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Changes in the Phytochemical Composition and Profile of Raw, Boiled, and Roasted Peanuts

YVONNE CHUKWUMAH,[†] LLOYD WALKER,*[,†] BERNHARD VOGLER,[‡] AND MARTHA VERGHESE[†]

Department of Food and Animal Sciences, Alabama A&M University, P.O. Box 1628, Normal, Alabama 35762, and Department of Chemistry, University of Alabama in Huntsville, 301 Sparkman Drive, Huntsville, Alabama 35899

Peanuts are consumed mostly as processed products. Although the effect of processing on isoflavone composition of legumes has been extensively studied, there has been no such study on peanuts. The objective of this study was to evaluate the effect of processing (boiling, oil- and dry-roasting) on the phytochemical composition of peanuts. Boiling had a significant effect on the phytochemical composition of peanuts compared to oil- and dry-roasting. Boiled peanuts had the highest total flavonoid and polyphenol content. The biochanin A and genistein content of boiled peanut extracts were two- and fourfold higher, respectively. *trans*-Resveratrol was detected only in the boiled peanuts, with the commercial product having a significantly ($p \leq 0.05$) higher concentration. Ultraviolet and mass spectrometry chromatograms for the boiled peanut extracts show the presence of four additional peaks that were not observed in the raw peanut extracts.

KEYWORDS: Peanut (*Arachis hypogaea* L.); groundnut; isoflavones; *trans*-resveratrol; high performance liquid chromatography–mass spectrometry; HPLC-MS; diode-array detector

INTRODUCTION

The consumption of nuts has been shown to be beneficial to health. This is primarily due to their desirable lipid profile, which is higher in unsaturated fatty acids than in saturated fatty acids. Although classified as a legume, peanuts also have a high lipid content (ca. 46%) that is rich in monounsaturated fatty acids, and they do not contain cholesterol (*1*). Epidemiological and intervention studies have shown that the frequent consumption of peanuts promotes cardiovascular health by lowering serum low density lipoprotein (LDL)-cholesterol levels and reduces the risk of development of type II diabetes (*2*–*6*). It has also been shown to promote weight management when consumed as part of a moderate fat diet as a result of its satiating effect (*7*). In addition to their nutrient composition, peanuts contain certain bioactive compounds that may also play a role in the reduction of the risk for the development of chronic diseases such as cancer, diabetes, and coronary heart diseases (*1*, *8*, *9*). These compounds, such as the isoflavones and *trans*-resveratrol, have been previously identified and quantified in peanuts by several authors (*10*–*13*); however, there has been no study on the effect of processing, especially boiling, on the phytochemical composition of the peanuts.

Legumes are inexpensive sources of proteins; however, they contain antinutritional factors such as tannins, phytates, and trypsin inhibitors, which if ingested can reduce the nutritional quality of the food and lead to undesirable physiological effects (*14*–*17*). Therefore, they need to be processed prior to consumption to reduce the levels of these antinutritional factors. Peanuts, like other members of the legume family, are consumed mostly as processed products. There are four market-types of peanuts (Runner, Virginia, Valencia, and Spanish) typically grown and processed in the U.S. They are mainly consumed as peanut butter or roasted nuts. While peanuts are mainly consumed in the boiled form in Asia and Africa, boiled peanuts have been popular in the southern region of the U.S. and, in recent years, can be found in grocery stores as a snack item.

The effect of processing on isoflavone composition of legumes has been extensively studied in soy, but there has been no such study on peanuts (*18*–*21*). Several studies on the effect of thermal processing on soy isoflavones reported changes in the isoflavone profile at high processing temperatures as a result of the conversion of conjugate glycosides and the degradation of the aglycones (*18*–*20*, *22*, *23*). In some cases, these changes were shown to be pH and time dependent, daidzein being the most labile of the isoflavones (*21*, *24*).

Studies on the phytochemical composition of peanuts have focused on the quantitation of isoflavones and *trans*-resveratrol in raw peanuts and peanut products (*11*, *13*, *25*). Yu et al. (*26*), in their study on the effect of processing on peanut skin phenolics using 80% ethanol as extraction solvent, reported a 39.5% increase in peanut skin phenolics after roasting. In another study on the effects of processing on peanut skin procyanidins, they reported that roasting had a limited effect (*27*). The

* Corresponding author. Telephone: (256) 372-4166. Fax: (256) 372-5432. E-mail: lloyd.walker@email.aamu.edu.
[†] Alabama A&M University.
[‡] University of Alabama in Huntsville.

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isoflavone concentration of peanuts is much lower than in soy and soy products. It is therefore important to determine how different peanut processing methods affect the concentration of these and other bioactive compounds, such as *trans*-resveratrol in peanuts, as this would consequently affect the potential health benefits derived from the consumption of peanuts and peanut products. Therefore, the objective of this study was to evaluate the effect of processing (boiling, oil- and dry-roasting) on the phytochemical composition of peanuts.

