±)-naringenin and sakuranetin identified by Figueroa et al. [24]. Phenolics and flavonoids are bioactive compounds that have been related with a decrement of different deteriorative processes in the human body owing to their ability to reduce the formation and to scavange free radicals [25]. Rodríguez-Carpena et al. [26] ascribed the high antioxidant activity exhibited by avocado extracts invarious in vitro assays to these phenolic compounds. Chia and Dykes [27] studied the essential oils of avocado and were able to demonstrate the antimicrobial activity of the skin and seeds of three different varieties of avocado (‘Hass’, ‘Fuerte’ and ‘Shepard’). Avocado (‘Hass’ and ‘Fuerte’) seeds, that contain diverse active compounds (phenolic acids and flavonoids), showed to act effectively against pathogenic bacteria, demonstrating high antimicrobial activity [28]. The peel of this fruit also showed a wide range of antimcrobial activities against Gram positive or Gram negative bacteria [29].

Other studies revealed that the avocado contains other constituents that are equally beneficial to Human metabolism, such as minerals (iron, phosphorus, magnesium, potassium, sodium, manganese, calcium, selenium, zinc and copper), hydro and liposoluble vitamins (vitamin E, B, C, K_1 and β-carotene, or provitamin A) [11,30,31]. The predominant carotenoid in this fruit is lutein, but α-carotene, β-carotene, zeaxanthin, neoxanthin and violaxanthin are also present in small quantities [11]. Cortés-Rojo et al. [8] found lutein and zeaxanthin and provitamin A (β-carotene and β-cryptoxanthin) carotenoids in avocado *Hass* from Costa Rica. Peel, seed and pulp of avocado, if consumed on a daily basis, have pharmacologically active constituents with lipid-lowering and antihyperlipidemic effects. This tropical fruit possesses effects on different components of metabolic syndrome, mainly on lipid profile, being LDL-cholesterol, HDL-cholesterol, triglyceride, total cholesterol and phospholipids the most affected biomarkers [32]. A study with diabetic rats demonstrated that avocado oil decreases ROS levels and lipidperoxidation, improving brain mitochondrial function [33]. Aqueous extracts of leaf and seed revealed to have inhibitory effect on angiotensin 1 converting enzyme activity, showing the seed a better antihypertensive activity than the leaf [34].

Given the above, public information about the avocado and its health promoting properties has been given in several countries. An independent Australian organization, “The Heart Foundation” certified the fruit as healthy food for the heart and this certification with its appropriate logo is already used in advertising. The Californian Avocado Commission, has also driven efforts to publicize the fruit as health promoter, including conjoint publications with the American Dietetic Association, American Heart Association, and more recently, some press releases. For all the reasons above, the avocado is gaining worldwide recognition as healthy food and, consequently, a significant economic value. Hence, quite naturally, the avocado culture has attracted the interest of European farmers and, currently, it is already possible to find avocado orchards spread across Spain, Italy, Greece and Portugal. Regarding cultivars produced, ‘Hass’ and ‘Fuerte’ dominate the international market [26]. In Portugal these fruits are being cultivated in the south (Algarve), where the soil and climatic conditions are more favorable [35]. The cultivated area has expanded, being currently about 1500 hectares spread over 180 farms [36].The avocado tree is one of the most productive plants per unit of cultivated area. The Algarve region has a temperate Mediterranean climate, characterized by mild short winters and long, hot and dry summers. The soils of this region are mostly litholic not humic of sandstone, stoneware of Silves or similar. Given that the edaphoclimatic conditions play a fundamental role in plant metabolism and by this route in the chemical makeup of fruits, one of the objectives of this study was to evaluate the chemical and antioxidant composition of the Algarvian ‘Hass’ avocado and compare their content of phytochemicals with those of the same variety of fruit produced elsewhere. This is pioneering study, since, to the best of our knowledge, this is the first scientific characterization of the Portuguese avocado fruit [37]. The non-edible parts of the fruit (skin and seed) were also studied in order to assess their potential use as cheap source of bioactive compounds for the food, pharmaceutical and dermocosmetic industries [24,36]. The exploitation of non-edible parts of the fruits is an emerging trend which may prove to be very profitable in the near future. Firstly because it entails an important reduction in the production of waste, secondly, because the non-edible parts of some fruits, can concentrate high levels of valuable bioactive compounds, particularly natural antioxidants [37].

3. MATERIALS AND METHODS

3.1 Sample Collection and Preparation

All the avocado fruits, variety ‘Hass’ used in the present study came from an orchard located in the Faro area (Latitude: 37.019°, Longitude: -7.926°). The fruits, a total of 100 at the onset of ripening, were randomly collected and selected by their firmness, absence of mechanical damage and visible decay. Immediately after harvest the fruits were cleaned and prepared according to the requirements of the intended analysis. They were cut open to obtain their edible and non-edible portions (pulp, peel, and seeds, respectively) and stored at 4ºC. Six replicates of each sample were selected and analyzed. All analyzes were carried out over a period of time not exceeding two weeks after harvest.

3.2 Proximate Composition Analysis

Moisture, titratable acidity (TA), total soluble solids (TSS) were evaluated as quality fruit indices. The ash, total protein and total fat contents were also analyzed. A gravimetric assay was performed to evaluate the physiological weight loss of the avocado fractions (pulp, peel, and seeds). Results were expressed in water percentage (%) according to the methodology described by the Association of Official Analytical Chemists [38]. Likewise, the following methods (AOAC, 2005) were used to determine protein (method 960.52), fat (method 920.39C) and ash content (method 923.03) in stored avocado pulp, peel and seed samples.

3.3 Bioactive Compounds Quantification

3.3.1 Extraction and analysis of ascorbic acid

Avocado fruit fractions (5 g) were dissolved in a mixture of 200 ml of water, 5 ml of metaphosphoric acid (30%) and 20 ml glacial acetic acid. The mixture was titrated with Tillmans reagent. Ascorbic acid (expressed as mg/ 100 g (on a FW – fresh weight basis)) was quantified using an analytical validated method published in a previously work [39].

