Effect of Maturing Stages on Bioactive Properties, Fatty Acid Compositions, and Phenolic Compounds of Peanut (Arachis hypogaea L.) Kernels Harvested at Different Harvest Times

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Abstract: The present study investigated the effects of harvesting time on the physicochemical properties, antioxidant activity, fatty acid composition, and phenolic compounds of peanut kernels. The moisture content (air-dried basis) of peanut kernels was determined between 4.47% (September 15, 2019) and 7.93% (October 6, 2019), whereas the oil contents changed from 45.95% (October 6, 2019) to 49.25% (September 22, 2019). The total carotenoid, chlorophyll, and phenolic contents were low throughout the harvest, showing differences depending on the harvest time. Total phenolic content changed from 0.28 mg GAE/L (September 29, 2019) to 0.43 mg GAE/L (September 8, 2019), whereas the antioxidant activity varied from 4.42% (August 25, 2019) to 4.70% (September 1, 2019). The dominant fatty acids were palmitic, oleic, and linoleic acids, depending on the harvest time, followed by stearic, behenic, arachidic, and linolenic acids. The (+)-catechin content ranged from 2.17 mg/L (September 8, 2019) to 5.15 mg/L (September 1, 2019), whereas 1,2-dihydroxybenzene content changed between 2.67 mg/L (October 6, 2019) and 5.85 mg/L (September 29, 2019). The phenolic compound content fluctuated depending on the harvest time. The results showed that peanut kernel and oil had distinctive phenolic profiles and fatty acid contents. The findings of the present study may provide information for the best time to harvest peanut to achieve its maximum health benefits.

Key words: peanut kernels, harvest time, maturity stages, functional properties

1 Introduction

Peanut (Arachis hypogaea L.) is an important annual oilseed plant belonging to the Leguminosae family, which is grown in both tropical and sub-tropical countries. Peanut contains a considerable amount of oil, ranging from 44% to 56% on dry weight basis. Peanuts rank fourth in terms of production amount oilseed plant sources of vegetable oil. The total fat composition of peanut kernel is approximately 10.44% and 33.51% for saturated and unsaturated fatty acids, respectively. Oleic, linoleic, and palmitic are the most abundant fatty acids in peanut kernel oil. According to Jonnala et al., the health benefits of peanut consumption are related to the bioactive components in the oil fraction. Peanut is a rich source of polyphenolic antioxidant compounds, including resveratrol, tocopherol, phytoestrol, catechin, epicatechin, and quercetin, which were found to reduce degenerative nerve disease, Alzheimer’s disease, hypertension, and cardiovascular disorders. Polyphenols are secondary plant metabolites that synergistically act with other phytochemicals and modify total antioxidant capacity, thereby reducing oxidative stress, as well as the risk for inflammatory and chronic diseases. Peanut oil is rich in oleic and linoleic acids, with ratio of 1.3–1.4, which represent approximately 75% of the total fat content. Peanut consumption is correlated with preventing coronary heart disease, which is attributed to its high oleic and linoleic acid contents, among other bioactive components.

The peanut kernel is manufactured into peanut butter, oil, and other products. China, India, Nigeria, and USA...
are the biggest peanut-producing countries. The total production of these countries constitutes approximately 69% of worldwide peanut production\(^1\)\(^{19}\). Peanut seeds are directly used or processed, as cookies, biscuits, confectionery, chocolate products, pistachio-added ice cream, peanut butter, and ready-made breakfast packages\(^2\). About 53% of peanut production in the world is allocated for cooking oil manufacture, 32% for peanut butter and cookies, and 15% for animal feed\(^2\). Moreover, oil composition is affected by the production location, cultivar, and climate (soil humidity and temperature)\(^5\)\(^\text{-}^\text{23}\). Variations in climatic conditions affect the oleic/linoleic acid ratio\(^5\). The aim of present study was to investigate the effects of harvest time on moisture, oil, carotenoid, chlorophyll, total phenol, and total flavonoid contents, antioxidant activity, fatty acid composition, and phenolic components of peanut \((Arachis hypogaea L.)\) kernels harvested at different periods were investigated.

