Influence of Drying Methods on Bioactive Properties, Fatty Acids and Phenolic Compounds of Different Parts of Ripe and Unripe Avocado Fruits

Elfadıl E Babiker^{1*}, Isam A. Mohamed Ahmed¹, Nurhan Uslu², Mehmet Musa Özcan^{2*}, Fahad Al Juhaimi¹, Kashif Ghafoor¹, and Ibrahim A. Almusallam¹

¹ Department of Food Science & Nutrition, College of Food and Agricultural Sciences, King Saud University, Riyadh-SAUDI ARABIA

² Department of Food Engineering, Faculty of Agriculture, Selcuk University, 42031 Konya, TURKEY

Abstract: All drying processes increased oil content, antioxidant activity, total phenolic contents, and most of the phenolic compounds in the pulp, peel and seeds of both ripe fruits with varied degrees ($p < 0.05$). In addition, the processes reduced the oil contents, linoleic acids, 3,4-dihydroxybenzoic acid, (+)-catechin, and naringenin of the pulp, antioxidant activity of the peels and seeds, and 3,4-dihydroxybenzoic acid, (+)-catechin of the seeds and it enhanced all other parameters in the pulp, peel, and seeds of unripe fruits ($p < 0.05$). Comparing the phenolic profiles of avocado pulp, peels, and seeds of ripe and unripe fruits indicated that the peel and seeds are richer than the pulp and that is superior in unripe fruits than ripe ones. In addition, drying processes particularly microwave and air drying greatly enhanced the bioactive properties of ripe and unripe avocado fruits and could thus be used to elongate the shelf-life of avocado fruit products without major impact on the overall quality.

Key words: avocado, drying, tissue, oil, antioxidants, fatty acids, phenolics, GC, HPLC

1 Introduction

Avocado fruit (*Persea americana* Mill.) is one of the most valuable tropical fruit that is utilized by many peoples around the globe¹. In many countries, avocado fruit is consumed as a vegetable in the form of salads, with onions and cheese or as a soup with salt and pepper, or and as a canned products². Industrially, the pulp of avocado fruits is used for the development of various products such as oil, dried avocados, purée or guacamole, and packaged slices³. Due to the wide utilization of avocado pulp in numerous applications, substantial quantities of avocado processing by products such as peels, seeds, and leaves are produced annually³. In addition, seven hydroxycinnamic acid derivatives (sinapic acid-*c*-hexoside, *p*-coumaric acid glucoside and one of its isomers, ferulic acid glucoside and its isomer, *p*-coumaric acid rutinoside and coumaric acid and octyl gallate) were also identified in avocado fruits⁴⁻⁶. The total phenolic, flavonoid, antioxidant activity of Hass avocado cultivars were affected by the ripening stage and research on the investigation of the impact of postharvest processing on the ripe and unripe avocado fruits and by-products are scarce^{7,8}. Drying is an appropriate and well-known

postharvest technology used to prolong the shelf life of fruits or vegetables, while preserving their quality and stability by reducing water activity and moisture content and thereby avoiding spoilage and contamination during storage. The aim of this study was to characterize oil, bioactive properties and phytochemicals of the pulp, seed and peel of unripe and ripe avocado fruit of the Pinkerton cultivar dried by air, microwave or oven.

2 Material and Methods

2.1 Material

Avocado (Pinkerton cultivar) fruits were used at two different maturity stages (unripe and ripe) obtained from Antalya, Turkey. They were transferred to Laboratory (Department of Food Engineering, Faculty of Agriculture, Selcuk University, Konya, Turkey) in cool bags. After washing by clean water, the pulp, seed and peel of avocado fruits were separated from each other. The pulp, peel and seeds of both ripe and unripe fruits were separately subjected to different treatments as; control (untreated

*Correspondence to: Elfadıl E Babiker and Mehmet Musa Özcan, Department of Food Science & Nutrition, College of Food and Agricultural Sciences, King Saud University, Riyadh-SAUDI ARABIA; Department of Food Engineering, Faculty of Agriculture, Selcuk University, 42031 Konya, TURKEY

E-mail: mozcan@selcuk.edu.tr; ebabiker.c@ksu.edu.sa

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samples), air-drying treatment, microwave-drying treatment (540 W, 15 min), and conventional oven drying treatment (60°C, 19 h).

2.2 Methods

2.2.1 Drying of Avocado fruit parts

Avocado fruits were manually cleaned, pulp, peel and seeds were separated from the fruits and then about 100 g of each part was dried either by air drying at room temperature (24°C) for two week or microwave (Arçelik ARMD 580, Turkey) oven capable to generate at 720 W power at 2450 MHz or in an oven (Nüve FN055 Ankara, Turkey, 55 L volume) at 60°C (19 h). After drying, the fruit samples were cooled at room temperature, and then kept frozen at -25°C under nitrogen in sealed bottles for further analyses.

2.2.2 Moisture content

The moisture contents of the samples were measured at 100°C ± 5°C in an oven (Nüve FN055 Ankara, Turkey) according to AOAC method⁹.

2.2.3 Oil content

The oil content of avocado samples was determined according to AOAC⁹ method. Total oil content of the samples was extracted with petroleum benzene in Soxhlet Apparatus for 5 h and the solvent was removed with a rotary vacuum evaporator at 50°C.

