Available online at www.sciencedirect.com
SCIENCE DIRECT®
Food Chemistry 90 (2005) 199–206
Food Chemistry
www.elsevier.com/locate/foodchem

Effects of processing methods and extraction solvents on concentration and antioxidant activity of peanut skin phenolics

Jianmei Yu, Mohamed Ahmedna *, Ipek Goktepe

Food Science and Nutrition Program, Department of Human Environment and Family Science, North Carolina Agricultural and Technical State University, NC 27411, USA

Received 9 February 2004; accepted 22 March 2004

Abstract

Peanut skin is a by-product of the peanut industry that has low economic value despite its high content of antioxidants such as phenolics. The effects of three skin removal methods (direct peeling, blanching, and roasting) and extraction solvents (water, ethanol, and methanol) on total phenolics and total antioxidant activities (TAA) of peanut skin extracts were studied, and the composition of extracts were determined by HPLC. Results show that both skin removal methods and extraction solvents had significant effects on total extractable phenolics and TAA, with the combination of roasting and ethanol extraction being the most efficient recovery method. One gram dry peanut skin contained 90–125 mg total phenolics. TAAs of water and ethanol extracts of peanut skin were 3.39 and 4.10 mM Trolox Equivalent/mM of total phenolics compared with 1.91 and 2.46, respectively, for green tea. Three classes of phenolics (phenolic acids, flavonoids, and stilbene) were found in peanut skin extracts.

Keywords: Peanut skin; Polyphenols; Antioxidant activity; HPLC separation

1. Introduction

Peanuts are a multimillion dollar industry in North Carolina and an important crop in the Southeastern United States. In the United States, nine states grow 99% of the US peanut crop: Georgia with about 39%, followed by Texas, Alabama, North Carolina, Florida, Oklahoma, Virginia, South Carolina, and New Mexico. The kernels are used to make peanut butter, roasted snack peanuts, peanut confections, and peanut oil. The skin becomes the waste of above industry, and is mainly used as animal feed for less than a penny a pound (Lee, 2002).

The literature has reported many health benefits associated with consumption of peanuts including weight gain control (Alper & Mattes, 2002), prevention against cardiovascular diseases (Feldman, 1999), protection against Alzheimer disease (Peanut-Institute, 2002), and cancer inhibition (Awad, Chan, Downie, & Fink, 2000). These benefits are mainly attributed to the fact that peanuts do not contain *trans*-fatty acids (Sanders, 2001), while rich in mono- and polyunsaturated fatty acids (Kris-Etherton et al., 1999), micronutrients such as vitamin E, folate, minerals (potassium, magnesium, and zinc), fiber, and health promoting phytochemicals, particularly resveratrol (Sanders, McMichael, & Hendrix, 2000; Sobolev & Cole, 1999) and other phenolic compounds.

The edible parts of peanuts consist of the kernel and protective skin. The skin has a pink-red color and astringent taste, and is typically removed before peanut consumption or inclusion in confectionary and snack products. However, peanut skin is rich in phenolics and potentially other health promoting compounds. Phenolics in green tea, fruits and vegetables, grape seeds and grape skin have been recognized as natural antioxidants and have been extensively studied by many investigators for their health promoting effects, such as cancer prevention, cardiovascular disease prevention, and

* Corresponding author. Tel.: +1-336-334-7963; fax: +1-336-334-7239.
E-mail address: ahmedna@ncat.edu (M. Ahmedna).

0308-8146/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2004.03.048

anti-inflammatory activities. Catechins, anthocyanins and resveratrol in red wine and grapes have been attributed as the active compounds responsible for "the French Paradox"; the low mortality rate from cardiovascular diseases among people who drink red wine and have high intakes of saturated fatty acids (Miller & Rice Evans, 1995; Renaud & de Lorgeril, 1992). Resveratrol in red wine has also been found to have cancer chemopreventive activity. It acts as an antioxidant and antimutagen by inducing phase II drug-metabolizing enzymes during the initiation stage of carcinogenesis; it mediates anti-inflammatory effects and inhibits cycloxygenase and hydroperoxidase; and it induces human promyelocytic leukemia cell differentiation (Jane et al., 1997). Chlorogenic acid is another major antioxidant in commercial long-life apple juice (Miller, Diplock, & Rice-Evans, 1995).