2 Materials and Methods

2.1 Materials

The peanut was obtained from the field cultivated on May 15, 2019 in Osmaniye City, Turkey. Harvesting dates were scheduled on August 25, September 1, September 8, September 15, September 22, September 29, and finally on October 6, at 1-week intervals. Peanut samples were air-dried after harvesting.

2.2 Methods

2.2.1 Moisture content

The moisture content of the samples were measured at 105°C in an oven (Nüve FN055 Ankara, Turkey) until reaching a constant weight.

2.2.2 Oil content

The dried peanut material was extracted using petroleum ether in a Soxhlet apparatus for 6 h at 50°C to determine the oil content (Harwood, 1984). After drying the extract in a rotary evaporator, oil content was determined as the difference in weight between the dried peanut sample before and after extraction\(^2\).\(^3\)

2.2.3 Fatty acid composition

The method of ISO-5509\(^2\) was used for fatty acid methylation. Methyl esters were analyzed through gas chromatography–flame ionization detection (GC–FID) using a Shimadzu GC 2010 chromatograph equipped with a flame ionization detector (FID) on a capillary column coated with Teknokroma TR CN100, P/N TR 882162 fused silica column (60 mm length; 0.25 mm id; 0.2 mm film thickness). The temperature of the injection block and detector was 260°C. Nitrogen was used as the mobile phase, with 1.51 mL/min flow rate. The total flow rate was 80 mL/min, and split rate was also 1/40 mL/min. Column temperature was programmed at 120°C for 5 min and increased to 240°C at 4°C/min and held for 25 min at 240°C.

2.2.4 Extraction procedure

The samples were extracted according to the method previously described by Iacopini et al.\(^24\), with slight modifications. The ground samples \((5 g)\) were added to 15 mL of methanol. The mixture was kept in an ultrasonic water-bath for 1 h, followed by centrifugation at 6,000 rpm for 10 min, and then the supernatant was filtered using a 0.45-μm membrane. Then, \((n\)-hexane \((15 mL)\) was added and mixed using a vortex apparatus. The methanol and \((n\)-hexane layer were separated using separating funnel. This step was carried out twice with 10 mL of \((n\)-hexane. In each step, the methanol phases were collected and then evaporated at 40°C. The dried extracts were dissolved in 25 mL of methanol.

2.2.5 Chlorophyll analysis

The chlorophyll content of the peanut oil samples were measured at 670 nm using a spectrophotometer\(^2\).

\[
\text{Chlorophyll (mg/kg)} = A \times \frac{106}{613} \times 100 \times d
\]

where, \(A\) is the absorbance, and \(d\) is the bathtub thickness.

2.2.6 Total phenolic content

The total phenolic content of the extracts were determined using Folin–Ciocalteu (FC) reagent as previously described by Yoo et al.\(^26\), with slight modifications. For the extraction, 20 mL of methanol water \((80:20 \text{ v/v})\) was added to approximately 2 g of the sample and shaken for 3 h at room temperature in a shaking water bath. Then, 20 mL of \((n\)-hexane was added to the remaining extract from the filtered samples, and after phase separation was achieved in the separation funnel, the underlying methanol phase was transferred into the tubes and used for further analysis. FC reagent \((1 \text{ mL})\) was added and mixed for 5 min after 10 mL of 7.5% \(Na_2CO_3\) was added. The solution in the tubes was mixed again, and the final volume was adjusted to 25 mL using deionized water. At the end of 1 h, the total phenolic content was determined at a wavelength of 750 nm using a spectrophotometer. The results were given as mg gallic acid equivalent (GAE)/L of fresh weight.

2.2.7 Total flavonoid content

Total flavonoid content was determined according to the method previously described by Dewanto et al.\(^27\). Methanol extracts were appropriately diluted with distilled water. Then, 0.3 mL of 5% \(NaNO_2\) solution was added to each test tube. After 5 min, 0.3 mL of 10% \(AlCl_3\) solution was added, and after 6 min, 2 mL of \(1.0 \text{ M NaOH}\) was added. At the end of this period, the total volume was adjusted to 5 mL using water, and the solutions in the test tubes were thoroughly mixed. The absorbance of the pink solution obtained was measured at 510 nm. The calibration curve was prepared using catechol as a standard. Flavonoid content was expressed as mg catechol equivalents (CE)/per dry weight (mg CE/L DW).
2.2.8 Antioxidant activity