3.3.2 Colorimetric determination of vitamin E

The determination of the vitamin E content in the different constituents of Algarvian avocado fruit followed the procedure described by Amin [40]. The experiments were performed in sextuplicate for each avocado fruit fraction (pulp, peel, and seed).

3.3.3 Total carotenoids assay

Total carotenoids were extracted according to Akin et al. [41] with some minor modifications. Results were expressed as β-carotene equivalents (milligrams per 100 g of FW).

3.3.4 Total polyphenolic content assays

Total phenolics were determined according to the improved Folin-Ciocalteu method [39]. Total phenol content was expressed as milligrams of GA equivalent (GAE) per 100 grams of fresh fruit weight (mg GAE /100 g-1 FW) [42]. Flavonoid contents were determined using a method described by Soares et al. [43] with slight modifications. The flavonoid contents were express in milligrams per 100 grams of FW.

3.4 DPPH$^•$ Radical-scavenging Activity

Pulp, peel and seeds of avocado aqueous extracts were determined in accordance with the Shimada [43] method, which is based on the principle of scavenging the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical DPPH$^•$. The radical scavenging activity (RSA) was calculated as a percentage of DPPH$^•$ discoloration using the equation: % RSA = [(ADPPH$^•$ – AS)/ADPPH$^•$] x 100, where AS represents the absorbance of the sample solution extract with DPPH$^•$ and ADPPH$^•$ is the absorbance of the DPPH$^•$ solution.

3.5 Statistical Analysis

A completely randomized design was used, with six replications. Statistical analysis was performed using SPSS v. 21 (IBM Corp., Armonk, NY, USA). Data of all chemical analysis were expressed as mean ± standard deviation. The independent samples T-test or Analysis of Variance (ANOVA) were used to assess the statistical differences among means followed, in the case of ANOVA, by Tukey's HSD post-hoc test for multiple comparisons. Pearson correlation tests were used to ascertain the existence of linear relationships between the contents of bioactive compounds and antioxidant activity (*P=.05*).

4. RESULTS AND DISCUSSION

To determine the patterns of biologically active compounds accumulation in pulp fruit and agro-industrial by-products (peel and seed), it is important to identify their composition and content in separate parts. The results obtained for the fruit physicochemical parameters are presented in Table 1.

Table 1. Physicochemical parameters of the different fractions of the Algarvian avocado variety 'Hass'. Moisture, proteins, ash and fat are expressed in percentage. The Total Soluble Solids (TSS) in °Brix and the acidity in mg of tartaric acid equivalents /100 g FW

	Fraction of the Algarvian avocado var. "Hass"		
Parameter**	**Pulp***	**Peel***	**Seeds***
Moisture (%)	70.83±3.53^{a}	69.13±2.58^{b}	54.45±2.33^{c}
Ash (%)	1.77±0.16^{a}	1.50±0.08^{b}	1.29±0.03^{c}
Protein (%)	1.82±0.07^{a}	1.91±0.08^{a}	2.19±0.16^{b}
Fat (%)	43.5±4.62^{a}	2.20±1.65^{b}	14.7±0.32^{c}
TSS (ºBrix)	6.68±1.02^{a}	3.01±2.03^{b}	3.54±1.97^{b}
Acidity	1.07±0.02^{a}	2.05±0.24^{b}	2.67±0.17^{c}

**Values represented as mean±standard deviation (n=6). **A letter is used to express the results of the comparison between the different fractions. Different letters indicate significant statistical differences (P=.05)*

Avocados have been recognized for their high nutritional value and therapeutic importance for centuries. The moisture content is one of the most important indices evaluated in foods, especially fruits. It is a good indicator of their economic value because it reflects solid contents and serves to assess its perishability. The results indicate that the Algarvian avocado pulp has higher water content (70.83%), in agreement with values of United States Department of Agriculture [31] (72.3%), followed the peel (69.13%) and seed (54.45%). The fat and ash quantified in pulp were significantly superior to those found in the skin. The seed was the part of the fruit that had higher amounts of total protein (2.19%) and lowest ash content (1.29%), nevertheless, relative to its fat content, pulp showed higher percentages. Morais et al. [44] also reported superior total lipids values for pulp 28.6±7.8 g/100 g in dried basis than for avocado by-products, in agreement with Alkhalaf et al. [45] (seed 0.85%, fruit 30.86%), being oleic acid the most predominant unsaturated fatty acid in both samples. Ejiofor et al. [46] referred higher values for protein (15.55±0.36 g/100 g), lipid (17.90±0.4 g/100 g) and ash (2.26±0.23 g/100 g) for Nigerian avocado seeds. According to Hernández-Muñoz et al. [47] the total acidity is a measure of the organic acid content. The predominant acid found in avocados is tartaric acid although, theoreticaly, every species capable of donating a proton, including fatty acids, also contribute to the total acidity of the fruit [48]. Acidity and soluble solids content are the common quality attributes that are associated with the maturity index of agricultural products, especially fruits. The total acidity tends to decrease during the ripening period as a result of the breathing process or conversion into sugars. In the period of maturation of the fruit there is an increase in metabolic activity and organic acids are, par excellence, a source of energy reserve of the fruit through the Krebs cycle. In the case of the mature Algarvian avocado, the seed has higher acidity than peel or pulp. The acidity of the pulp was found to be superior to that exhibited by 'Hass' avocados of American origin (0.04±0.01% citric acid) [49]. Astudillo-Ordóñez and Rodríguez [50] reported values of acidity (percentage of tartaric acid) for Colombian avocado pulp between 19.47 to 9.24%, decreasing acidity with storage time. In any case Algarvian 'Hass' avocados may be considered a non acidic fruit.

Among the various components of fruit, the total soluble solids (i.e., the percentage of solids that are dissolved in the matrix of the food) in °Brix, have a primary role in their quality due to the influence on thermophysical, chemical and biological properties. It is also a parameter which tends to increase with the progress of ripening due to the biosynthesis of the plant and degradation of polysaccharides. As expected, given that this physico-chemical parameter represents one of the best ways to evaluate the degree of sweetness of the fruit, and the fruit pulp is the only edible part of the avocado, the total soluble solids are higher in the pulp. This parameter follows a trend that is opposite to acidity. Nevertheless the content of soluble solids, although superior to those reported for 'Hass' avocados of American origin (5.1±0.1°Brix) [49], can be considered low, favoring the consumption of the Algarvian avocado in natura. Astudillo-Ordóñez and Rodríguez [50] referred values of °Brix degrees between 5.07 and 7.26, depending on maturity stage of Colombian avocado. Superior values of TSS have been reported for 'Hass' avocados from New Zeland (~9° Brix) [51].