2.2.4 Fatty acid composition

The sample oils were esterified according to ISO-5509¹⁰ method. Commercial mixtures of fatty acid methyl esters were used as reference data for the relative retention times. Fatty acid methyl esters of oil samples were analyzed on gas chromatograph (Shimadzu GC-2010) equipped with flame-ionization detector (FID) and capillary column (Tecnocroma TR-CN100, 60 m × 0.25 mm, film thickness: 0.20 µm). The temperature of injection block and detector was 260°C. Mobile phase was nitrogen with 1.51 mL/min flow rate. Total flow rate was 80 mL/min and split rate was also 1/40.

2.2.5 Preparation of the sample extracts

The extracts of avocado fruit parts were done according to Lopez-Cobo *et al.*¹¹. Ground sample (1 g) of each part was added to 20 mL of hexane and mixture of 10 mL methanol: water (80:20, v/v). The mixture was kept in ultrasonic water-bath for 15 min, followed by centrifugation at 6000 rpm for 15 min. The supernatant was removed. The steps were repeated twice and the lower phases were collected. The extract was concentrated at 37°C under vacuum. The volume was made up to 10 mL with a mixture of methanol: water (50:50) and then filtered with 0.45 µm filter.

2.2.6 Total phenolic content

Total phenolics contents of avocado fruit parts were determined using the Folin-Ciocalteu (FC) reagent as applied by Yoo *et al.*¹². Folin-Ciocalteu (1 mL) and Na₂CO₃ (10 mL) were added to extract and mixed with vortex. The deionised water was added until the final volume was 25 mL, and

kept at dark for 1 h. The absorbance was measured at 750 nm in a spectrophotometer. The results are shown as mg gallic acid equivalent (GAE)/100 g of fresh weight.

2.2.7 Antioxidant activity

The free radical scavenging activity of the extracts was determined using DPPH (1,1-diphenyl-2-picrylhydrazyl) according to Lee *et al.*¹³. The extract was mixed with 2 mL methanolic solution of DPPH. The mixture was shaken vigorously and allowed to stand at room temperature for 30 min and the absorbance was recorded at 517 nm by using a spectrophotometer. Antioxidant activity (%) was calculated using following relation:

$$\text{Inhibition (\%)} = \left[\frac{\Delta A_{\text{Control}517} - \Delta A_{\text{Extract}517}}{\Delta A_{\text{Control}517}} \right] \times 100$$

2.2.8 Determination of phenolic compounds

A Shimadzu-HPLC equipped with a PDA detector and an Inertsil ODS-3 column was applied for the qualification and quantification of phenolic compounds were performed. The mobile phase was composed of 0.05% acetic acid (A) and acetonitrile (B) and 20 µL of the extract was injected and run at 1 mL/min at 30°C for a total running time of 60 min. The peaks were measured at 280 and 330 nm using a PDA detector. The total running time per sample was 60 min.

2.3 Statistical analysis

The analyses of variance were performed using JMP version 9.0. Tukey's tests was applied to determine the significant variations among results of control, maturation and drying types ($p < 0.05$). All analyses were carried out three times and the results are mean ± standard deviation (MSTAT C) of independent tissue values.

3 Results and Discussion

3.1 Effect of drying methods on moisture, oil, total phenolics and antioxidant activity

The effect of drying methods on moisture, oil, total phenolics and antioxidant activity of unripe and ripe avocado (Pinkerton) fruit parts are shown in **Table 1**. Unripe and ripe avocado fruit parts (pulp, peel and seed) were dried by different methods (air-, microwave- and oven drying). The moisture contents of fresh pulp (68.47% and 73.01%), peel (74.31% and 74.26%) and seeds (57.81% and 59.11%) of unripe and ripe fruits, respectively, were significantly ($p < 0.05$) reduced by all drying methods with the highest reduction being observed in oven-dried samples. Previous studies indicated that increasing the drying temperature significantly reduced the moisture contents of avocado seeds and pulp^{14, 15}. In peel and pulp of ripe fruits, all drying treatment significantly ($p < 0.05$) increased the oil contents compared to fresh samples. Mostert *et al.*¹⁶ reported that both ripening and drying treatment enhanced the oil contents of avocado pulp. In addition, dos Santos *et*

Table 1 Some chemical composition of different parts of "Pinkerton" avocado fruit.