MATERIALS AND METHODS

Raw, dried in-shell, jumbo size Virginia market-type peanuts (from here on referred to as Virginia peanuts) were purchased from a local grocery store. Commercially available processed peanuts (boiled, dry- and oil-roasted) were also purchased from a local grocery store. Pure standards of genistein, biochanin A, gallic acid, catechin, Folin-Ciocalteau reagent, aluminum chloride, sodium carbonate, and sodium nitrite were purchased from Sigma Chemical Company (St. Louis, MO, U.S.A.); *trans*-resveratrol was purchased from MP Biomedicals (Solon, OH, U.S.A.); daidzein was purchased from Spectrum Chemical Mfg Corp. (New Brunswick, NJ, U.S.A.); and genistin and daidzin were purchased from LC Laboratories (Woburn, MA, U.S.A.). Ethyl alcohol, acetonitrile (high performance liquid chromatography (HPLC) grade), glacial acetic acid, and water (HPLC grade) were purchased from Fisher Scientific Inc. (Fair Lawn, NJ, U.S.A.). Equipment used included a Blixer RSI BX3 processor (Robot Coupe U.S.A., Inc., MS).

Sample Preparation. Raw in-shell peanuts were shelled by hand with their skin intact prior to dry blanching and roasting. The roast color of a retail brand was used as the standard for roasted peanuts. Consequently, a preliminary study was conducted using a convection laboratory oven to determine the roasting temperature and time combination necessary to accomplish a roast color similar to that of the retail brand. Five hundred grams of peanut kernels was used. Dry-roasting at 180 ± 5 °C for 22 min was required to achieve a roast color similar to that of the retail brand while 7 min at 140 ± 3 °C was adequate for oil-roasting.

Dry-Roasting. Five hundred grams of peanut kernels was spread evenly on a perforated aluminum tray and blanched in a convection oven at 138 °C for 20 min. The blanched kernels were then dry-roasted in a preheated convection oven at 180 ± 5 °C for 22 min with periodic shaking for even roasting. The peanuts were then cooled, and their skin was manually removed.

Oil-Roasting. Five hundred grams of peanut kernels was spread evenly on a perforated aluminum tray and blanched in a convection oven at 138 °C for 20 min. The kernels were then cooled, and the skin was removed prior to deep frying in 2 L of preheated peanut oil at 140 ± 3 °C for 7 min with periodic agitation for even roasting. The roasted peanuts were rapidly cooled under forced air at room temperature.

Boiling. In-shell peanuts (908 g) were boiled as recommended on the product label. The peanuts were placed in a 6-quart stainless steel stockpot, and 2 L of water containing 50 g of salt was added. The stock pot was covered and boiled for 2 h after which an additional 2 L of water was added and brought to a boil for an additional 2 h. The peanuts were allowed to cool to room temperature and then shelled.

Samples of the raw and roasted peanut kernels were taken for the determination of the roast color, and the texture of the boiled peanut kernels was determined.

Texture Analysis. The texture of the boiled peanuts (processed and commercial) was determined using a texture press T-2000 (Food Technology Corporation, Sterling, VA, U.S.A.). The boiled peanut sample (50 g) was evenly spread in the 10-blade shear compression test cell (CS-2, model no. 2961). A one bite shear resistance test was performed on each sample using a 454 kg capacity force transducer.

Roast Color. The color of raw and roasted peanuts was objectively measured using a Colorflex spectrocolorimeter (Hunter Associates Laboratories Inc., Reston, VA, U.S.A.). The CIE L (lightness) value was determined using 50 g of whole peanuts after calibration of the colorimeter according to manufacturer's specifications. Commercially available roasted peanuts were evaluated for color. Their lightness values were used as a standard for the roast quality of the peanut samples used in this study.

Sample Extraction. Raw and processed peanut kernels were stored at −80 °C overnight and then freeze-dried. The freeze-dried samples were then milled and defatted at room temperature by stirring them in *n*-hexane (10% w/v) for 2 h. The suspension was then filtered through a Whatman No. 1 filter paper, and the residue was air-dried. One gram of the defatted sample was extracted in 6 mL of 80% aqueous methanol by sonicating for 2 h at room temperature. Samples were then centrifuged for 20 min at 2100*g* at 20 °C. The supernatants were evaporated to dryness under vacuum at 38 °C and reconstituted in 8 mL of extraction solvent. The extracts were filtered (0.45 μm poly(vinylidene difluoride) filters) prior to the analyses.

Total Flavonoids. Total flavonoid content of the raw and processed peanuts was determined by the method of Jia et al. (*28*). To 2 mL of diluted (5 times) sample extract was added 150 μL of 5% sodium nitrite. After 5 min, 150 μL of 10% aluminum chloride was added. One milliliter of 1 M sodium hydroxide and 1.2 mL of distilled water were added to the mixture after 10 min. The absorbance was read at 510 nm. The catechin standard curve (10–50 μg/mL) was used to calculate the flavonoid content of the sample extracts which was expressed as catechin equivalent (CE)/g.

Total Phenolics. Total polyphenol content of the raw and processed peanuts was determined by the method of Singleton and Rossi (*29*). Ten microliters of the sample extract was brought up to 2 mL with deionized water. Folin-Ciocalteau reagent (100 μL) was added to the diluted samples. After 8 min, 300 μL of 7% sodium carbonate was added. The mixture was kept in a water bath at 40 °C for 30 min. The absorbance was read at 750 nm. The gallic acid standard (50–500 μg/mL) curve was used to calculate the total polyphenol content of the sample extracts which was expressed as gallic acid equivalent (GAE)/g.

