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

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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 globe¹⁻⁵. 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 product⁶. 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 hydroxycinnamonic 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 scarce⁷⁻⁸. 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, peel and seeds of both ripe and unripe 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...
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 ARMG 580, Turkey) oven capable to generate at 720 W power at 2450 MHz or in an oven (Nuve 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 (Nuve FN055 Ankara, Turkey) according to AOAC method.

2.2.3 Oil content

The oil content of avocado samples was determined according to AOAC 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-5509 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 a gas chromatograph (Shimadzu GC-2010) equipped with flame-ionization detector (FID) and capillary column (Tecnocroma TR-CN100, 60 m x 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. 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. 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. 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:

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

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

|                | Moisture (%) | Oil (%) | Antioxidant activity (%) | Total phenol (mg AE/100g) | Antioxidant activity (%) | Total phenol (mg AE/100g) |
|----------------|--------------|---------|--------------------------|---------------------------|--------------------------|---------------------------|
|                | Fresh | Air-drying | Microwave drying | Oven drying | Fresh | Air-drying | Microwave drying | Oven drying | Fresh | Air-drying | Microwave drying | Oven drying | Fresh | Air-drying | Microwave drying | Oven drying |
| Pulp           | Fresh | 73.02 ± 0.01a | 7.89 ± 0.07b | 20.75 ± 0.07d | 129.39 ± 0.01d | 7.89 ± 0.07b | 20.75 ± 0.07d | 129.39 ± 0.01d | 7.89 ± 0.07b | 20.75 ± 0.07d | 129.39 ± 0.01d | 7.89 ± 0.07b | 20.75 ± 0.07d | 129.39 ± 0.01d |
| Peel           | Fresh | 68.17 ± 0.03a | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d |
| Seed           | Fresh | 68.17 ± 0.03a | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d | 7.38 ± 0.09b | 19.56 ± 0.09d | 120.95 ± 0.09d |

* Standard deviation; **Values in each row with different letters are significantly different (p < 0.05)
Table 2  Fatty acid compositions of different parts of “Pinkerton” avocado fruit.

|            | Fresh   | Air-drying | Microwave drying | Oven drying   | Fresh | Air-drying | Microwave drying | Oven drying | Fresh   | Air-drying | Microwave drying | Oven drying | Fresh   | Air-drying | Microwave drying | Oven drying |
|------------|---------|------------|-----------------|--------------|-------|------------|-----------------|-------------|-------|------------|-----------------|-------------|-------|------------|-----------------|-------------|
| Pulp       |         |            |                 |              |       |            |                 |              |       |            |                 |              |       |            |                 |              |
| Myristic   | 17.59 ± 0.05c | 20.46 ± 0.20b** | 17.07 ± 0.10d | 20.60 ± 0.11a | 15.59 ± 0.10c | 14.84 ± 0.20d | 15.81 ± 0.35a | 15.15 ± 0.16c | 18.04 ± 0.37d | 18.71 ± 0.24c | 18.93 ± 0.21b | 36.16 ± 0.34a | 1.20 ± 0.02a | 0.49 ± 0.03d | 1.70 ± 0.00a |
| Palmitic   | 0.00b ± 0.03a | 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 | 3.28 ± 0.00d | 3.69 ± 0.00c | 27.28 ± 0.05c | 34.25 ± 0.23b | 23.34 ± 0.10d |
| 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 | 34.25 ± 0.23b | 23.34 ± 0.10d |
| 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 | 31.64 ± 0.12a | 22.95 ± 0.02c |
| Linolenic  | 0.07 ± 0.00c | 0.09 ± 0.00b | 0.10 ± 0.00a | 0.12 ± 0.02a | 0.12 ± 0.00a | 0.12 ± 0.01a | 0.62 ± 0.00d | 0.67 ± 0.01c | 0.73 ± 0.01b | 1.12 ± 0.01a |
| Behenic    | 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 | 5.23 ± 0.07a | 3.97 ± 0.02b | 2.98 ± 0.02d |
| Erucic     | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.10 ± 0.00a | 0.11 ± 0.00b | 0.10 ± 0.00b | 0.11 ± 0.00b | 0.09 ± 0.00b | 0.08 ± 0.00b | 0.10 ± 0.00b | 0.09 ± 0.00b |
| Anchidonic | 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 ± 0.00bc | 0.70 ± 0.03b | 0.60 ± 0.05c | 1.02 ± 0.02a |
| Seed       |         |            |                 |              |       |            |                 |              |       |            |                 |              |       |            |                 |              |
| Myristic   | 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 | 20.22 ± 0.36b | 19.44 ± 0.03c |
| Palmitic   | 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 ± 0.00b | 3.70 ± 0.16b | 9.63 ± 0.00a | 2.50 ± 0.02d | 3.08 ± 0.02c |
| Oleic      | 58.20 ± 0.38d | 62.35 ± 0.31b | 60.99 ± 0.05c | 62.92 ± 0.13a | 56.40 ± 0.17b | 56.73 ± 0.05b | 57.73 ± 0.02a | 55.30 ± 0.06c | 51.30 ± 0.18a | 26.66 ± 0.09d | 35.05 ± 0.25c | 36.41 ± 0.03b |
| Linoleic   | 13.33 ± 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 | 31.16 ± 0.12b | 32.14 ± 0.06a |
| 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 | 4.21 ± 0.01b | 3.07 ± 0.00c |
| Behenic    | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.11 ± 0.00a | 0.11 ± 0.00a | 0.09 ± 0.00b | 0.11 ± 0.00a | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.09 ± 0.00b |
| Erucic     | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.11 ± 0.00a | 0.11 ± 0.00a | 0.09 ± 0.00b | 0.11 ± 0.00a | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.09 ± 0.00b | 0.09 ± 0.00b |
| Anchidonic | 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 ± 0.00bc | 0.70 ± 0.03b | 0.60 ± 0.05c | 1.02 ± 0.02a |