The variety, grade of ripening, climate, the composition of the soil, and fertilizers are the major factors that largely influence the nutritional profiles of avocados [52]. Tango et al. [53] studied 24 varieties of avocado, and found levels for moisture and fat in the pulp of 'Hass' variety fruits of 57.3% and 31.1%, respectively. These values are significantly lower than those found in the Algarvian avocado studied here. Regarding the avocado seeds, Olaeta et al. [54] observed higher protein concentrations and ash, compared with those recorded in this study (3.18% and 1.51%, respectively). On the other hand, Lu et al. [55] reported a value of 25% fat for the pulp of 'Hass' avocados cultivated in California. Dias et al. [56] obtained for peel powder higher values for ash (2.94%) and lipids (35.22%), and lower values for moisture (37.79%) and proteins (0.25%).Comparing with the values of United States Department of Agriculture [31], Algarvian avocado pulp had similar values for protein (1.96%) and ash (1.66%).The Algarvian avocado develops mainly during the winter because during the rest of the year the orchards in the Algarve are subjected to water stress. This is an important factor to justify the results presented in Table 1.

There is already evidence that the ingestion of fruits confers protection against human chronic diseases, neurological disorders and some types of cancer [57,58]. These properties are assigned to the presence of significant levels of bioactive antioxidant compounds in fruits. During the last decades, ample evidence of the benefits of avocado on health has been gathered [58,59]. This promoted their consumption, stimulating also the research about their pharmacological potential. The maturation of any fruit promotes an increase of bioactive compounds [60]. Among the different secondary metabolites with antioxidant properties, phenolics, flavonoids and carotenoids are the most cited. The levels of these compounds, as well as those of the vitamins C and E, found in the Algarvian avocado are presented in Table 2.

Table 2. Bioactive compounds quantification in different Algarvian avocado var. "Hass" fruit fractions (mg/ 100 g FW)

	Avocado fraction var. "Hass"		
Bioactive compound**	**Pulp***	**Peel***	**Seeds***
Total Phenolics	$410.2±69.0^{b}$	$679.0±117.0^{a}$	$704.0±130.0^{a}$
Flavonoids	$21.9±1.0^{b}$	$44.3±3.1^{a}$	$47.9±2.7^{a}$
Carotenoids	$0.815±0.201^{b}$	$2.585±0.117^{a}$	$0.966±0.164^{b}$
Vitamin C	$1.2±0.7^{c}$	$4.1±2.7^{a}$	$2.6±1.1^{a,c}$
Vitamin E	$5.36±1.77^{a}$	$2.13±1.03^{b}$	$4.82±1.42^{a}$

*Values represented as mean±standard deviation (n=6). **A letter is used to express the results of the comparison between the different fractions. Different letters indicate significant statistical differences (P=.05)

The results reveal that is in the avocado seed that the highest levels of total phenolics and flavonoids are found. This agrees with the results reported for avocados cultivated in Mexico [13]. The skin of the fruit had the highest carotenoid content, as expected, since this tissue is usually the fraction were these phytochemicals are concentrated. Recently a study proved that the composition of carotenoids and vitamin E in fruits is affected by several factors, including the degree of maturation and edaphoclimatic [60]. Significant differences were found in the levels of carotenoids and vitamin E in 'Hass' avocados cultivated in four different Californian counties. It was concluded in the same study that the levels of carotenoids in the fruit pulp increased with the fat present in it and that the xanthophylls, in particular lutein and cryptoxanthin, were the predominant phytochemicals of this group, contributing approximately to 90% of the total carotenoids present in the 'Hass' avocado [15]. When one compares the contents of bioactive compounds of the Algarvian fruit with those of other fruits produced in different parts of the globe, it may be noted that it has levels of phenolics in the pulp comparable to those found in Mexican 'Hass' avocados (4.9±0.7 mg GAE/g FW), inferior levels in peel (12.6±0.3 mg GAE/g FW) and seeds (51.6±1.6 mg GAE/g FW) [13] while possessing comparable levels of flavonoids (26.36 QE/100 g FW) [26]. The phenolic levels are also superior to those reported for the same fruit of Turkish provenance (1.20 g/kg FW) [61]. Amado et al. [62] obtained total phenolic content (TPC) of 16.15 (peel), 2.04 (pulp) and 8.07 (seed) mg GAE /g dry weight (DW) for Brazilian avocado. The same authors presented 0.26 mg QE/g DW for flavonoid content of seed. Kosińska et al. [5] obtained values of TPC of 25.32 mg CE/g DW for peel and 9.51 mg CE/g DW for seed of "Hass" cultivar. These authors compared TPC values with those of "Shepard" variety and conclued that peels from "Hass" are richer in phenolic compounds, but seeds present less TPC. Tremocoldi et al. [63] demonstrated that "Hass" and "Fuerte" varieties peels presented superior phenolic contents (63.5 and 120.3 mg GAE/g, respectively) than seed (57.3 and 59.2 mg GAE/g, respectively). These studies, were in disagreement with our results. Thus, it seems that seeds of the "Hass" Algarve cultivar contained more phenolic compounds than avocado seeds of other parts of world, but all studies are in line with the fact that the pulp is the part of the fruit that has less TPC values. Gómez et al. [64] reported values of polyphenolic content between 35.10 and 46.95 mg GAE/g FW, depending on extraction conditions (etanol concentration and time).