HPLC Analysis. Filtered extracts (50 μL) were analyzed on an Agilent 1100 series liquid chromatography (LC) system (Agilent Technologies, Foster City, CA, U.S.A.) equipped with a diode-array detector (DAD) interfaced to Agilent LC-MS Chemstation software. Separation of the compounds was performed on a 250 mm × 4.6 mm i.d. Zorbax SB C18 reverse-phase column (Agilent Technologies Inc., Newcastle, DE). Preceding the analytical column was a 7.5 mm × 4.6 mm i.d. C18 guard column (Agilent Technologies Inc., Newcastle, DE). The columns were kept at ambient temperature. A constant flow rate of 1.0 mL/min was used with two solvents (A and B). Solvent A was 0.1% formic acid in water (HPLC grade). Solvent B consisted of 80% acetonitrile and 20% acetic acid. The elution profile was as follows: 0–10 min, 78% A; 30–35 min, 0% A. The analysis was monitored from 200 to 600 nm in 2 nm steps. Spectroscopic data were acquired simultaneously at the absorption maxima of the reference compounds. The isoflavones and their glycosides were acquired at 260 nm with the exception of daidzein, which was acquired at 254 nm. Data for *trans*-resveratrol were also simultaneously acquired at 310 nm. UV calibration curves of the pure standards at different concentrations were used for the quantification of detected compounds with similar retention times and UV/vis spectra.

Mass Spectrometry Analysis. MS analyses of the reverse-phase LC eluates were performed on an Agilent 1100 series (LC/MSD model G1946D) quadrupole mass spectrometer. The LC eluents were directly introduced into the MS interface without stream splitting after leaving the UV/vis detector, which was connected in series to the MS detector. Mass spectra were acquired with an atmospheric pressure chemical ionization (APCI) source (positive and negative ionization) under the following APCI conditions: nitrogen nebulizing pressure of 60 psi (4.2 bar), a vaporization temperature of 350 °C, a nitrogen drying-gas temperature of 325 °C at 10 L/min, a capillary voltage of 4 kV, and a corona current of 5.0 μA for positive ionization and 25 μA for negative ionization. Ion abundance was acquired in scan mode within a mass range of *m*/*z* 50–600 at 1.90 s per cycle. The identification of the analytes was done by comparing the retention time and MS spectra of authentic standards (reference) with those of the sample chromatograms. The analytes where characterized by the characteristic mass-to-charge ratio (*m*/*z*) of the reference compounds.

Table 1. Total Flavonoid and Polyphenol Content of Raw and Dry- and Oil-Roasted Peanuts[a]

peanuts	total flavonoids (mg CE/g (dwb))[b]	total polyphenols (mg CE/g (dwb))[b]
raw	0.01 ± 0.00^{f}	25.71 ± 0.41^{d}
raw (with skin)	0.05 ± 0.00^{e}	28.71 ± 1.91^{d}
dry-roasted (DR)	0.01 ± 0.00^{f}	27.33 ± 0.83^{d}
oil-roasted (OR)	0.01 ± 0.00^{f}	28.61 ± 1.44^{d}
boiled (with skin)	0.06 ± 0.00^{d}	36.42 ± 1.39^{c}
commercial OR	0.01 ± 0.00^{f}	21.53 ± 1.11^{e}
commercial DR	0.01 ± 0.00^{f}	20.06 ± 1.28^{e}
commercial boiled (with skin)	0.11 ± 0.00^{c}	38.59 ± 1.38^{c}

[a] Except where stated, peanut sample extracts were prepared without the skin. [b] Values are mean ± SD of three replicates. Mean separation by Tukey's studentized test at $p \leq 0.05$. [c–f] Means with the same letter in a column are not significantly ($p \leq 0.05$) different.

Statistical Analysis. The experiment was replicated three times. Statistical analyses (ANOVA) of data were done using the SAS version 9.1 software, and where significant, mean separations were obtained using Tukey's studentized test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Texture Analysis. Texture analysis was performed on the boiled kernels using the texture of the retail brand as a standard measure of an adequately boiled peanut. This is important because the processing technique used in this study is different from that used in the industry. The texture of the boiled peanuts (1359 ± 132.46 N) was comparable to that of the commercially boiled peanuts (1166 ± 101.61 N). Although the commercial peanuts were immature and uncured, there was no significant ($p \leq 0.05$) difference in their texture. This may be partly due to their comparably high moisture content (38.4 ± 4.5% for boiled Virginia peanuts and 46.5 ± 2.4% for the boiled commercial peanuts).

Roast Color. The roast color of dry- and oil-roasted Virginia peanuts was compared with that of the commercially roasted peanuts. There were significant differences among the raw and the dry- and oil-roasted Virginia peanut kernels. The raw kernels were the lightest with a lightness value of 69.71 ± 0.54 followed by the dry-roasted (DR) kernels with a lightness value of 65.28 ± 1.04. The oil-roasted kernels were the darkest in color with a lightness value of 57.35 ± 1.50. This is because oil has a higher heat transfer capacity than air; therefore, even though the kernels were removed from the hot oil, the roasting action continued until the oil lost all heat. This accounted for the darker roast color of the oil-roasted peanuts. Comparison of the roasted Virginia peanuts with the commercially roasted peanuts showed that there were no significant differences among the DR kernels, and also, the oil-roasted kernels from both sources had similar roast color.