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging ability of the peanut kernel extracts was measured according to the methods described by Lee et al.\textsuperscript{30}. The mixture was vigorously shaken and allowed to stand at room temperature for 30 min. After which, absorbance was recorded at 517 nm using a spectrophotometer. DPPH radical-scavenging ability was calculated using the following equation:

\[ \text{DPPH-scavenging effect (\%)} = \left( \frac{A_0 - A_1}{A_0} \right) \times 100 \]

where, \( A_0 \) is the absorbance of the control at 30 min, and \( A_1 \) is the absorbance of the sample at 30 min. All samples were analyzed in triplicate.

2.2.9 Determination of phenolic compounds

HPLC analysis of phenolic compounds were performed using a Shimadzu HPLC equipped with a PDA detector and an Inertsil ODS-3 (5 µm; 4.6 × 250 mm) column. The mobile phase was a mixture of 0.05% acetic acid in water (A) and acetonitrile (B). The flow rate of the mobile phase was 1 mL/min at 30°C, and the injection volume was 20 µL. The peaks were recorded at 280 and 330 nm using a PDA detector. The gradient program was as follows: 0–0.10 min 8% B; 0.10–2 min 30% B; 2–27 min 30% B; 27–37 min 56% B; 37–37.10 min 8% B; and 37.10–45 min 8% B. The total running time per sample was 60 min.

2.2.10 Carotenoid content

Extraction of carotenoids was performed according to the method previously described by Silva da Rocha et al.\textsuperscript{29}. The ground sample (2 g) was added to 25 mL of acetone. The mixture was shaken by vortex for 10 min and filtered using filter paper (Whatman No. 1) and passed through a separation funnel. The filtrate was fractionated with 20 mL of petroleum ether and washed with 100 mL of distilled water to remove the acetone. These steps were repeated twice. Whatman No. 1 covered with anhydrous sodium sulfate (5 g) for removing residual water was used to filter the petroleum ether layer. The volume of the extracts was adjusted to 25 mL using petroleum ether. Then, absorbance was measured at 450 nm.

2.3 Statistical analyses

A complete randomized split-plot block design was used, and analysis of variance (ANOVA) one way was performed using the JMP software version 9.0 (SAS Inst. Inc., Cary, N.C., USA). All analyses were done in triplicate, and the results are presented as mean ± standard deviation (MSTAT-C) of independent harvest times\textsuperscript{30}.

3 Results and Discussion

3.1 Effects of harvest time on the physicochemical properties, bioactive compound content, and antioxidant activity of peanut kernels

Table 1 presents the physicochemical properties, bioactive compound content, and antioxidant activity of peanut kernels harvested at 1-week intervals starting from August 25 to October 6, 2019. Results showed several variations, depending on the harvest time. Statistically significant differences (\( p < 0.05 \)) were observed among the moisture, oil, total carotenoid, chlorophyll, total phenol, and total flavonoid contents, as well as antioxidant activity of peanut kernels harvested at different times. The moisture content (air-dried basis) of peanut kernels ranged from 4.47% (September 15, 2019) to 7.93% (September 29, 2019), whereas the oil content of peanut kernels ranged from 45.95% (October 6, 2019) to 49.25% (September 22, 2019). With the progress of the harvest time, a certain decrease was observed in the moisture content of peanut kernels; however, a partial increase was observed in the last harvest time. With the progress of the harvest time until September 29, 2019, the oil content of peanut kernels was increased. Rosales-Martínez et al.\textsuperscript{31} reported that raw and roasted peanut kernels contained 2.91% and 2.1% moisture, and 47.14% and 51.87% lipids, respectively. The moisture and oil contents of peanut cultivars grown in Tunisia ranged from 7.3% to 8.48% to 45.32% to 48.53%, respectively\textsuperscript{7}. Mora-Escobedo et al.\textsuperscript{32} reported that the oil content of eight peanut varieties grown in Mexico ranged from 37.9% to 56.3%. Chukwumah et al.\textsuperscript{32} reported that peanut kernels