	Green (unripe)									
	Pulp			Peel			Seed			
	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying
Moisture (%)	68.47 ± 0.03 ^a	3.93 ± 0.02b	2.51 ± 0.06c	2.62 ± 0.02c	74.31 ± 0.08a	5.95 ± 0.07b	5.10 ± 0.05c	4.07 ± 0.04d	57.81 ± 0.05a	8.43 ± 0.05b
Oil (%)	73.54 ± 1.38 ^{a**}	72.09 ± 0.77b	72.62 ± 0.71b	71.26 ± 0.12c	8.94 ± 0.73c	8.19 ± 0.09d	14.63 ± 0.74b	16.02 ± 0.70a	3.50 ± 0.55b	4.04 ± 0.25a
Antioxidant activity(%)	6.93 ± 0.10d	56.23 ± 0.17b	52.85 ± 0.12c	58.10 ± 0.90a	82.82 ± 0.14a	78.03 ± 0.14b	18.48 ± 0.82d	77.75 ± 0.09c	83.15 ± 0.12a	82.25 ± 0.44b
Total phenol (mg AE/100g)	40.56 ± 1.41d	129.39 ± 0.27c	144.45 ± 0.61a	130.36 ± 0.08b	450.83 ± 4.76d	723.02 ± 0.65a	704.65 ± 0.55b	512.79 ± 0.18c	625.56 ± 12.03c	765.92 ± 0.04a
Ripe										
	Pulp			Peel			Seed			
	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying
	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying
Moisture (%)	73.02 ± 0.01a	3.71 ± 0.02b	2.41 ± 0.05c	2.26 ± 0.04d	74.26 ± 0.05a	5.43 ± 0.20b	4.33 ± 0.05d	4.36 ± 0.03c	59.11 ± 0.20a	8.91 ± 0.03b
Oil (%)	68.98 ± 2.33d	72.59 ± 0.59c	72.82 ± 0.39b	73.52 ± 0.21a	6.23 ± 1.41d	18.19 ± 0.03c	22.16 ± 0.85a	20.39 ± 0.38b	3.60 ± 0.56b	3.73 ± 0.04a
Antioxidant activity(%)	7.89 ± 0.07d	62.70 ± 0.21a	53.69 ± 0.09c	53.89 ± 0.26b	77.75 ± 0.08c	80.90 ± 0.40a	10.76 ± 0.47d	79.21 ± 0.09b	79.72 ± 0.08b	81.63 ± 0.21a
Total phenol (mg AE/100g)	25.00 ± 0.98d	107.38 ± 0.13c	138.01 ± 0.45a	115.67 ± 0.09b	205.0 ± 3.67d	638.82 ± 0.29c	713.35 ± 0.12a	682.79 ± 0.07b	600.83 ± 5.49d	608.37 ± 0.04c

* mean ± standard deviation; ** Values in each row with different letters are significantly different ($p < 0.05$)

*al.*¹⁷⁾ stated that temperature had positive effect on the oil yield of avocado pulp. However, Moreno *et al.*¹⁸⁾ reported that drying Hass avocado at temperatures higher than 100°C reduced the oil yield and attributed that to structural changes to idioblastic cells. With exception of unripe peels and seeds, drying processes increased the antioxidant activity in the pulp, peel, and seeds of ripe fruits and the pulp of unripe fruits ($p < 0.05$) with the highest activity being observed in air-dried pulp, peel and seeds of ripe fruits and conventional oven-dried pulp of unripe fruits. In addition, all drying treatments significantly enhanced the total phenolic contents of the pulp and peel of both ripe and unripe fruits compared to fresh samples. Among the treated samples, the highest total phenolic content was observed in all parts of ripe and the pulp of unripe avocado fruits dried with microwave oven and the peel and seeds unripe fruits subjected to air drying treatment. The enhancement of the antioxidant activity and total phenolic contents with drying treatments could be linked to the reduction of moisture content and consequently the concentration of the bioactive compounds. Krumreich *et al.*¹⁹⁾ studied the effect of oven drying under ventilation (40°C and 60°C) and vacuum oven (60°C) of avocado pulp on the quality of extracted oil and they observed that drying the pulp at 60°C resulted in high bioactive compounds and antioxidant activity of the oil. They attribute that to the inactivation of polyphenol degrading enzyme namely polyphenol oxidase at 60°C, thereby preserving the phenolic compounds in the oil¹⁹⁾. Figueroa *et al.*²⁰⁾ reported that the highest total phenolic content of avocado peel was achieved with a conventional oven drying at 85°C. Furthermore, Saavedra *et al.*⁵⁾ reported that increasing drying temperature from 45 to 60°C increased the antioxidant capacity values of avocado seeds whereas it reduced that of the peels. Apparently, the oil contents, antioxidant activity, and total phenolic contents of avocado are greatly influenced by many factors such as ripening stage, fruit parts, drying process conditions (type, temperature, and duration) as well as other factors such as genotypes, growing conditions, and post-harvest processing.

3.2 Effect of drying methods on fatty acids composition

Fatty acid composition of different fruit part oils of avocado (Pinkerton cultivar) extracted by Soxhlet system dried at the different drying systems (air-, microwave- or oven-drying) are presented in Table 2. Generally, the fatty acid profile is differed among the tested fruit parts of ripe and unripe fruits subjected to different drying treatments ($p < 0.05$). With exceptions of oleic in unripe fruits and palmitic in ripe ones, drying treatments significantly ($p < 0.05$) enhanced the values of all fatty acids of the pulp with the highest values being observed in pulp dried using conventional oven. In the peel samples of unripe fruits, drying treatment significantly ($p < 0.05$) increased fatty acids,

Table 2 Fatty acid compositions of different parts of "Pinkerton" avocado fruit.