Total Flavonoids and Polyphenols. Total flavonoid contents of raw peanuts with skin (0.05 mg CE/g) and of boiled and commercially boiled peanuts (0.06 and 0.11 mg CE/g, respectively) were significantly ($p \leq 0.05$) higher than those of the raw peanuts without skin (0.01 mg CE/g) and those of all roasted peanuts (0.01 mg CE/g) (**Table 1**). The higher flavonoid content of the raw (with skin) and boiled peanuts can be attributed to the presence of proanthocyanidins in the peanut skin. Previous studies on the polyphenolic content of peanut skin show that it is rich in proanthocyanidins. Lou et al. (*30*, *31*) were able to isolate and characterize six proanthocyanidins from mature peanut skins. Karchesy and Hemingway (*32*) estimated the procyanidin content of peanut skins to be 17% by weight, 50% of which were low molecular weight oligomers. It was also

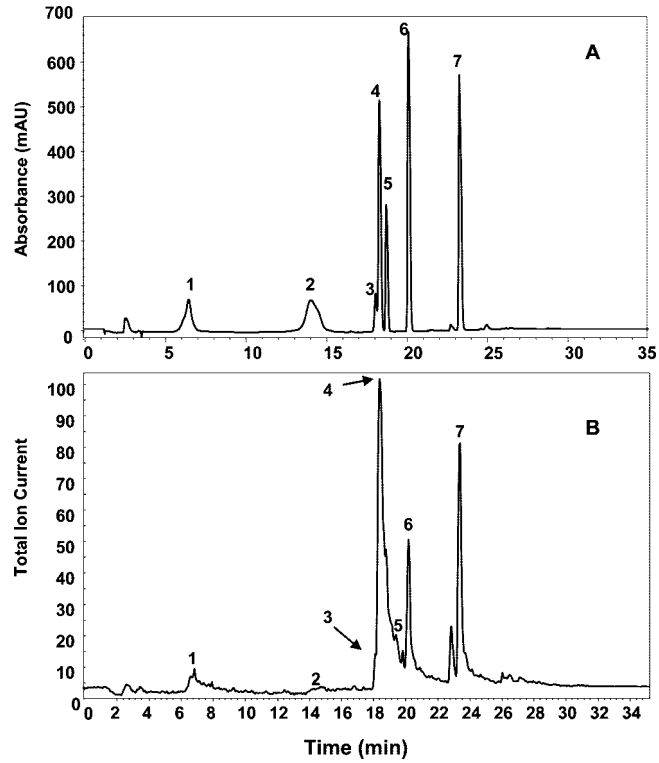

Figure 1. (**A**) LC-UV and the (**B**) corresponding LC-APCI-MS chromatograms of reference standards (1) daidzin, (2) genistin, (3) *trans*-resveratrol, (4) daidzein, (5) sissostrin, (6) genistein, and (7) biochanin A.

observed that processing did not affect the total flavonoid content of the peanuts. However, this was not the case for the total polyphenols. Boiled peanuts had significantly ($p \leq 0.05$) higher total polyphenol content (36.4–38.6 mg GAE/g) than raw and roasted peanuts (20.1–28.8 mg GAE/g). These values are much higher than those reported earlier by Talcott et al. (*33*). This may be due to interference by other UV absorbing compounds, such as amino acids and sugars present in the extracts, that were not corrected for in the Folin-Ciocalteau assay. The significantly higher total polyphenolic content of boiled peanuts could be explained by the presence of polyphenolic compounds in the peanut hull. Boiled peanuts are processed without dehulling, and several studies have shown that peanut hulls are rich in polyphenolic compounds that increase with peanut maturity (*34*, *35*) giving rise to the high antioxidant capacity of peanut hull extracts.

Polyphenols occur in nature in free or bound forms; thus, some processing methods such as boiling or heating have been shown to increase the polyphenolic content of foods. In their study of free and hydrolyzable polyphenols in 10 oilseeds, Dabrowski and Sosulki (*36*) demonstrated that defatted peanut flour contained *p*-coumaric, ferulic, and caffeic acids in esterified forms. Also, the presence of vanillin in peanut hulls and kernels of boiled peanuts formed by the hydrolysis of lignin, a major constituent of the peanut hull, was established by Sobolev (*37*). This suggests that during the boiling process, as the peanut kernel absorbs the water that has permeated the hull, water soluble polyphenols from the hulls are also absorbed by the kernels.

Although roasted peanuts had a numerically larger amount of total polyphenols than the raw peanuts (without skin), there were no significant differences between the raw and roasted peanuts. A similar finding was reported earlier by Talcott et al. (*33*).