| Harvest times | Moisture (%) | Oil (%) | Total carotenoid (mg/kg) | Chlorophyll (mg/kg) | Total phenolic content (mg/L) | Total flavonoid content (mg/L) | Antioxidant activity (%) |
|---------------|--------------|---------|--------------------------|--------------------|-----------------------------|-------------------------------|--------------------------|
| August 25     | 5.12 ± 0.01c | 47.10 ± 0.50d | 0.77 ± 0.00e              | 0.22 ± 0.00c       | 0.35 ± 0.00b                | 8.76 ± 0.00b                 | 4.42 ± 0.03c             |
| September 1   | 4.76 ± 0.02**| 48.20 ± 0.20c | 0.69 ± 0.00f              | 0.26 ± 0.00d       | 0.31 ± 0.00d                | 8.44 ± 0.00c                 | 4.70 ± 0.00a             |
| September 8   | 4.50 ± 0.30f | 46.95 ± 1.15e | 0.88 ± 0.00c              | 0.42 ± 0.00b       | 0.43 ± 0.00a                | 7.79 ± 0.00e                 | 4.67 ± 0.01b             |
| September 15  | 4.47 ± 0.11fg| 49.00 ± 0.30b | 0.93 ± 0.00d              | 0.15 ± 0.00f       | 0.31 ± 0.00d                | 9.09 ± 0.00a                 | 4.63 ± 0.01c             |
| September 22  | 4.57 ± 0.20e | 49.25 ± 0.35a | 0.51 ± 0.00g              | 0.14 ± 0.00g       | 0.31 ± 0.00d                | 8.11 ± 0.00d                 | 4.66 ± 0.01b             |
| September 29  | 5.32 ± 0.02b | 46.95 ± 0.35e | 0.80 ± 0.00d              | 0.32 ± 0.00c       | 0.28 ± 0.00e                | 7.79 ± 0.00e                 | 4.57 ± 0.01d             |
| October 6     | 7.93 ± 0.21a | 45.95 ± 0.15f | 1.34 ± 0.00a              | 0.73 ± 0.00a       | 0.36 ± 0.00bb               | 8.76 ± 0.00b                 | 4.66 ± 0.00b             |

*standard deviation; **values within each column followed by different letters are significantly different at \( p < 0.05 \).

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had a high lipid content (approximately 46%) rich in mono¬
unsaturated fatty acids. Raw, oven-roasted, and micro¬
wave-roasted peanut kernel oil contents were 27.13%, 41.79%, and 26.12%[33]. The amount of oil contained in oil¬
seeds may vary, depending on the climatic conditions, agri¬
cultural techniques, and especially, seed characteristics.
The total carotenoid content of kernels ranged from 0.51
mg/kg (September 22, 2019) to 1.34 mg/kg (October 6, 2019), whereas the chlorophyll content of peanut kernels
ranged from 0.14 mg/kg (September 22, 2019) to 0.73 mg/
kg (October 6). Generally, the carotenoid and chlorophyll
contents exhibited an increasing trend throughout the
harvest time. The total phenolic content of peanut kernels
ranged from 0.28 mg GAE/L (September 29, 2019) to 0.43
mg GAE/L (September 8, 2019). However, total flavonoid
content of the peanut kernel samples ranged from 7.79 mg/
L (September 8 and 29, 2019) to 9.09 mg/L (September 15,
2019). Chukwumah et al.[34] reported that the total phenolic
and flavonoid contents of raw peanut kernels were 25.71
mg catechin equivalent (CE)/g and 0.01 mg GAE/g, re¬
spectively. Although the carotenoid, chlorophyll, and total pha¬
nolic contents of peanut kernel samples were found at low
levels throughout the harvest time, they showed partial
differences, depending on the harvest time. The antioxi¬
dant activity of the peanut oil extracts ranged from 4.42%
(first harvest time on August 25, 2019) to 4.70% (Sep¬
tember 1, 2019). Additionally, it was observed that the antioxi¬
dant activity of mature peanut kernels was increased with
the progress of the harvest time. There were positive rela¬
tions among the total phenol content, flavonoid content,
and antioxidant activity of peanut oil extracts. The total
phenolic content and antioxidant activity of Tunisian peanut
cultivars ranged from 1.0 and 2.1 mg GAE/g DW to
550 and 1550 µg/mL, respectively[4]. The total phenol
content and antioxidant activity of raw peanut kernels were
determined as 370 mg GAE/100 g DW and 6 µmol
Trolox equivalent/g DW, respectively[35]. Gimeno et al.[31]
reported that olive phenol content decreased during rip¬
ening. When results were compared with the previous
studies, partial differences were observed. These differ¬
ences may be attributed to variety, the place of origin, cli¬
matic factors, maturation, cultivation factors; such as irri¬
gation, fertilization, harvest time, and extraction; and
quantification methods used.