	Green (unripe)									
	Pulp					Peel				
	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying
Myristic	—	—	—	—	—	—	—	—	0.50 ± 0.05c	0.55 ± 0.02b
Palmitic	19.06 ± 0.08*c	20.46 ± 0.20b**	17.07 ± 0.22d	20.60 ± 0.21a	15.59 ± 0.10b	14.84 ± 0.20d	15.81 ± 0.35a	15.15 ± 0.16c	18.04 ± 0.37d	18.71 ± 0.24c
Stearic	— ***	0.84 ± 0.00b	0.70 ± 0.00c	0.87 ± 0.00a	0.64 ± 0.00c	1.13 ± 0.00a	0.93 ± 0.00b	0.85 ± 0.01d	3.74 ± 0.02b	13.14 ± 0.03a
Oleic	47.53 ± 0.11d	61.72 ± 0.16c	61.80 ± 0.20b	62.92 ± 0.22a	57.68 ± 0.09b	54.86 ± 0.19d	56.10 ± 0.22c	60.76 ± 0.07a	45.66 ± 0.16a	27.28 ± 0.05c
Linolelaidic	—	—	—	—	—	—	—	—	1.39 ± 0.02a	0.54 ± 0.02b
Linoleic	13.26 ± 0.03a	9.72 ± 0.02c	13.23 ± 0.01b	8.70 ± 0.02d	17.20 ± 0.01c	20.15 ± 0.06a	19.32 ± 0.06b	16.60 ± 0.03d	22.06 ± 0.01d	27.27 ± 0.05b
Arachidic	0.07 ± 0.00c	—	0.10 ± 0.00a	0.09 ± 0.00b	—	0.12 ± 0.02a	0.12 ± 0.00a	0.12 ± 0.01a	0.62 ± 0.06d	0.67 ± 0.01c
Linolenic	0.45 ± 0.00d	0.53 ± 0.00c	0.95 ± 0.00a	0.90 ± 0.00b	1.94 ± 0.01a	1.86 ± 0.00b	1.52 ± 0.01c	1.37 ± 0.00d	3.17 ± 0.01c	5.23 ± 0.07a
Behenic	—	—	—	—	1.10 ± 0.01b	1.57 ± 0.04a	0.81 ± 0.02c	0.24 ± 0.02d	0.76 ± 0.01c	0.77 ± 0.01d
Erucic	—	—	—	—	—	—	—	—	0.56 ± 0.01d	3.29 ± 0.09b
Arachidonic	—	0.12 ± 0.01a	0.09 ± 0.01b	0.09 ± 0.00b	0.32 ± 0.01b	0.50 ± 0.01a	0.24 ± 0.01c	0.08 ± 0.01d	0.69 ± 0.06bc	0.70 ± 0.08b
										0.60 ± 0.05c
										1.02 ± 0.02a

	Ripe									
	Pulp					Peel				
	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying
Myristic	—	—	—	—	—	—	—	—	0.91 ± 0.09	—
Palmitic	22.08 ± 0.50a	17.50 ± 0.48c	16.60 ± 0.05d	18.03 ± 0.15b	20.82 ± 0.20a	17.36 ± 0.11b	16.09 ± 0.04c	15.77 ± 0.00d	23.62 ± 0.54a	18.47 ± 0.47d
Stearic	0.64 ± 0.02d	0.65 ± 0.01c	0.67 ± 0.00b	0.88 ± 0.00a	0.92 ± 0.01b	1.03 ± 0.00a	0.89 ± 0.00c	0.80 ± 0.00d	3.70 ± 0.16b	9.63 ± 0.08a
Oleic	58.20 ± 0.38d	62.35 ± 0.31b	60.99 ± 0.05c	62.92 ± 0.13a	56.40 ± 0.17bc	56.73 ± 0.05b	57.73 ± 0.02a	55.30 ± 0.00c	51.30 ± 0.18a	26.66 ± 0.09d
Linolelaidic	—	—	—	—	—	—	—	—	—	7.16 ± 0.10
Linoleic	11.33 ± 0.06c	12.51 ± 0.06b	14.23 ± 0.01a	11.21 ± 0.01d	13.54 ± 0.02d	17.31 ± 0.03c	18.27 ± 0.01b	19.80 ± 0.00a	15.04 ± 0.15d	27.80 ± 0.03c
Arachidic	—	0.09 ± 0.00b	0.09 ± 0.00b	0.11 ± 0.00a	—	—	0.09 ± 0.00	—	—	0.96 ± 0.09a
Linolenic	0.55 ± 0.01d	0.73 ± 0.01c	1.16 ± 0.00a	0.76 ± 0.00b	1.11 ± 0.00d	1.31 ± 0.00c	1.47 ± 0.00b	1.63 ± 0.00a	0.76 ± 0.03d	4.60 ± 0.05a
Behenic	—	—	—	—	0.89 ± 0.00b	0.57 ± 0.02c	0.29 ± 0.01d	0.93 ± 0.00a	—	0.58 ± 0.01b
Erucic	—	—	—	—	—	—	—	—	1.52 ± 0.08d	2.40 ± 0.16a
Arachidonic	—	—	—	0.15 ± 0.00	0.37 ± 0.00a	0.20 ± 0.00c	—	0.24 ± 0.00b	0.70 ± 0.01b	0.56 ± 0.13d
										0.58 ± 0.00c
										1.02 ± 0.04a