The content of carotenoids is inferior to that found in Californian avocados (42.2 µg/g) [55], and higher tan that found in the corresponding fractions of Mexican 'Hass' avocados ((7.1 µg/g (pulp), 15.2 µg/g (peel), 6.3 µg/g (seed)) [13]. Furthermore, the Algarvian avocado has superior levels of carotenoids in the pulp than the 'Hass' avocados cultivated in New Zeland (~5.2 µg/g), but inferior levels in the peel (~50 µg/g) (Ashton et al., 2006). Cortés-Rojo et al. [8] separated and quantified carotenoids in Costa Rican Hass avocados, obtaining astaxanthin, lutein, zeaxanthin, β-cryptoxanthin and β-carotene (0.64, 15.13, 0.02, 3.37, 2.28 mg/100g, respectively).

The mesocarp of the Algarvian avocado presented higher levels of vitamin E, with a value that is statistically similar to that found in the seeds and above that found in the skin. The amount of this vitamin found in the pulp is comparable to that found in avocados grown in Brazil (6.4 mg/ 100 g) [65], (Salgado et al., 2008) but superior to that of avocados from california (27 µg/g) [55]. The concentration of ascorbic acid was inferior to that reported for Californian avocados (17.3 mg/100 g) [31]. More recently, Talabi et al. [66] described in Nigerian avocado seeds contents of 14.63 and 0.65 mg/100 g for vitamin C and E, respectively.

Overall these results also demonstrate the potential of the non-edible parts of the avocado as a source of bioactive compounds. The peel of the Algarvian 'Hass' avocado contains 59% of the carotenoids and the seeds 39% of total phenolic compounds and 42% of the flavonoids present in the fruit. Instead of being wasted as trash, fruit peel could constitute an inexpensive source of carotenoids in the dermocosmetic and food industries. Indeed the avocado is the fruit with the highest content of carotenoids in the exocarp. The carotenoid compounds are known to exert a protective action against cell damage caused by UV rays and pollution, which make them an essential ingredient of several dermatological formulations. Additionally the carotenoids, phenolics and flavonoids are known to prevent the risk of developing certain diseases related to age, such as premature aging, cancer and heart disease [25,67,68]. Both peel and seeds can also be harnessed as a source of these compounds to use as food additives or functional food ingredients [69-71]. Remarkably the peel and seeds of avocado have higher levels of these compounds than those that exist in many other fruits and vegetables such as apple (*Malus domestica*), banana (*Musa cavendish*), tomatoes (*Lycopersicum esculentum*) or red cabbage (*Brassica oleracae* var. botrytis) [37,72,73]. According to Amado et al. [62] avocado by-products could also prevent food contamination with the advantage of not showing toxicity, and consequently peel and seed appear to be a promising alternative for food applications.

Consistent with the fact that they contain higher levels of bioactive antioxidant compounds, it was found that the avocado seeds also exhibit higher, and statistically different, values of *in vitro* antioxidant activity (measured in this work through the ability to scavenge the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•)) (Fig. 1).

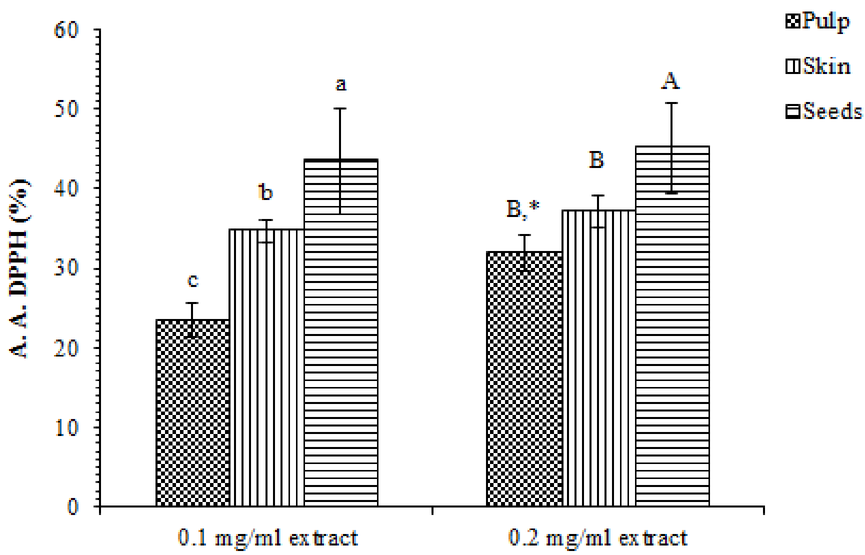

Fig. 1. Antioxidant activity (A.A.) of aqueous extracts obtained from the various avocado fractions on 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•). The symbol "*"indicates the existence of significant statistical differences (*P=.05*) among the antioxidant activity exhibited by the two aqueous extracts of the same fraction. Identical letters signalize extracts that exhibit the same antioxidant activity

These results differ slightly from those reported in the literature since both Wang et al. [13], Rodríguez-Carpena et al. [26] and Amado et al. [62], showed that the peel presented superior antioxidant activity, but in agreement with Tremocoldi et al. [63]. However, according with the referred studies, and in agreement with this work, the antioxidant activity was higher for avocado by-products. Fruit seeds and peel are very rich in antioxidant compounds, however the seed showed higher contents of flavonoids and phenolic compounds while fruit peel is richer in carotenoids. In general, the contribution of vitamin C to the total antioxidant capacity of extracts varies with the type of fruit. In fact, vitamin C due to its hydrophilic character is unique among the vitamins present in the avocado matrix, the majority of which, namely vitamins A, D and E, are all liposoluble. It is well known fact that the bioactive compounds do not all have the same antioxidant activity. Thus, an increase in the level of a compound does not mean a proportional increase of antioxidant activity of the matrix [74]. Furthermore for a complex extract, as the one in question, it is also necessary to take into account the synergistic or antagonistic effects among the various compounds present, which makes not only the antioxidant activity dependent of the concentration of each compound but also of the interaction between different compounds, antioxidants or not. Perhaps this is why when the concentration of the extracts doubles, the antioxidant activity exhibited by the pulp increases but remains unaltered in case to the peel and seeds.

Most studies have demonstrated a linear correlation between total phenolic content and the antioxidant activity evaluated by different methodologies in fruits and vegetables [75-77]. Regression analyses were performed to correlate the antioxidant activity of avocado samples with the antioxidants quantified in the avocado tissues (Table 3).