3.2 Effects of harvest time on the fatty acid content of
peanut kernels
Table 2 shows the fatty acid composition of oil extracted
from peanut kernels harvested at 1-week intervals (August
25–October 6, 2019). The dominant fatty acids were pal¬
mitic, oleic, and linoleic acids, depending on the harvest
time, followed by stearic, behenic, arachidic, and linolenic
acids. The palmitic acid content of peanut kernel oils
ranged from 7.58% (first harvest time on August 25, 2019)
to 9.16% (September 15, 2019), whereas the stearic acid
content of the oil samples was ranged from 2.76% (Sep¬
tember 1, 2019) to 3.21% (September 22, 2019). While de¬
pending on the harvest time, the oleic acid content of
peanut oil ranged from 58.02% (September 15, 2019) to
65.20% (September 22, 2019), and linoleic acid content
ranged from 18.60% (September 22, 2019) to 25.48% (Sep¬
tember 29, 2019). Additionally, the arachidic acid content
of peanut kernel oils ranged from 1.30% (October 6, 2019)
to 1.43% (September 22, 2019), whereas the behenic acid
content ranged from 2.37% (October 6, 2019) to 3.17%
(September 1, 2019). Other fatty acids identified in peanut
kernel oils obtained at different harvest times were found
at low levels ( < 0.08%). Myristic acid was only identified in
peanut kernel oil harvested on September 29, 2019. Statis¬
tically significant differences were observed among the
fatty acid composition of peanut kernel oils, depending on
the harvest times ( p < 0.05). With the advancement of
harvest time, stearic acid, oleic acid, and linoleic acid were
increased until a certain harvest time, whereas polysaturated
fatty acids, such as linolenic acid, were decreased.

Their amounts were increased until a certain harvest time,

Table 2 Fatty acid composition of peanut kernel oils harvested at different maturity stages (%).

| Fatty acids | August 25 | September 1 | September 8 | September 15 | September 22 | September 29 | October 6 |
|-------------|-----------|-------------|-------------|--------------|--------------|--------------|-----------|
| Myristic | – * | – | – | – | – | 0.03 ± 0.00 | – |
| Palmitic | 7.58 ± 0.27**g | 8.21 ± 0.01d | 8.38 ± 0.04b | 9.16 ± 0.04a | 7.95 ± 0.04f | 8.27 ± 0.01c | 8.14 ± 0.00c |
| Stearic | 2.80 ± 0.02*** | 2.76 ± 0.00c | 2.81 ± 0.00d | 2.85 ± 0.02c | 3.21 ± 0.01a | 2.97 ± 0.00b | 2.82 ± 0.02cd |
| Oleic | 62.08 ± 0.22b | 61.21 ± 0.02c | 62.27 ± 0.02b | 58.02 ± 0.10d | 65.20 ± 0.05a | 58.12 ± 0.01d | 61.81 ± 0.23c |
| Linoleic | 21.85 ± 0.05e | 21.91 ± 0.00d | 21.42 ± 0.01f | 24.87 ± 0.14b | 18.60 ± 0.01g | 25.48 ± 0.03a | 22.46 ± 0.13c |
| Arachidic | 1.37 ± 0.01c | 1.41 ± 0.00ab | 1.32 ± 0.00d | 1.32 ± 0.02d | 1.43 ± 0.01a | 1.37 ± 0.01c | 1.30 ± 0.03e |
| Linolenic | 1.15 ± 0.01a | 1.10 ± 0.00b | 1.03 ± 0.01c | 0.96 ± 0.01d | 0.89 ± 0.00f | 0.93 ± 0.00e | 0.95 ± 0.02d |
| Behenic | 2.65 ± 0.03b | 3.17 ± 0.03a | 2.58 ± 0.01c | 2.52 ± 0.04e | 2.45 ± 0.01f | 2.54 ± 0.03d | 2.37 ± 0.08g |
| Erucic | 0.06 ± 0.00a | 0.06 ± 0.00a | 0.06 ± 0.00a | 0.05 ± 0.00b | 0.05 ± 0.00b | 0.05 ± 0.00b | 0.05 ± 0.00b |
| Arachidonic | 0.05 ± 0.00b | 0.08 ± 0.00a | 0.05 ± 0.00b | 0.08 ± 0.00a | 0.05 ± 0.00b | 0.03 ± 0.01c | 0.05 ± 0.00b |