*mean ± standard deviation; **Values in each row with different letters are significantly different ($p < 0.05$); ***unidentified

except linolenic, with the enhancement of the majority of fatty acids was found in air-dried peels. Palmitic and arachidonic acid amounts of avocado fruit parts (peel, pulp and seed) varied depending on drying type and maturity ($p < 0.05$). In addition, a partial decrease in some fatty acids was observed with drying. While oleic acid amounts of raw and ripe fruit pulps did not change much depending on the drying type, fluctuations were observed in the oleic acid amounts of shell and seed oils ($p < 0.05$). Interestingly, microwave- and air-drying treatments significantly enhanced the level of linoleic acid in the seeds of both ripe and unripe fruits. In addition, all drying treatments increased the amounts of linoleic acid in the pulp of both ripe and unripe fruits, and in the peel and seeds of ripe fruits. The increase in linoleic acid following drying treatment is likely due to thermal degradation of cell matrix and decomposition of conjugated lipids and phospholipids and thereby releasing more free form of linoleic acid. Previously, various studies indicated that oleic, palmitic, linoleic are the major fatty acids in the pulp and seed oils of various avocado cultivars^{1, 8, 21–24}. Krumreich *et al.*¹⁹ studied the effect of drying on the fatty acids of oil extracted for the pulp of mature avocado fruits and observed that oven drying treatment at 60°C influenced positively the fatty acid compositions of the oil. However, Santana *et al.*⁸ reported that the fatty acid composition of avocado pulp oil was not affected by drying process; however, it was affected marginally with the ripening stage and peeling process. The variation in the fatty acid composition of avocado oils between these studies could be attributed to the differences in the, genetic makeup, the fruits parts (pulp, peel, and seeds), maturity stage, postharvest practices, environmental conditions, drying conditions, and oil extraction methods.

3.3 Effect of drying methods on phenolic compounds

The profiles of phenolic compounds of the pulp, peel, and seeds of ripe and unripe avocado fruits as affected by different drying methods are shown in Tables 3, 4 and 5. The major phenolic compounds in the pulp of both ripe and unripe avocado fruits were (+)-catechin, 1,2-dihydroxybenzene, and 3,4-dihydroxybenzoic acid (Table 3). With few exceptions, the quantities of all phenolic compounds were higher in the pulp of unripe fruits compared to that in ripe ones. While the (+)-catechin contents of fresh, air-dried, microwave and oven-dried unripe avocado fruit peels were 203.04 mg / 100 g, 208.87 mg / 100 g, 36.71 mg / 100 g and 99.82 mg / 100 g, respectively, the (+)-catechin contents of fresh, air-dried, microwave and oven-dried ripe avocado fruit peels were 111.70 mg / 100 g, 79.60 mg / 100 g, 212.93 mg / 100 g and 118.01 mg / 100 g, respectively. There was an increase in the amount of (+)-catechin of ripe avocado peel dried in microwave and oven. Probably, this may be due to the decrease in the amount of (+)-catechin in the pulp during maturation as a result of

the biochemical reaction. In previous studies, the quantities of phenolic compounds of avocado pulp was differed between avocado cultivars from different countries and growing seasons^{8, 11, 28, 29} and the composition was different than that reported herein for Pinkerton cultivar. Santana *et al.*⁸ reported that fruit ripening and unpeeling process enhanced the phenolic compounds of avocado oils. Regardless of drying process, the peel of both ripe and unripe avocado fruits contained considerable quantities of phenolic compounds (Table 4). (+)-Catechin and 1,2-dihydroxybenzene were found to be the dominant phenolic compounds in both unripe and ripe fruit peel extract. (+)-Catechin content of unripe fruit peel extract was significantly high when the peel was dried by air (208.87 mg/100 g) while that of ripe peel extract was significantly high when the peel was dried by microwave (212.93 mg/100 g). A high level of quercetin was observed in unripe and ripe peel (1174.08 mg/100 g and 773.18 mg/100 g, respectively) dried by microwave. Among the drying methods used, microwave drying greatly improved the quantities of phenolic compounds in the peels of both ripe and unripe avocados. Similarly, Figueroa *et al.*²⁰ reported that increasing drying temperature from 45 to 85°C significantly increased the phenolic compounds in avocado peels. The phenolic compounds of unripe and ripe fruit seed extracts dried by different drying methods are shown in Table 5. In the seeds obtained from unripe fruits, air-drying treatment greatly enhanced the quantities of most phenolic compounds of the seeds compared to other drying treatments, except gallic and caffeic acids which were improved more by conventional oven drying and syringic acid by microwave drying. Interestingly, a higher level of quercetin (2369.94 mg/100 g) content of unripe seeds was observed in air-dried seeds compared to than in fresh seeds (137.66 mg/ 100 g) suggesting that such drying treatment enhanced its contents by more than 17 folds. In the seeds of ripe avocados, air drying treatment improved the contents of 3,4-dihydroxybenzoic, *trans*-ferulic, and *trans*-cinnamic acids, kaempferol and isorhamnetin and microwave drying improved that of apigenin 7 glucoside and resveratrol, whereas conventional drying increased the levels of all other phenolic compounds. Comparing the phenolic profiles of avocado pulp, peels, and seeds of ripe and unripe fruits indicated that the peel and seeds are richer than the pulp and that is superior in unripe fruits than ripe ones. The present results highlight the suitability of using the avocado by product, namely, peel and seed, of unripe fruits as sources of phenolic compounds after suitable drying processes. Saavedra *et al.*⁵ reported that avocado peels and seeds contain large variety and high amounts of phenolic compounds and drying process improved the quantities of phenolic compounds. Variations in phenolic compounds between fruit parts might be associated with maturity stage but also may be due to environmental con-

Table 3 Phenolic compounds of pulp of avocado (mg/100 g).