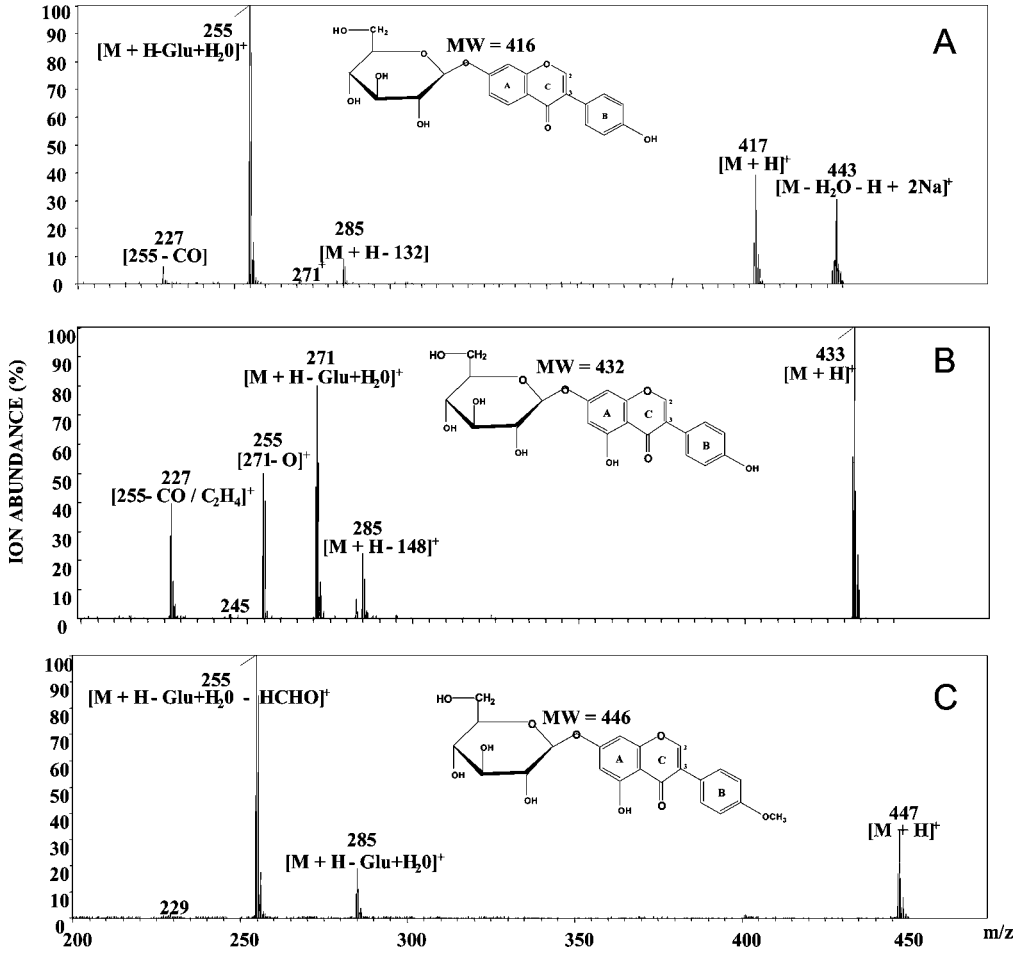

Figure 2. LC–APCI–MS spectra showing relative abundance of molecular $[M + H]^+$ and daughter ions of pure isoflavone glycosides (**A**) daidzin, (**B**) genistin, and (**C**) sissostrin (biochanin A glycoside).

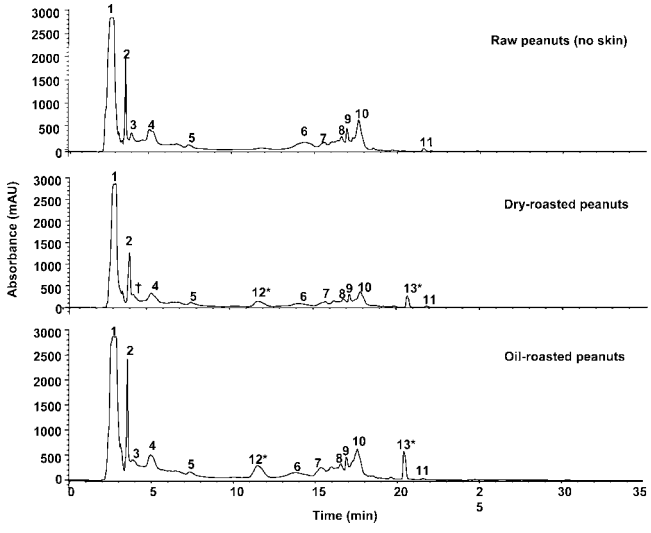

Figure 3. HPLC-UV chromatograms of raw and roasted peanut extracts at 260 nm (*, new peaks).

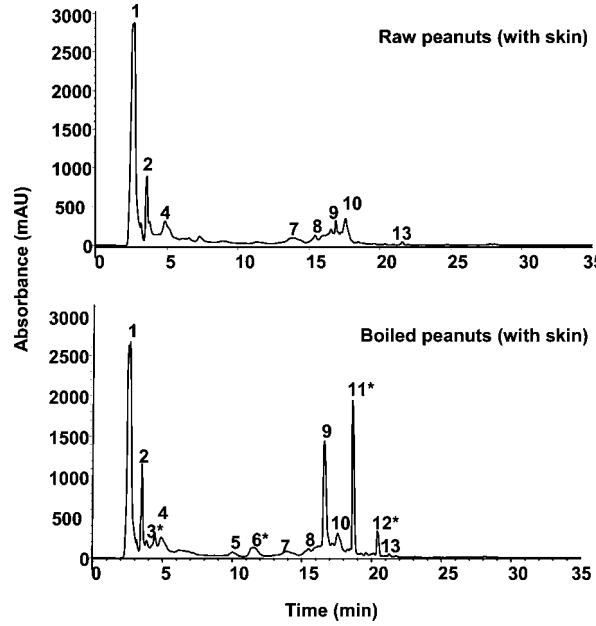

Figure 4. HPLC-UV chromatograms of raw and boiled peanut extracts at 260 nm (*, new peaks).