*mean ± standard deviation; **Values in each row with different letters are significantly different (p < 0.05); ***nonidentified
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 $60^\circ C$ influenced positively the fatty acid composition 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$^{8,13,28,29}$ 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 $85^\circ C$ 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 content 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.$^{55}$ 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).

| Process                | Maturity Unripe | Maturity Ripe | Process                | Maturity Unripe | Maturity Ripe |
|------------------------|----------------|---------------|------------------------|----------------|---------------|
|                        | Fresh          | Air-drying    | Microwave drying       | Oven drying    | Fresh         | Air-drying    | Microwave drying | Oven drying    |               |
| Gallic Acid            | 37.92 ± 0.13*  | 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           | 19.51 ± 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 |               |
| p-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  |               |
| trans-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 |               |
| trans-Cinnamic Acid    | 4.10 ± 0.09e   | 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 | Process     | Fresh   | Unripe | Microwave drying | Oven drying | Ripe     | Microwave drying | Oven drying |
|----------|-------------|---------|--------|------------------|-------------|----------|------------------|-------------|
|          |             |         |        |                  |             |          |                  |             |
|          | Gallic Acid | 35.82 ± 0.72b | 30.13 ± 0.61c | 26.47 ± 0.44d | 36.45 ± 0.88a | 30.64 ± 0.03d | 53.90 ± 0.07a | 32.72 ± 0.98c | 46.05 ± 0.09b |
|          | 3,4-Dihydroxybenzoic Acid | 31.74 ± 0.43d** | 45.88 ± 0.82b | 63.31 ± 0.24a | 40.35 ± 0.60c | 73.78 ± 0.15a | 66.59 ± 2.23b | 51.59 ± 1.07c | 50.89 ± 1.09d |
|          | (+)-Catechin | 203.04 ± 1.34b | 208.87 ± 1.29a | 36.71 ± 0.04d | 99.82 ± 2.73c | 111.70 ± 5.48c | 79.60 ± 1.13d | 212.93 ± 4.81a | 118.01 ± 2.77b |
|          | 1,2-Dihydroxybenzene | 101.71 ± 2.72c | 267.88 ± 2.21b | 309.97 ± 3.16a | 92.09 ± 3.74d | 77.25 ± 0.43d | 248.91 ± 2.23b | 51.59 ± 1.07c | 107.88 ± 3.92c |
|          | Syringic Acid | 41.21 ± 0.56d | 74.14 ± 0.00b | 101.45 ± 5.73a | 49.03 ± 0.55c | 47.68 ± 0.47a | 45.76 ± 0.31b | 40.47 ± 0.71c | 29.42 ± 0.10d |
|          | Caffeic Acid | 9.98 ± 0.49d | 277.83 ± 2.57a | 74.60 ± 0.12b | 17.23 ± 0.13c | 10.59 ± 0.94d | 13.94 ± 0.45c | 49.49 ± 0.87a | 25.89 ± 0.26b |
|          | Rutin trihydrate | 5.68 ± 0.04c | 4.60 ± 0.44d | 167.18 ± 5.52a | 71.59 ± 0.41b | 22.67 ± 0.50c | 124.02 ± 0.99a | 42.81 ± 0.81b | 22.10 ± 0.13d |
|          | p-Coumaric Acid | 2.38 ± 0.83d | 22.89 ± 0.13a | 12.79 ± 0.01b | 8.66 ± 0.61c | 3.37 ± 0.90d | 11.26 ± 0.06a | 7.60 ± 0.22c | 8.83 ± 0.21b |
|          | trans-Ferulic Acid | 5.40 ± 0.36d | 154.09 ± 2.64b | 368.98 ± 3.47a | 82.00 ± 0.50c | 16.25 ± 0.08d | 48.27 ± 1.00c | 49.48 ± 0.13b | 85.48 ± 0.77a |