Maturity		Unripe				Ripe			
Process		Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying
Galic Acid		37.92 ± 0.13 ^{*b}	58.35 ± 0.58a	29.99 ± 0.68c	29.60 ± 0.67d	15.74 ± 0.49d	50.27 ± 0.23b	59.80 ± 1.05a	37.20 ± 0.65c
3,4-Dihydroxybenzoic Acid		64.91 ± 0.33a [*]	35.83 ± 0.22c	60.41 ± 0.31b	23.70 ± 0.39d	60.08 ± 0.94b	49.02 ± 0.83d	51.06 ± 0.78c	63.93 ± 0.63a
(+)-Catechin		191.55 ± 0.55a	98.62 ± 1.48d	99.08 ± 1.45b	98.78 ± 1.25c	109.37 ± 1.30c	108.00 ± 1.70d	188.62 ± 1.37a	165.42 ± 2.56b
1,2-Dihydroxybenzene		81.81 ± 1.90c	90.18 ± 1.95b	118.60 ± 1.81a	69.59 ± 0.45d	152.04 ± 1.56a	101.16 ± 1.32b	85.47 ± 1.47d	94.68 ± 1.59c
Syringic Acid		47.88 ± 0.64b	27.35 ± 0.56d	72.45 ± 1.34a	43.52 ± 0.11c	27.13 ± 0.19c	32.08 ± 0.76b	36.74 ± 0.34a	22.83 ± 0.03d
Caffeic Acid		12.12 ± 0.92b	11.88 ± 0.03d	13.33 ± 0.51a	12.06 ± 0.14c	8.43 ± 0.23d	10.20 ± 0.53c	11.85 ± 0.31b	12.79 ± 0.93a
Rutin trihydrate		22.49 ± 0.37d	23.26 ± 0.54c	24.42 ± 0.28b	25.50 ± 0.99a	19.44 ± 0.46c	15.36 ± 0.75d	21.53 ± 0.25b	36.95 ± 0.03a
<i>p</i> -Coumaric Acid		1.20 ± 0.23d	1.56 ± 0.30c	3.04 ± 0.85a	1.77 ± 0.33b	2.29 ± 0.25a	1.48 ± 0.13c	1.51 ± 0.09b	0.95 ± 0.18d
<i>trans</i> -Ferulic Acid		12.06 ± 0.13c	6.58 ± 0.38d	22.34 ± 0.81b	66.36 ± 0.19a	5.08 ± 0.57d	8.12 ± 0.86a	7.19 ± 0.86b	5.33 ± 0.64c
Apigenin 7 glucoside		32.27 ± 1.30c	33.90 ± 0.35b	25.40 ± 0.62d	35.34 ± 0.49a	11.97 ± 0.65d	33.06 ± 0.77b	15.74 ± 0.76c	39.34 ± 0.53a
Resveratrol		6.93 ± 0.65c	10.01 ± 0.07b	5.93 ± 0.82d	11.98 ± 0.63a	5.07 ± 0.62b	3.95 ± 0.01d	4.78 ± 0.90c	11.49 ± 0.71a
Quercetin		18.21 ± 0.38c	58.18 ± 0.30b	18.22 ± 0.47c	75.10 ± 0.50a	26.67 ± 0.24b	7.37 ± 0.50c	4.86 ± 0.52d	64.95 ± 0.61a
<i>trans</i> -Cinnamic Acid		4.10 ± 0.09c	3.75 ± 0.39d	5.42 ± 0.73a	5.34 ± 0.35b	2.76 ± 0.50d	4.96 ± 0.39c	6.17 ± 0.60a	6.00 ± 0.32b
Naringenin		12.81 ± 0.33a	10.88 ± 0.84d	11.54 ± 0.61c	11.62 ± 0.83b	2.26 ± 0.53d	9.59 ± 0.80a	5.23 ± 0.00c	6.17 ± 0.60b
Kaempferol		13.10 ± 0.74b	20.21 ± 0.45a	7.32 ± 0.00d	19.05 ± 0.67c	9.33 ± 0.31d	17.83 ± 0.16a	16.28 ± 0.32b	13.15 ± 0.53c
Isorhamnetin		15.87 ± 0.42b	13.03 ± 0.37c	15.95 ± 0.52a	7.19 ± 0.61d	11.64 ± 0.67d	14.70 ± 0.23a	13.12 ± 0.05b	12.36 ± 0.94c

*mean ± standard deviation; **Values in each row with different letters are significantly different ($p < 0.05$)

Table 4 Phenolic compounds of peel of avocado (mg/100 g).