Phytochemical Composition. Liquid chromatography–UV–mass spectrometry analysis of pure isoflavone standards and *trans*-resveratrol showed a complete separation of the compounds with the exception of the *trans*-resveratrol peak, which overlapped with that of daidzein (**Figure 1**). Their corresponding total ion chromatograms (TICs) and mass spectra showed characteristic $[M + H]^+$ and fragment ions at their respective retention times for the isoflavone glycosides (**Figure 2**) and *trans*-resveratrol while the aglycones showed the presence of $[M + H]^+$ molecular ions in high abundance.

Thermal processing of peanuts had a significant effect on the isoflavone composition. Comparison of the UV and MS chromatograms of the raw peanuts to those of the processed peanuts

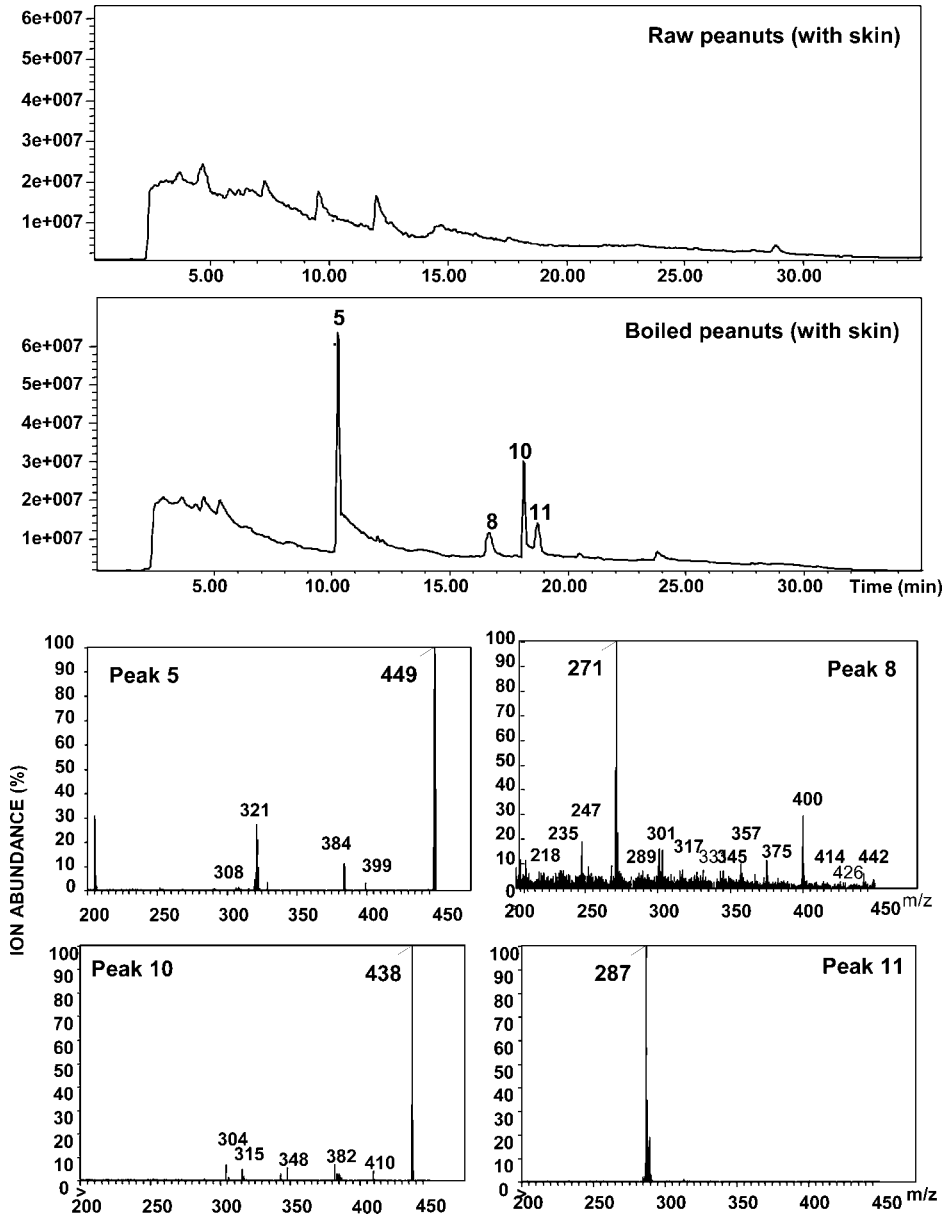

Figure 5. HPLC-APCI-MS chromatograms of (**A**) raw peanuts (with skin) and (**B**) boiled peanuts (with skin) extracts, and MS spectra $[M + H]^+$ of additional peaks (5, 8, 10, and 11) in boiled peanut extracts.

showed a change in the profile of the processed peanuts, and the profile of the boiled peanuts showed the presence of more peaks than were observed in the raw peanut extract. The chromatogram for DR peanuts shows the absence of a peak 3 and the presence of additional peaks, 12 and 13 (**Figure 3**). These peaks (12 and 13) were also present in the oil-roasted (OR) peanuts; however, they were larger than those in the DR (**Figure 3**) indicating the presence of higher amounts of these compounds as a result of oil-roasting.