Table 3. Correlation among the content of bioactive compounds and antioxidant activity

Extracts	Flavonoids x DPPH•	Pehnolics x DPPH•	Carotenoids x DPPH•	Vitamin C x DPPH•	Vitamin E x DPPH•
Pulp	-0.436	-0.094	-0.314	0.238	0.123
Peel	0.678	-0.430	-0.132	0.220	-0.880
Seeds	-0.506	0.715	0.703	0.011	0.641

Considering all the different antioxidant compounds, a good correlation was found between total phenolic content and flavonoids contents and DPPH• radical scavenging capacity (r = 0.783) and (r = 0.820), respectively. However, analyzing the fruit fractions separately, good positive correlations were only found for the contents of carotenoids, total phenolics and vitamin E and antioxidant activity exhibited by the seeds extracts and the contents of flavonoids in the case of the peel extracts.

5. CONCLUSIONS

Several studies carried out in the last decades report and highlight the exceptional nutritional and phytochemical composition of avocado, as well as their biological potential in the treatment and prevention of different diseases. Some studies have underlined its importance as the source of lead molecules for pharmaceutical industry due to the abundance of novel chemical compounds. The cumulative effects of avocado components described in the pulp fruits as well as in their by-products (peel and seed) in the prevention and treatment of oxidative stress and age-related degenerative diseases are also described. However, more comprehensive *in vitro*, *in vivo*, and clinical investigations are fundamental to significantly expand the understanding of the molecular mechanisms of action of its phytochemicals for developing subsequent therapeutic and nutritional interventions against cancer, diabetes, inflammatory, microbial, and cardiovascular diseases. Interestingly, despite its popularity as a “superfood”, clinical studies evaluating the therapeutic potential of avocado for the prevention and management of different desiases are few in the literature. More investigations to understand the bioavailability and pharmacokinetics of avocado phytochemicals and antioxidants are also crucial to determine their clinical efficacy and potential toxicity.

Therefore, consuming avocados as a part of the diet can be beneficial to human health. The fact that the non-edible parts of the fruit (peel and seeds) contains such high levels of carotenoids, flavonoids and phenolics makes the idea of their exploitation, as a cheap source of these compounds in the food industry and dermo-cosmetics, very appealing. The mass of by-products obtained as a result of processing tropical exotic crops, such as that of avocado, may approach or even exceed that of the corresponding edible part affecting the economics of growing of these crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Segovia FJ, Hidalgo GI, Villasante J, Ramis X, Almajano, MP. Avocado seed: A comparative study of antioxidant content and capacity in protecting oil models from oxidation. Molecules. 2018;23:2421.
   DOI: 10.3390/molecules23102421
2. Nayak BS, Raju SS, Chalapathi-Rao AV. Wound healing activity of Persea americana (avocado) fruit: a preclinical study on rats. Journal Wound Care. 2008;17(3):123-6.
   DOI: 10.1155/2013/472382
3. Raharjo SHT, Gomez-Lim WMA, Padilla G, Litz RE. Recovery of avocado (Persea americana Mill.) plants transformed with the antifungal plant defensin gene PDF12. In Vitro Cell Dev Biol Plant. 2008;44(4):254-62.
   DOI: 10.1007/s11627-008-9117-2

4. Anaka ON, Ozolua RI, Okpo SO. Effect of the aqueous seed extract of Persea americana Mill. (Lauraceae) on the blood pressure of spraguedawley rats. Afr J Pharm Pharmacol. 2009; 3(10):485-90.
Available:http://www.academicjournals.org/ajpp
5. Kosińska A, Karamác M, Estrella I, Hernández T, Bartolomé B, Dykes GA. Phenolic compound profiles and antioxidant capacity of Persea americana Mill. Peels and seeds of two varieties. J Agric Food Chem. 2012;60(18):4613-19.
DOI: 10.1021/jf300090p
6. Odo CE, Nwodo OF, Joshua PE, Ugwu OP. Acute toxicity investigation and anti-diarrhoeal effect of the chloroform-methanol extract of the leaves of *Persea americana*. Iranian J Pharm Res. 2014;13(2):651-8.
7. Peou S, Milliard-Hasting B, Shah SA. Impact of avocado-enriched diets on plasma lipoproteins: A meta-analysis. J Clin Lipidol. 2016;10(1):161-71.
DOI: 10.1016/j.jacl.2015.10.011
8. Cortés-Rojo C, Montoya-Pérez R, Rodríguez-Orozco AR, Saavedra-Molina, A, Calderón-Cortés E. Avocado oil and diabetic complications related to mitochondrial dysfunction. In: Watson R, Preedy V, editors. Bioactive Food as Dietary Interventions for Diabetes. 2nd Ed. Academic Press; 2019.
9. Jesus D, Oliveira JR, Oliveira FE, Higa KC, Junqueira JC, Jorge AOC, et al. Persea americana glycolic extract: In nitro study of antimicrobial activity against *Candida albicans* biofilm and cytotoxicity evaluation. The Scientific World Journal. 2015;Article ID 531972.
DOI:10.1155/2015/531972
10. Korać RR, Khambholja KM. Potential of herbs in skin protection from ultraviolet radiation. Pharmacogn Rev. 2011;5(10):164-73.
DOI: 10.4103/0973-7847.91114
11. Gupta RS, Lo B, Son J. Phylogenomics and comparative genomic studies robustly support division of the genus *Mycobacterium* into an emended genus *Mycobacterium* and four novel genera. Front Microbiol. 2018;9:67.
DOI: 10.3389/fmicb.2018.00067
12. Bhuyan DJ, Alsherbiny MA, Perera S, Low M, Basu A, Devi OA, et al. The odyssey of bioactive compounds in avocado (*Persea americana*) and their health benefits. Antioxidants. 2019; 8(10):E426.
DOI: 10.3390/antiox8100426
13. Wang W, Bostic TR, Gu L. Antioxidant capacities procyanidins and pigments in avocados of different strains and cultivars. Food Chem. 2010;122:1193-8.
DOI: 10.1016/j.foodchem.2010.03.114
14. Nair SS, Chandran AC. Nutrient composition of avocado fruits of selected cultivars grown in Kerala. Int J Food Sci Nutr. 2018;3(3):65-7.
15. Lu Q, Arteaga JR, Zhang Q, Huerta S, Go VL, Heber, D. Inhibition of prostate cancer cell growth by an avocado extract: Role of lipid-soluble bioactive substances. J Nutr Biochem. 2005; 16(1):23-30.
DOI: 10.1016/j.jnutbio.2004.08.003
16. Naveed M, Hejazi V, Abbas M, Kamboh AA, Khan GJ, Shumzaid M, et al. Chlorogenic acid (CGA): A pharmacological review and call for further research. Biomed Pharmacother. 2018; 97:67-74.
DOI: 10.1016/j.biopha.2017.10.064
17. Ortega-Arellano HF, Jimenez-Del-Rio M, Velez-Pardo C. Neuroprotective effects of methanolic extract of avocado *Persea americana* (var. Colinred) peel on paraquat-induced locomotor impairment, lipid peroxidation and shortage of life span in transgenic knockdown parkin drosophila melanogaster. Neurochem Res. 2019;44:1986-98.
DOI: 10.1007/s11064-019-02835-z
18. Santana I, Castelo-Branco VN, Guimarães BM, Silva LDO, Peixoto VODS, Cabral LMC et al. Hass avocado (*Persea americana* Mill.) oil enriched in phenolic compounds and tocopherols by expeller-pressing the unpeeled microwave dried fruit. Food Chem. 2019;286:354-61.
DOI:10.1016/J.FOODCHEM.2019.02.014