*nonidentified; **standard deviation; ***values within each row followed by different letters are significantly different at p < 0.05.
and then they were decreased. The major fatty acids found in the peanut oil samples were palmitic (11.9–13.2%), oleic (45.2–53.8%), and linoleic (25.1–29.2%) acids. Sebei et al. reported that peanut kernels contained 11.89–17.45% palmitic, 1.93–3.43% palmtoleic, 4.01–4.59% stearic, 27.16–32.63% oleic, 39.65–41.85% linoleic, 2.22–2.73% erucic, and 2.04–2.82% lignoceric acid. These results were similar to those obtained in different studies. Rao et al. reported that oleic and linoleic acid contents of flax seed at different development stages increased and then became steady until full maturation. Raw (control), oven-, and microwave-roasted peanut kernel oils contained 8.51%, 12.34%, and 8.78% palmitic; 2.1%, 2.75%, and 2.31% stearic; 54.62%, 62.64%, and 56.33% oleic; 28.64%, 14.58%, and 27.84% linoleic; and 2.22%, 3.27%, and 2.21% linoleic acids. The fatty acid composition of the oil from peanut kernels exhibited greater variation at different harvesting dates. Although changes were clearly observed between total saturated and unsaturated acids, these differences were quite pronounced in palmitic, stearic, oleic, and linoleic acids. Results showed several differences, compared with the results of previous studies. These differences can be probably due to agricultural factors, genetic structure, locations, climatic factors, maturation time, several analytical conditions, and solvent types.

3.3 Effect of harvest time on the phenolic compounds of peanut kernels

Table 3 illustrates the amounts of phenolic compounds of peanut kernels harvested at a 1-week interval. Depending on the harvest time, the amount of phenolic compounds of peanut kernels exhibited partial variations. Statistically significant differences were observed among the amount of phenolic compounds of peanut kernels harvested at different maturity stages (p < 0.05). The key phenolic compounds of peanut kernels were gallic acid, 3,4-dihydroxybenzoic acid, (±)-catechin, and 1,2-dihydroxybenzene. The gallic acid content of peanut kernels ranged from 1.36 mg/L (September 8, 2019) to 2.85 mg/L (October 6, 2019), whereas the 3,4-dihydroxybenzoic acid content of peanut samples ranged from 1.73 mg/L (August 25, 2019) to 3.56 mg/L (October 6, 2019). Additionally, the (±)-catechin content of the peanut kernel samples changed between 2.17 mg/L (September 8, 2019) and 5.15 mg/L (September 1, 2019), whereas the 1,2-dihydroxybenzene content of peanut kernels ranged from 2.67 mg/L (October 6, 2019) to 5.85 mg/L (September 29, 2019). However, while the syringic acid content of kernels was found between 0.65 mg/L (October 6, 2019) and 1.35 mg/L (September 1, 2019), the caffeic acid content of peanut kernel samples ranged from 0.49 mg/L (September 15, 2019) to 1.11 mg/L (September 22, 2019). Also, the rutin-trihydrate content of peanut kernels ranged from 0.42 mg/L (September 15, 2019) to 1.06 mg/L (September 22, 2019), whereas the trans-ferulic acid content ranged from 0.12 mg/L (September 15, 2019) to 0.73 mg/L (September 22, 2019). Additionally, the quercetin content of peanut kernels ranged from 0.20 mg/L (October 6, 2019) to 0.52 mg/L (August 25, 2019), and the isorhamnetin content of kernel samples ranged from 0.21 mg/L (October 6, 2019) to 0.46 mg/L (August 25, 2019). In a previous study, the predominant phenolic compounds pre-