During roasting, compounds with free amino groups, such as lysine, undergo a sequence of complex reactions with carbohydrates to produce tetrahydrofuran, melanoidins, pyrazines, and their derivatives that impart color, flavor, and aroma (*38*, *39*). Melanoidins are end products of the Maillard reaction, and as a result of their complexity, they have not yet been fully characterized. Because roasting, especially oil-roasting, imparts a dark roast color to the peanuts, it is therefore possible that the additional peaks, which were larger in OR extracts, are due to the nonvolatile products of the Maillard reaction that are soluble in aqueous methanol.

UV chromatograms for the boiled peanuts showed the presence of additional peaks (peaks 3, 6, 11, and 12) that were not observed in the raw peanuts with skin (RWS) extracts (**Figure 4**). Also, there was an increase in the peak area for peak 9 (**Figure 4**). The TIC of the boiled peanut extracts showed the presence of four distinct peaks that were not present in the TIC for the RWS extract (**Figure 5**). Mass spectra of these four peaks (5, 8, 10, and 11) showed the $[M + H]^+$ ions corresponding to *m*/*z* 449, *m*/*z* 271, *m*/*z* 438, and *m*/*z* 287, respectively (**Figure 5**). Because the peanuts were boiled in-shell with their skin intact, it is possible that these ions correspond to the monomeric and oligomeric proanthocyanidins that have been reported to be present in peanut skin (*30*, *32*, *40*). Also, the peanut hull (shell) has been reported to contain vanillin (a hydrolytic product of lignin) and luteolin (*34*, *37*). Thus, peak 11 of the HPLC-UV chromatograms for the boiled peanuts (**Figure 5**), having a $[M + H]^+$ ion with a *m*/*z* of 287 amu, could possibly be luteolin, which has a molecular weight (MW) of 286. Also, peak 5 (**Figure 5**) may be the flavonol kaempferol,

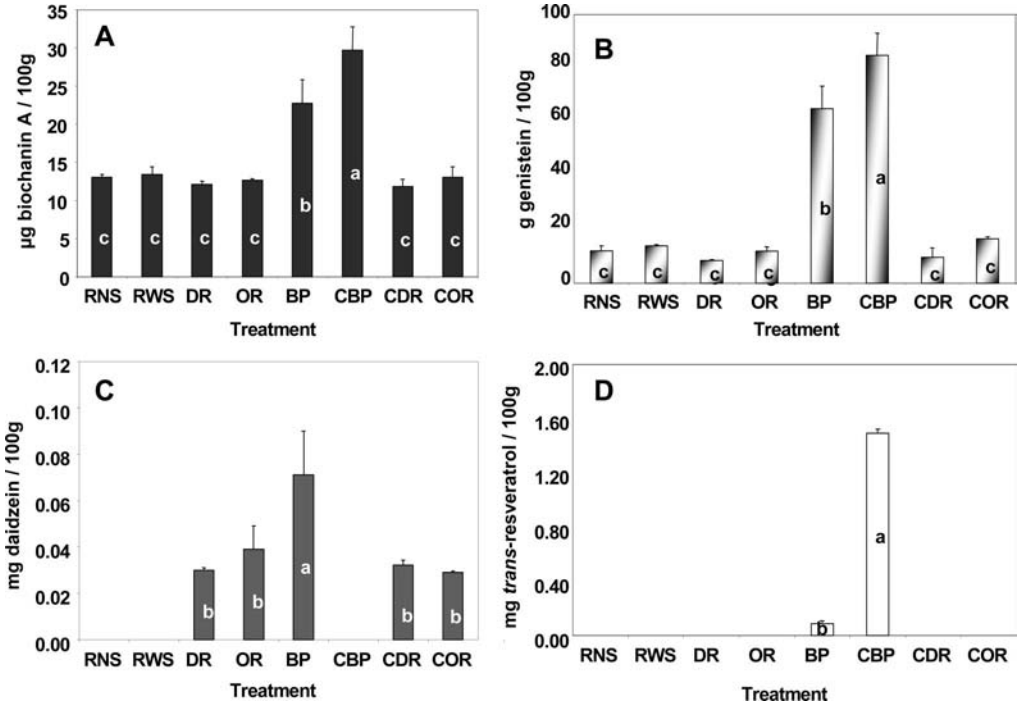

Figure 6. (**A**) Biochanin A, (**B**) genistein, (**C**) daidzein, and (**D**) *trans*-resveratrol content of raw, roasted, and boiled peanuts. RNS (raw no skin), RWS (raw with skin), DR (dry-roasted), OR (oil-roasted), BP (boiled peanuts), CBP (commercial boiled peanuts), CDR (commercial dry-roasted), and COR (commercial oil-roasted).

which has an MW of 448. Confirmation of the identity of these ions depends on further characterization.