19. Wu YH, Tseng CK, Wu HC, Wei CK, Lin CK, Chen IS, et al. Avocado (*Persea americana*) fruit extract (2R,4R)-1,2,4-trihydroxyheptadec-16-yne inhibits dengue virus replication via upregulation of NF-κB-dependent induction of antiviral interferon responses. Sci Rep. 2019; 9(1):423.
DOI: 10.1038/s41598-018-36714-4
20. Athaydes BR, Alves GM, Assis ALEM, Gomes JVD, Rodrigues RP, Campagnaro BP, et al. Avocado seeds (*Persea americana* Mill.) prevents indomethacin-induced gastric ulcer in mice. Food Res Int. 2019;119:751-60.
DOI: 10.1016/j.foodres.2018.10.057
21. Oboh G, Odubanjo VO, Bello F, Ademosun AO, Oyeleye SI, Nwanna EE, Ademiluyi AO. Aqueous extracts of avocado pear (*Persea americana* Mill.) leaves and seeds exhibit anti-cholinesterases and antioxidant activities in vitro. J Basic Clin Physiol Pharmacol. 2016; 27(2):131-140.
DOI: 10.1515/jbcpp-2015-0049
22. Yasir M, Das S, Kharya MD. The phytochemical and pharmacological profile of *Persea americana* Mill. Pharmacogn Rev. 2010;4(7):77-84.
DOI: 10.4103/0973-7847.65332
23. Pahua-Ramos ME, Ortiz-Moreno A, Chamorro-Cevallos G, Hernández-Navarro MD, Garduño-Siciliano L, et al. Hypolipidemic effect of avocado (Persea americana Mill) seed in a hypercholesterolemic mouse model. Plant Food Hum Nutr. 2012;67:10-16.
DOI: 10.1007/s11130-012-0280-6
24. Figueroa JG, Borrás-Linares I, Lozano-Sánchez J, Segura-Carretero, A. Comprehensive characterization of phenolic and other polar compounds in the seed and seed coat of avocado by HPLC-DAD-ESI-QTOF-MS. Food Res Int. 2018;105:752-63.
DOI: 10.1016/j.foodres.2017.11.082
25. Hidalgo M, Sánchez-Moreno C, Pascual-Teresa S. Flavonoid-flavonoid interaction and its effect on their antioxidant activity. Food Chem. 2010;121(3):691-96.
DOI: 10.1016/j.foodchem.2009.12.097
26. Rodríguez-Carpena J, Morcuende D, Andrade MJ, Kylli P, Estévez M. Avocado (*Persea americana* Mill.) Phenolics, in vitro antioxidante and antimicrobial activities, and inhibition of lipid and protein oxidation in porcine patties. J Agric Food Chem. 2011;59(10):5625-35.
DOI: 10.1021/jf1048832
27. Chia TWR, Dykes GA. Antimicrobial activity of crude epicarp and seed extracts from mature avocado fruit (*Persea americana*) of three cultivars. Pharm Biol. 2010;48(7):753-6.
DOI: 10.3109/13880200903273922
28. Guil-Guerrero JL, Ramos L, Moreno C, Zúñiga-Paredes JC, Carlosama-Yepez M, Ruales P. Antimicrobial activity of plant-food by-products: A review focusing on the tropics. Livest Sci. 2016;189:32-49.
DOI: 10.1016/j.livsci.2016.04.021
29. Lubis YM, Chaidir ZR, Dharma A. Antimicrobial activity of Persea americana peel extract from North Sumatera, Indonesia, against gram positive and gram negative bacteria in vitro. American Scientific Research Journal for Engineering, Technology, and Sciences. 2017;38(2):247-51.
30. Dreher ML, Davenport AJ. Hass avocado composition and potential Health fffects. Crit Rev Food Sci Nutr. 2013;53:738-50.
DOI:10.1080/10408398.2011.556759
31. USDA (United States Department of Agriculture), Agricultural Research Service. Avocados, Raw, California. Food Data Central; 2019.
Available:https://fdc.nal.usda.gov/fdc-app.html#/food-details/171706/nutrients
32. Tabeshpour J, Razavi BB, Hosseinzadeh H. Effects of avocado (Persea americana) on metabolic syndrome: A comprehensive systematic review. Phytother Res. 2017;31:819-37.
DOI: 10.1002/ptr.5805
33. Ortiz-Avila O, Esquivel-Martinez M, Olmos-Orizaba BE, Saavedra-Molina A, Rodriguez-Orozco AR, Cortes-Rojo C. Avocado oil improves mitochondrial function and decreases oxidative stress in brain of diabetic rats. J Diabetes Res. 2015;Article ID 485759,1-9.
DOI: 10.1155/2015/485759