Maturity		Unripe				Ripe			
Process	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying	Oven drying	
Gallic Acid	35.82 ± 0.72 ^{*b}	30.13 ± 0.61 ^c	26.47 ± 0.44 ^d	36.45 ± 0.88 ^a	30.64 ± 0.03 ^d	53.90 ± 0.07 ^a	32.72 ± 0.98 ^c	46.05 ± 0.09 ^b	
3,4-Dihydroxybenzoic Acid	31.74 ± 0.43 ^{d**}	45.88 ± 0.82 ^b	63.31 ± 0.24 ^a	40.35 ± 0.60 ^c	73.78 ± 0.15 ^a	66.59 ± 2.23 ^b	51.59 ± 1.07 ^c	50.89 ± 1.09 ^d	
(+)-Catechin	203.04 ± 1.34 ^b	208.87 ± 1.29 ^a	36.71 ± 0.04 ^d	99.82 ± 2.73 ^c	111.70 ± 5.48 ^c	79.60 ± 1.13 ^d	212.93 ± 4.81 ^a	118.01 ± 2.77 ^b	
1,2-Dihydroxybenzene	101.71 ± 2.72 ^c	267.88 ± 2.21 ^b	309.97 ± 3.16 ^a	92.09 ± 3.74 ^d	77.25 ± 0.43 ^d	248.91 ± 3.99 ^a	234.05 ± 4.00 ^b	107.88 ± 3.92 ^c	
Syringic Acid	41.21 ± 0.56 ^d	74.14 ± 0.00 ^b	101.45 ± 5.73 ^a	49.03 ± 0.55 ^c	47.68 ± 0.47 ^a	45.76 ± 0.31 ^b	40.47 ± 0.71 ^c	29.42 ± 0.10 ^d	
Caffeic Acid	9.98 ± 0.49 ^d	277.83 ± 2.57 ^a	74.60 ± 0.12 ^b	17.23 ± 0.13 ^c	10.59 ± 0.94 ^d	13.94 ± 0.45 ^c	49.49 ± 0.87 ^a	25.89 ± 0.26 ^b	
Rutin trihydrate	5.68 ± 0.04 ^c	4.60 ± 0.44 ^d	167.18 ± 5.52 ^a	71.59 ± 0.41 ^b	22.67 ± 0.50 ^c	124.02 ± 0.99 ^a	42.81 ± 0.81 ^b	22.10 ± 0.13 ^d	
<i>p</i> -Coumaric Acid	2.38 ± 0.83 ^d	22.89 ± 0.13 ^a	12.79 ± 0.01 ^b	8.66 ± 0.61 ^c	3.37 ± 0.90 ^d	11.26 ± 0.06 ^a	7.60 ± 0.22 ^c	8.83 ± 0.21 ^b	
<i>trans</i> -Ferulic Acid	5.40 ± 0.36 ^d	154.09 ± 2.64 ^b	368.98 ± 3.47 ^a	82.00 ± 0.50 ^c	16.25 ± 0.08 ^d	48.27 ± 1.00 ^c	49.48 ± 0.13 ^b	85.48 ± 0.77 ^a	
Apigenin 7 glucoside	27.85 ± 0.68 ^c	21.24 ± 0.20 ^d	110.47 ± 2.05 ^a	30.89 ± 0.23 ^b	30.24 ± 0.53 ^c	69.92 ± 0.17 ^a	19.44 ± 0.65 ^d	34.53 ± 0.25 ^b	
Resveratrol	8.04 ± 0.33 ^d	28.37 ± 0.76 ^b	133.91 ± 2.59 ^a	18.18 ± 0.82 ^c	3.86 ± 0.80 ^d	24.70 ± 0.33 ^b	36.63 ± 0.00 ^a	13.89 ± 0.57 ^c	
Quercetin	36.25 ± 0.24 ^d	133.05 ± 1.77 ^b	1174.08 ± 4.98 ^a	40.97 ± 0.57 ^c	4.77 ± 0.90 ^d	109.00 ± 1.70 ^b	773.18 ± 2.63 ^a	64.82 ± 0.22 ^c	
<i>trans</i> -Cinnamic Acid	14.99 ± 0.37 ^c	22.28 ± 0.15 ^b	394.35 ± 1.70 ^a	5.50 ± 0.82 ^d	3.76 ± 0.66 ^c	10.49 ± 0.48 ^b	237.42 ± 4.91 ^a	3.54 ± 0.36 ^d	
Naringenin	18.86 ± 0.97 ^b	18.90 ± 0.00 ^b	65.89 ± 0.93 ^a	5.85 ± 0.78 ^c	9.06 ± 0.97 ^d	14.78 ± 0.28 ^b	104.53 ± 2.64 ^a	9.32 ± 0.58 ^c	
Kaempferol	46.01 ± 0.54 ^b	46.00 ± 0.00 ^b	238.66 ± 1.65 ^a	19.83 ± 0.83 ^c	10.01 ± 0.23 ^d	28.11 ± 0.71 ^b	92.74 ± 0.99 ^a	17.72 ± 0.05 ^c	
Isorhamnetin	31.09 ± 0.09 ^c	36.88 ± 0.00 ^b	83.53 ± 0.15 ^a	10.09 ± 0.51 ^d	7.54 ± 0.14 ^d	24.33 ± 0.18 ^b	260.53 ± 1.74 ^a	11.21 ± 0.08 ^c	

*mean ± standard deviation; **Values in each row with different letters are significantly different ($p < 0.05$)

Table 5 Phenolic compounds of seed of avocado (mg/100 g).