Among the seven compounds investigated, four (biochanin A, daidzein, genistein, and *trans*-resveratrol) were identified by comparison of their retention times from UV chromatograms of peanut extracts to those of the authentic standards. Biochanin A was detected in both the raw and the processed peanuts; however, the levels were significantly higher (twofold) in the boiled peanuts compared to those in the raw and roasted peanuts (**Figure 6A**). This corresponds with higher molecular ion abundance in the positive ionization mode having *m*/*z* 285 in the extracted ion chromatograms of their MS spectra. This may be explained by the hydrolytic effect of boiling, which may have caused the release of bound biochanin A. There were no significant differences in the biochanin A levels of the raw and roasted peanuts. This was also the case for genistein (**Figure 6B**); however, the amount of genistein in the boiled peanuts was four times higher (65 μg/100 g) than in the RWS (13.89 μg/100 g). Daidzein, on the other hand, was not detected in RWS and commercially boiled peanuts (CBP); however, it was detected in the Virginia boiled peanuts in significantly higher amounts than in the roasted peanuts (**Figure 6C**). The ability to detect daidzein in the boiled and roasted peanuts but not in the raw peanuts suggests that daidzein may be present in the bound form in the raw peanut kernel. Graham (*41*) , in his study of isoflavone distribution, reported that isoflavones are selectively secreted into the soybean roots and seed exudates and stored as glucosyl- and malonyl-glucose conjugates. Maturity of the peanut kernel may also play a role as immature kernels are used for the production of CBP. Another study on the biosynthesis and accumulation of isoflavones in soybean has shown that the amount of isoflavonoids present depended on the tissue and developmental stage (*42*). The authors noted that the highest amounts of isoflavones were found in the mature seeds and leaves.

Although the total isoflavone content remains unchanged during thermal processing, several studies on the thermal stability of isoflavones in soy have shown that the thermal conversion of glycoside conjugates and degradation of isoflavone aglycones occurred at temperatures above 70 °C and was pH dependent (*19*, *21*, *43*, *44*). While isoflavones were found to be rather stable at pH 7.0 and 5.6 and the thermal degradation of aglycones was significant at pH 3, daidzein was found to be the most labile. The stabilities of biochanin A and genistein, especially at physiological pH at which roasting occurs, may explain their unchanged levels in the raw and roasted peanuts. However, this does not account for the detectable levels of daidzein in the roasted and boiled peanuts but not in the raw peanuts. Although daidzin (the glycoside form of daidzein) was also not detected in both the UV and the MS analyses, it is possible that daidzein in the raw peanuts was present as its conjugate glycoside in the bound form and that, upon thermal processing, it was degraded to release its aglycone.

trans-Resveratrol was detected only in the boiled peanuts (**Figure 6D**) at the concentration of 0.09 mg/100 g for the boiled Virginia peanuts. This is within the range (0.002–0.179 mg/100 g) previously reported by Sanders et al. (*11*) from the 15 peanut cultivars they investigated. The CBP had significantly ($p \leq 0.05$) higher resveratrol concentration (1.492 mg/100 g). This is because CBP are immature kernels that have a higher capacity to synthesize *trans*-resveratrol than mature kernels and, as they mature, their *trans*-resveratrol concentration is reduced (*45*). Immature peanut kernels have been reported to contain higher amounts of *trans*-resveratrol compared to mature peanut kernels (*46*). The raw peanuts used in this study were mature peanuts. In their study of *trans*-resveratrol in peanuts and peanut products, Sobolev and Cole (*46*) showed that boiled peanuts had the highest *trans*-resveratrol content (0.18–0.71 mg/100 g) and that roasted peanuts had levels (0.0018–0.0080 mg/100 g) similar to those of the raw peanut fractions used in their production. In this study, *trans*-resveratrol was not detected in the raw and roasted Virginia peanuts. It may be that their concentrations were well below the UV detection limit (1.0 μg/mL).

The effect of oven heat on *trans*-resveratrol content was investigated in raw and baked (190 °C) blueberries and bilberries (*47*). The authors reported a loss in resveratrol content of 17–46% as a result of heat degradation. Therefore, with already low *trans*-resveratrol concentration in the mature peanuts coupled with dry- and oil-roasting temperatures of 180 °C and 140 °C, respectively, the inability to detect *trans*-resveratrol in the roasted kernels could be a result of thermal degradation.

Boiling had a significant effect on the phytochemical composition of peanuts compared to oil- and dry-roasting. Boiled peanuts had higher total isoflavone content with a two- and fourfold increase in biochanin A and genistein content, respectively. *trans*-Resveratrol was detected only in the boiled peanuts, with the commercial peanuts having significantly ($p \leq 0.05$) higher concentration. Also, other UV absorbing compounds were detected in the boiled peanut extracts. These may be products of the hydrolysis due to boiling, may have migrated into the peanut kernels from the hull during boiling, or may be components of the skin. Significantly ($p \leq 0.05$) higher levels of total flavonoids and polyphenols were observed in the boiled peanut extracts compared to raw and roasted peanut extracts.

Further structural characterization of the new peaks in the boiled peanut extract is necessary. In addition, the determination of the antioxidant capacities of boiled and roasted peanuts would be useful as this will provide critical information on which processed product will be more beneficial to health.

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