34. Odubanjo VO, Oboh G, Makinde OA. Inhibitory effect of aqueuos extracts of avocado pear (*Persea americana*) leaf and seed on angiotensin 1- converting enzyme: A possible means in treating/managing hypertension. J Appl Life Sci Inter. 2015;4(1):1-9.
DOI: 10.9734/JALSI/2016/21605
35. Freire E. Abacate: Uma nova aposta para o Algarve. Vida Rural, 2012;1778:30-32.
Available:www.vidarural.pt/news.aspx?menuid=8&eid=6479
36. Algarvedailynews.com; 2019.
Available:https://algarvedailynews.com/news/17471-microclimate-and-rising-demand-drive-avocado-production-in-the-algarve
37. Vinha AF, Barreira SVP, Castro A, Costa A, Oliveira, MBPP. Influence of the storage conditions on the physicochemical properties, antioxidant activity and microbial flora of different tomato (*Lycopersicon esculentum* L.) cultivars. J Agric Sci. 2013;5(2):118-28.
DOI: 10.5539/jas.v5n2p118
38. Association of Official Analytical Chemists (AOAC). Official methods of analysis of the Association of Official Analytical Chemists. 16 ed. Arlington; 2005.
Available:http://www.aoac.org
39. Vinha AF, Soares MO, Herdeiro T, Machado M. Chemical composition and antioxidant activity of Portuguese diospyrus kaki fruit by geographical origins. J Agric Sci. 2012;4(2):281-9.
DOI: 10.5539/jas.v4n2p281
40. Amin AS. Colorimetric determination of tocopheryl acetate (vitamin E) in pure form and in multivitamin capsules. Eur J Pharm Biopharm. 2001;51(3):267-72.
DOI: 10.1016/S0939-6411(00)00148-X
41. Akin EB, Karabulut I, Topcu A. Some compositional properties of main Malatya apricot (*Prunus armeniaca* L.) varieties. Food Chem. 2008;107:939-48.
DOI: 10.1016/j.foodchem.2007.08.052
42. Zieliski H, Kozowska H. Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions. J Agric Food Chem. 2000;48:2008-16.
DOI: 10.1021/JF990619O
43. Shimada K, Fujikawa K, Yahara K, Nakamura T. Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. J Agric Food Chem. 1992;40:945-8.
DOI: 10.1021/jf00018a005
44. Morais DR, Rotta EM, Sargi SC, Bonafe EG, Suzuki RM, Souza NE, et al. Proximate composition, mineral contents and fatty acid composition of the different parts and dried peels of tropical fruits cultivated in Brazil. J Braz Chem Soc. 2017;28(2):308-18.
DOI: 10.5935/0103-5053.20160178
45. Alkhalaf MI, Alansari WS, Ibrahim EA, ELhalwagya MEA. Anti-oxidant, anti-inflammatory and anti-cancer activities of avocado (*Persea americana*) fruit and seed extract. J King Saud Univ Sci. 2019;31(4):1358-62.
DOI: 10.1016/j.jksus.2018.10.010
46. Ejiofor NC, Ezeagu IE, Ayoola M, Umera EA. Determination of the chemical composition of avocado (*Persea americana*) seed. Advances in Food Technology and Nutritional Sciences. 2018;SE(2):S51-S55.
DOI: 10.17140/AFTNSOJSE-2-107
47. Hérnandez-Muñoz P, Almenar E, Ocio MJ, Gavara R. Effect of calcium dips and chitosan coatingon postharvest life of strawberries (Fragaria x ananassa). Postharvest Biol Technol. 2006;39(3):247-53.
DOI: 10.1016/j.postharvbio.2005.11.006
48. Omar AF, Atan H, MatJafri MZ. NIR Spectroscopic properties of aqueous acids solutions.Molecules. 2012;17:7440-50.
DOI: 10.3390/molecules17067440
49. Arias LEH, Gómez JHP, Salazar JA. Application of the matrixes engineering on the development of minimally processed Hass avocado (*Persea americana* Mill) with additions of vitamin C and calcium. Revista Lasallista Investigación. 2012;9(2):44-54.
Available:http://www.redalyc.org/articulo.oa?id=69525875016