|          | Apigenin 7 glucoside | 27.85 ± 0.68c | 21.24 ± 0.20d | 110.47 ± 2.05a | 30.89 ± 0.23b | 30.24 ± 0.53c | 69.92 ± 0.17a | 19.44 ± 0.65d | 34.53 ± 0.25b |
|          | Resveratrol | 8.04 ± 0.33d | 28.37 ± 0.76b | 133.91 ± 2.59a | 18.18 ± 0.82c | 3.86 ± 0.80d | 24.70 ± 0.33b | 36.63 ± 0.00a | 13.89 ± 0.57c |
|          | Quercetin | 36.25 ± 0.24d | 133.05 ± 1.77b | 1174.08 ± 4.98a | 40.97 ± 0.57c | 4.77 ± 0.90d | 109.00 ± 1.70b | 77.18 ± 2.63a | 64.82 ± 0.22c |
|          | trans-Cinnamic Acid | 14.99 ± 0.37c | 22.28 ± 0.15b | 394.35 ± 1.70a | 5.50 ± 0.82d | 3.76 ± 0.66c | 10.49 ± 0.48b | 237.42 ± 4.91a | 3.54 ± 0.36d |
|          | Naringenin | 18.86 ± 0.97b | 18.90 ± 0.00b | 65.89 ± 0.93a | 5.85 ± 0.78c | 9.06 ± 0.97d | 14.78 ± 0.28b | 104.53 ± 2.64a | 9.32 ± 0.58c |
|          | Kaempferol | 46.01 ± 0.54b | 46.00 ± 0.00b | 238.66 ± 1.65a | 19.83 ± 0.83c | 10.01 ± 0.23d | 28.11 ± 0.71b | 92.74 ± 0.99a | 17.72 ± 0.05c |
|          | Isorhamnetin | 31.09 ± 0.09c | 36.88 ± 0.00b | 83.53 ± 0.15a | 10.09 ± 0.51d | 7.54 ± 0.14d | 24.33 ± 0.18b | 260.53 ± 1.74a | 11.21 ± 0.08c |

*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 | Oven drying |
|                   |                                 |                                 |                   |             |                                 |                                 |                   |             |
| Gallic 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     | 116.78 ± 0.67a |
| 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     | 61.28 ± 0.38b |
| (+)-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     | 63.80 ± 0.57b |
| 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    | 154.03 ± 1.23a |
| 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     | 9.15 ± 1.18a  |
| 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     | 81.70 ± 0.72a |
| 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     | 79.91 ± 1.91a |
| p-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      | 16.68 ± 0.42a |
| trans-Fenilic 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      | 25.08 ± 0.47b |
| 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     | 37.52 ± 0.08b |
| 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     | 10.69 ± 0.57c |
| 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    | 59.84 ± 0.39c |
| trans-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     | 6.27 ± 0.52d  |
| 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     | 10.10 ± 0.31c |
| Kaempferol        | 25.95 ± 0.00c                   | 247.93 ± 0.00a                  | 33.40 ± 0.06b     | 11.77 ± 0.91d | 29.48 ± 0.00b                   | 98.34 ± 0.00a                   | 15.91 ± 0.00d     | 18.65 ± 0.78c |
| 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     | 11.15 ± 0.89d |

*mean ± standard deviation; **Values in each row with different letters are significantly different (p < 0.05); ***nonidentified
4 Conclusion
This study represents 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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