| Phenolic compounds | August 25 | September 1 | September 8 | September 15 | September 22 | September 29 | October 6 |
|--------------------|-----------|-------------|-------------|--------------|--------------|--------------|-----------|
| Gallic acid        | 2.41 ± 0.94d | 2.22 ± 0.43c | 1.36 ± 1.45g | 2.07 ± 1.06f | 2.53 ± 0.78c | 2.59 ± 0.25b | 2.85 ± 0.63a |
| 3,4-Dihydroxybenzoic acid | 1.73 ± 1.03g** | 2.92 ± 0.11c | 2.13 ± 2.11e | 1.84 ± 0.72f | 2.25 ± 0.68d | 3.02 ± 0.46b | 3.56 ± 0.29a |
| (±)-Catechin       | 3.17 ± 1.63f | 5.15 ± 0.42a | 2.17 ± 1.53g | 3.67 ± 1.08d | 4.57 ± 1.49c | 5.06 ± 2.80b | 3.57 ± 0.60a |
| 1,2-Dihydroxybenzene | 3.18 ± 2.96d | 4.85 ± 0.87c | 2.95 ± 2.42f | 3.05 ± 1.46e | 4.99 ± 1.92b | 5.85 ± 0.53a | 2.67 ± 1.05g |
| Syringic acid      | 0.99 ± 0.55c | 1.35 ± 0.44a | 0.67 ± 0.47c | 0.85 ± 0.32d | 1.07 ± 0.33b | 1.34 ± 0.15a | 0.65 ± 0.28f |
| Caffeic acid       | 0.71 ± 0.45e | 1.05 ± 0.16b | 0.72 ± 0.45e | 0.49 ± 0.18f | 1.11 ± 0.29a | 1.00 ± 0.12c | 0.78 ± 0.48d |
| Rutin trihydrate   | 0.52 ± 0.35f | 0.77 ± 0.20b | 0.65 ± 0.34d | 0.42 ± 0.20g | 1.06 ± 0.59a | 0.67 ± 0.14c | 0.63 ± 0.15e |
| p-Coumaric acid    | 0.05 ± 0.02e | 0.14 ± 0.01a | 0.06 ± 0.02d | 0.06 ± 0.04d | 0.08 ± 0.06c | 0.09 ± 0.03b | 0.06 ± 0.00d |
| trans-Ferulic acid | 0.23 ± 0.10c | 0.67 ± 0.18b | 0.20 ± 0.15f | 0.12 ± 0.02g | 0.73 ± 0.37a | 0.60 ± 0.42c | 0.27 ± 0.15d |
| Apigenin-7-glucoside | 0.19 ± 0.04f | 0.43 ± 0.16a | 0.45 ± 0.21a | 0.22 ± 0.04e | 0.40 ± 0.11c | 0.27 ± 0.16d | 0.27 ± 0.20d |
| Resveratrol        | 0.10 ± 0.07b | 0.01 ± 0.00e | 0.04 ± 0.02d | 0.05 ± 0.02e | 0.13 ± 0.07a | 0.04 ± 0.01d | 0.04 ± 0.01d |
| Quercetin          | 0.52 ± 0.08a | 0.32 ± 0.19a | 0.22 ± 0.22f | 0.26 ± 0.04d | 0.42 ± 0.32b | 0.31 ± 0.20d | 0.20 ± 0.05g |
| trans-Cinnamic acid | 0.05 ± 0.02e | 0.11 ± 0.04a | 0.03 ± 0.00f | 0.08 ± 0.04c | 0.08 ± 0.06c | 0.07 ± 0.05d | 0.09 ± 0.09b |
| Naringenin         | 0.14 ± 0.04a | 0.13 ± 0.02b | 0.08 ± 0.04d | 0.09 ± 0.02c | 0.06 ± 0.02e | 0.09 ± 0.04c | 0.09 ± 0.04c |
| Kaempferol         | –***       | –           | 0.11 ± 0.00  | –             | –             | –           | –         |
| Isoflavonoid       | 0.46 ± 0.19a | 0.25 ± 0.06d | 0.28 ± 0.24c | 0.26 ± 0.02d | 0.26 ± 0.05d | 0.39 ± 0.16b | 0.21 ± 0.06f |