50. Astudillo-Ordóñez CE, Rodríguez P. Physicochemical parameters of avocado *Persea americana* Mill. cv. Hass (Lauraceae) grown in Antioquia (Colombia) for export. Corpoica Ciencia y Tecnología Agropecuaria. 2018;19(2):393-402.
DOI: 10.21930/rcta.vol19num2art:694
51. Burdon J, Lallu N, Haynes G, Francis K., Boldingh H, Pak HA. et al. Cutting preliminary studies of physiological and morphological indicators of potential poor quality in late season New Zealand 'Hass' avocados. Proceedings VI World Avocado Congress (Actas VI Congreso Mundial delAguacate).
Available:http://www.avocadosource.com/wac6/en/.../4a-158.pd
52. Ahmed DM, Yousef ARM, Hassan HAS. Relationship between electrical conductivity, softening and color of Fuerte avocado fruits during ripening. Agriculture Biology Journal North America. 2010;1(5):878-85.
DOI: 10.5251/abjna.2010.1.5.878.885
53. Tango JS, Carvalho CR, Limonta SNB. Caracterização física e química de frutos de abacate visando a seu potencial para extração de óleo. Brazilian Magazine Fruit Culture. 2004;26(1):17-23.
Available:http://www.scielo.br/pdf/rbf/v26n1/a07v26n1
54. Olaeta JA, Undurraga P, Espinosa G. Evolución del contenido de aceite y compuestos no saponificables en paltas (*Persea americana* Mill.) CVS. Hass, Fuerte e Isabel. Actas VI Congreso Mundial del Aguacate. 2007;12-16.
Available:http://www.avocadosource.com/WAC6/es/.../4b-183.pdf
55. Lu Q, Zhang Y, Wang Y, Lee RP, Gao K, Byrns R, Heber D. California Hass avocado: Profiling of carotenoids, tocopherol, fatty acid, and fat contet during maturation and from different growing areas. J Agric Food Chem. 2009;57(21):10408-13.
DOI: 10.1021/jf901839h
56. Dias PGI, Sajiwanie JWA, Rathnayaka RMUSK. Chemical composition, physicochemical and technological properties of selected fruit peels as a potential food source. Int J Fruit Sci; 2020.
DOI: 10.1080/15538362.2020.1717402
57. Boeing H, Bechthold A, Bub A, Ellinger S, Haller D, Kroke A, et al. Critical review: vegetables and fruit in the prevention of chronic diseases. Eur J Nutr. 2012;51(6):637-63.
DOI: 10.1007/s00394-012-0380-y
58. Munhuweyi K, Mpai S, Sivakumar D. Extension of avocado fruit postharvest quality using non-chemical treatments. Agronomy. 2020;10:212.
DOI:10.3390/agronomy10020212
59. Al-Dosari MS. Hypolipidemic and antioxidant activities of avocado fruit pulp on high cholesterol fed diet in rats. Afr J Pharm Pharmacol. 2011;5(12):1475-83.
DOI: 10.5897/AJPP11.239
60. Arancibia-Avila P, Toledo F, Park YS, Jung ST, Kang SG, Heo BG, et al. Antioxidant properties of durian fruit as influenced by ripening. LWT – Food Sci Technol. 2008;41:2118-25.
DOI: 10.1016/j.lwt.2007.12.001
61. Golukcu M, Ozdemir F. Changes in phenolic composition of avocado cultivars during harvesting time. Chem Nat Compd. 2010;46(1):112-5.
DOI: 10.1007/s10600-010-9541-5
62. Amado DAV, Helmann GAB, Detoni AM, Carvalho SLC, Aguiar CM, Martin CA, et al. Antioxidant and antibacterial activity and preliminary toxicity analysis of four varieties of avocado (*Persea americana* Mill.). Braz J Food Technol. 2019;22:e2018044.
DOI: 10.1590/1981-6723.04418
63. Tremocoldi MA, Rosalen PL, Franchin M, Massarioli AP, Denny C, Daiuto ÉR, et al. Exploration of avocado by-products as natural sources of bioactive compounds. PLoS One. 2018; 13(2):e0192577.
DOI: 10.1371/journal.pone.0192577
64. Gómez FS, Sánchez SP, Iradi MGG, Azman NAM, Almajano MP. Avocado seeds: extraction optimization and possible use as antioxidant in food. Antioxidants. 2014;3:439-54.
DOI:10.3390/antiox3020439

65. Salgado JM, Danielli F, Regitano-D'arce MAB, Frias A, Mansi DN. The avocado oil (*Persea americana* Mill) as a raw material for the food industry. Ciência Tecnologia Alimentar. 2008;28:20-6.
DOI: 10.1590/S0101-20612008000500004
66. Talabi JY, Osukoya OA, Ajayi OO, Adegoke GO. Nutritional and antinutritional compositions of processed avocado (*Persea americana* Mill) seeds. Asian J Plant Sci Res. 2016;6(2):6-12.
Available:www.pelagiaresearchlibrary.com
67. Zhang YJ, Gan RY, Li S, Zhou Y, Li AN, Xu DP, Li HB. Antioxidant phytochemicals for the prevention and treatment of chronic diseases. Molecules. 2015;20(12):21138-56.
DOI: 10.3390/molecules201219753
68. Forni C, Facchiano F, Bartoli M, Pieretti S, Facchiano A, D'Arcangelo D, et al. Beneficial role of phytochemicals on oxidative stress and age-related diseases. BioMed Res Int. 2019;Article ID 8748253:16 pages.
DOI: 10.1155/2019/8748253
69. Ayala-Zavala JF, Vega-Veja V, Rosas-Domínguez C, Palafox-Carlos H, Villa-Rodriguez JA. Agro-industrial potential of exotic fruit byproducts as a source of food additives. Food Res Int. 2011;44:1866-74.
DOI: 10.1016/j.foodres.2011.02.021
70. Salinas-Salazar C, Hernández-Brenes C, Rodríguez-Sánchez DG, Castillo EC, Navarro-Silva JM, Pacheco A. Inhibitory activity of avocado seed fatty acid derivatives (Acetogenins) against *Listeria monocytogenes*. J Food Sci. 2017;82(1):134-44.
DOI: 10.1111/1750-3841.13553
71. Dabas D, Ziegler GR, Lambert JD. Anti-Inflammatory properties of a colored avocado seed extract. Adv Food Technol Nutr Sci. 2019;5(1):8-12.
DOI: 10.17140/AFTNSOJ-5-151
72. Sulaiman SF, Sajak AAB, Supriatno KLO, Seow EM. Effect of solvents in extracting polyphenols and antioxidants of selected raw vegetables. J Food Comp Anal. 2011;24:506–15.
DOI: 10.1016/j.jfca.2011.01.020
73. Vinha AF, Alves RC, Barreira SVP, Costa ASG, Oliveira MBPP. Impact of boiling on phytochemicals and antioxidant activity of green vegetables consumed in the Mediterranean diet. Food Funct. 2015;6:1157-63.
DOI: 10.1039/C4FO01209G
74. Sanjust E, Mocci G, Zucca P, Rescigno, A. Mediterranean shrubs as potential antioxidant sources. Nat Prod Res. 2008;22(8):689-708.
DOI: 10.1080/14786410801997125
75. Mahattanatawee K, Manthey J, Luzio G, Talcott S, Goodner K, Baldwin E. Total antioxidante activity and fiber content of select Florida-grown tropical fruits. J Agric Food Chem. 2006; 54(19):7355-63.
DOI: 10.1021/jf060566s
76. Corral-Aguayo R, Yahia EM, Carrillo-Lopez A, Gonzalez-Aguilar GA. Correlation between some nutritional components and the total antioxidant capacity measured with six different assays in eighthorticultural crops. J Agric Food Chem. 2008;56(22):10498−504.
DOI: 10.1021/jf801983r
77. Santana I, Castelo-Branco VN, Guimarães BM, Silva LO, Peixoto VODS, Cabral LMC, et al. Hass avocado (*Persea americana* Mill.) oil enriched in phenolic compounds and tocopherols by expeller-pressing the unpeeled microwave dried fruit. Food Chem. 2019;286:354–361.
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