Maturity	Unripe				Ripe			
	Process	Fresh	Air-drying	Microwave drying	Oven drying	Fresh	Air-drying	Microwave drying
	Galic Acid	7.90 ± 0.95 ^{*d}	13.40 ± 0.77c	20.19 ± 0.14b	53.64 ± 0.09a	32.72 ± 0.90c	38.41 ± 0.90b	23.37 ± 0.51d
	3,4-Dihydroxybenzoic Acid	67.78 ± 0.20a ^{**}	60.53 ± 2.69b	39.58 ± 0.87d	51.79 ± 0.38c	33.92 ± 0.83d	70.08 ± 1.79a	48.27 ± 0.52c
	(+)-Catechin	203.84 ± 4.61a	172.23 ± 3.24b	101.26 ± 2.97c	45.87 ± 0.61d	105.71 ± 1.27a	7.78 ± 0.71d	60.72 ± 0.46c
	1,2-Dihydroxybenzene	112.12 ± 2.34b	252.30 ± 4.24a	94.77 ± 1.28c	36.65 ± 0.42d	123.80 ± 1.86c	95.77 ± 1.37d	127.03 ± 1.31b
	Syringic Acid	59.80 ± 0.74b	31.71 ± 0.17d	49.42 ± 0.58c	94.28 ± 1.17a	83.63 ± 1.83b	19.94 ± 0.07c	16.45 ± 0.90d
	Caffeic Acid	13.07 ± 0.48c	11.31 ± 0.48d	23.37 ± 0.96a	15.74 ± 0.77b	11.05 ± 0.61c	8.70 ± 0.08d	14.97 ± 0.45b
	Rutin trihydrate	10.84 ± 0.63d	125.85 ± 4.40a	21.94 ± 0.86c	71.74 ± 0.44b	19.20 ± 0.68c	34.46 ± 0.36b	10.54 ± 0.27d
	<i>p</i> -Coumaric Acid	1.00 ± 0.29d	16.73 ± 0.26a	12.07 ± 0.65b	4.94 ± 0.01c	1.51 ± 0.50d	8.54 ± 0.09b	2.91 ± 0.31c
	<i>trans</i> -Ferulic Acid	8.49 ± 0.08c	53.13 ± 1.32a	4.14 ± 0.47d	25.37 ± 0.87b	5.94 ± 0.19c	25.63 ± 0.39a	1.36 ± 0.12d
	Apigenin 7 glucoside	64.44 ± 0.51b	47.94 ± 0.88c	106.16 ± 0.04a	45.76 ± 0.02d	23.94 ± 0.91c	7.18 ± 0.76d	55.89 ± 0.79a
	Resveratrol	45.76 ± 0.58a	27.42 ± 0.24b	15.04 ± 0.16c	8.44 ± 0.83d	13.28 ± 0.25b	10.03 ± 0.84d	20.76 ± 0.92a
	Quercetin	137.66 ± 2.74b	2369.94 ± 8.49a	42.04 ± 0.47c	34.83 ± 0.33d	241.43 ± 2.57a	52.53 ± 0.13d	147.79 ± 1.05b
	<i>trans</i> -Cinnamic Acid	43.40 ± 1.28b	178.61 ± 0.00a	9.96 ± 0.61c	4.89 ± 0.45d	77.06 ± 0.36b	91.97 ± 0.55a	44.95 ± 0.44c
	Naringenin	42.63 ± 0.00b	90.66 ± 0.00a	12.48 ± 0.98c	8.14 ± 0.46d	95.54 ± 0.00a	— ***	42.12 ± 0.55b
	Kaempferol	25.95 ± 0.00c	247.93 ± 0.00a	33.40 ± 0.00b	11.77 ± 0.91d	29.48 ± 0.00b	98.34 ± 0.00a	15.91 ± 0.00d
	Isorhamnetin	71.52 ± 1.50b	123.27 ± 2.24a	31.65 ± 0.82c	10.41 ± 0.80d	33.64 ± 0.28c	69.14 ± 0.62a	56.21 ± 0.39b

*mean ± standard deviation, **Values in each row with different letters are significantly different ($p < 0.05$), ***nonidentified

ditions, postharvest management, geographical conditions and genetic background^{25–27, 30}). Optimum harvest maturity and processes are the important factors determining the quality of avocado fruit.

4 Conclusion

This study represent one of the few studies on the combined impacts of avocado maturity stage and drying methods on the oil yield bioactive properties and fatty acid composition of the pulp, peel, and seeds. The results indicate that the avocado pulp, peel, and seeds are important sources of bioactive compounds and essential fatty acids at the ripe and unripe stages. With few exceptions, drying of the pulp, peel, and seeds significantly improved oil yield, bioactive properties and fatty acid composition of these parts of both ripe and unripe avocado fruits. The most suitable drying method for preserving the analyzed quality parameters was microwave-drying followed by air and oven. The present results highlight the suitability of using the avocado fruit pulp, peel and seed, of both ripe and unripe fruits as sources of bioactive compounds after suitable drying process.

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