*standard deviation; **values within each row followed by different letters are significantly different at p < 0.05; ***nonidentified.
sented in peanut kernels were \( p \)-hydroxybenzoic and \( p \)-coumaric acids.\(^{30}\) Al-Juhaimi and Özcan\(^{31}\) reported that raw, oven-, and microwave-roasted peanuts contained 1.17, 0.87, and 1.03 \( \mu \)g/g gallic acid; 13.56, 7.68, and 11.67 \( \mu \)g/g protocatechuic acid; 47.98, 31.57, and 43.81 \( \mu \)g/g hydroxybenzoic acid; 69.23, 44.81, and 53.19 \( \mu \)g/g vanillic acid; 3.17, 1.17, and 2.23 \( \mu \)g/g chlorogenic acid; 31.54, 17.22, and 29.61 \( \mu \)g/g \( p \)-coumaric acid; 47.89, 28.11, and 38.61 \( \mu \)g/g ferulic acid; 15.74, 8.62, and 14.71 \( \mu \)g/g quercetin; and 57.68, 38.63, and 49.24 \( \mu \)g/g cinnamic acid, respectively, as the key phenolic compounds. The amounts of other phenolic compounds of peanut kernels were found at low concentrations, depending on the maturity stages of the peanut kernels. It was determined that the amount of gallic acid decreased until a certain harvest time and then increased with the progress of the harvest time. The amount of gallic acid, which was 2.41% on August 25, 2019, decreased on September 8, 2019 (1.36%). Then, it started to increase, and its highest value was 2.85% on October 6, 2019. Fluctuations were recorded for (+)-catechin and 1,2-dihydroxybenzene contents as they were increased until a certain harvest time and then were decreased. Rosales-Martinez \textit{et al.}\(^{31}\), determined that raw and roasted peanut kernels contained 5.84 and 8.24 \( \mu \)g/g resveratrol, 114.35 and 122.14 \( \mu \)g/g catechin, 262.23 and 238.04 \( \mu \)g/g rutin, 114.35 and 122.14 \( \mu \)g/g quercetin, and 57.68, 38.63, and 49.24 \( \mu \)g/g cinnamic acid, respectively. Ballistreri \textit{et al.}\(^{30}\) determined the effects of the degree of maturity on the total polyphenol content in pistachio kernels, and they found that polyphenol content decreased with the maturity stage of pistachios. Persic \textit{et al.}\(^{30}\), reported an increase in polyphenol content with the ripening of hazelnuts. When the results were compared with those of previous studies, our findings showed partial differences. Moreover, the phenolic compound content of peanut kernels showed fluctuations, depending on the harvest time. These variations may be attributed to genetic factors, variety, agricultural factors, growing conditions, and ecological and climatic factors.

4 Conclusion

Depending on the maturity stage, all the peanut kernel samples that were analyzed exhibited differences in their bioactive compounds, antioxidant activity, fatty acid composition, and phenolic compounds. With the progress of the harvest time, a certain decrease was observed in the moisture content of peanut kernels; however, a partial increase was observed in the last harvest time. With the progress of the harvest time until September 29, 2019, the oil content of peanut kernels was increased. With the advancement of harvest time, stearic acid, oleic acid, and linoleic acid were increased until a certain harvest time, whereas polyunsaturated fatty acids, such as linolenic acid, were decreased. Their amounts were increased until a certain harvest time, and then they were decreased. The amounts of other phenolic compounds of peanut kernels were found at low concentrations, depending on the maturity stages of the peanut kernels. It was determined that the amount of gallic acid decreased until a certain harvest time and then increased with the progress of the harvest time. The results showed that peanut kernel and oil had distinctive phenolic profiles and fatty acid contents. The findings of the present study may provide information for the best time to harvest peanut to achieve its maximum health benefits.

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Conflict of Interest

The authors declare no conflict of interest.

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