However, despite a wealth of literature information on health benefits of phenolics in wine, very few if any studies are available on the health promoting compounds in peanut skin. Furthermore, an extensive review of literature found no information on methods of extraction for optimal recovery of phenolics from peanut skin. A recent study by Nepote, Grosso, and Guzman (2002) found that peanut skin contains about 150 mg total phenolics per gram defatted dry skin. Six A-type procyanidins were identified (Lou, Yamazaki, Sasaki, Uchida, & Tanaka, 1999). These six compounds were found to inhibit the activity of hyaluronidase, an enzyme that is responsible for the release of histamine, which causes inflammation. In addition, resveratrol, a phytochemical found in grape seed and wine, was also found in peanut skin in much higher concentration than that in peanut kernels (Sanders et al., 2000). These few studies have shown the potential of peanut skin as a potentially rich and inexpensive source of nutraceutical and functional ingredients such as phenolics.

The objectives of this study were to determine total phenolics in peanut skin removed by different peeling methods, to evaluate the effects of skin removal methods and extraction solvent on total phenolics and total antioxidant activity of peanut skin extracts, and to separate and identify active phenolic compounds in various peanut skin extracts by HPLC.

2. Materials and methods

2.1. Materials

Un-peeled peanuts were purchased from local grocery store. Standards including gallic acid (GA), catechin (C), epicatechin (EC), gallocatech (GC), epigallocatechin (EGC), catechin gallate (CG), epicatechin gallate (ECG), epigallocatechin gallate (EGCE), resveratrol, caffeic acid, *p*-coumaric acid, ferulic acid, quercetin glycoside, and chlorogenic acid were purchased from Sigma Chemical Co. (St. Louis, MO). 2,2′-Azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) and Peroxidase (EC 1.11.1.7) from horseradish were also purchased from Sigma Chemical Co. Trolox, hydrogen peroxide (30%), methanol, ethanol, acetonitrile, trifluoroacetic acid, and acetic acid were purchased from Fisher Scientific (Atlanta, GA).

2.2. Methods of peanut skin removal and drying

Peanut skins were removed by three different methods. In the direct method, the skin was directly peeled by hand from raw peanut kernels and freeze dried. For the moist method, peanuts were blanched in boiling water for 2 min, after which water was drained and boiled kernels were cooled to room temperature, their skin was hand peeled and freeze dried. The heat method consisted of heating peanuts at 175 °C for 5 min, cooling to room temperature, then rubbing dry skin off. Further drying was not needed for the skin obtained by this method. Dry skins obtained from each method were separately blended into powder and stored in plastic bottles in the refrigerator until used.

2.3. Extraction and purification of phenolics

The moisture of peanut skins removed by different methods was determined by oven drying (24 h at 105 °C) in triplicates. Three solvents, water, 80% ethanol or 80% methanol, were used to extract phenolics from peanut skin. Twenty milliliters of water/solvent was added to a flask containing 0.25 g of skin powder, the flask was wrapped by aluminum foil to prevent light degradation during extraction. The flasks were stirred overnight at room temperature. Mixtures were filtered through 0.45 μm GMF membrane to obtain crude extracts. Each solvent extraction was carried out in triplicate.

The crude extracts were purified by the method of Hara (2001) before injection into the HPLC system to remove protein and lipid to obtain a good base line. Water extraction filtrate was mixed with an equal volume of chloroform, then the aqueous and organic phases were separated using a separation funnel. The alcoholic extracts were evaporated under vacuum then re-dissolved in an equal amount of water before chloroform was added. In this process, lipid and lipid soluble compounds were removed with an chloroform and the water layer containing all hydrophilic compounds was then mixed with an equal volume of ethyl acetate. After partition and phase separation, the water layer was filtered through a 0.2 μm syringe filter and stored in amber glass vials in a freezer. The ethyl acetate layer was evaporated in a Büchi rotary evaporator (Büchi La-

bortechnik AG, Switzerland) under reduced pressure. The dried phenolics resulting from this step were quantitatively re-dissolved in methanol, and stored in amber glass vials in a freezer until analyzed. The whole process was completed under dim light to minimize light induced degradation of phenolics, which are generally light sensitive.

2.4. Determination of total phenolics

Total phenolics in crude extracts and different fractions were determined by the Folin–Ciocalteu method (Singleton & Rossi, 1965), which is considered the best method for total phenolics (including tannins) determination (Engelhardt, 2001). Gallic acid was used as the standard and the result was calculated as gallic acid equivalent (mg GAE/ml).

2.5. Antioxidant activity of peanut skin extract

An end-point free radical scavenging method (Cano, Herandez-Ruiz, Garcia-Canovas, Acosta, & Arnao, 1998) was used to measure total antioxidant activity (TAA) of peanut skin extracts. This method was used because it is simple, fast, highly reproducible, and uses a regular visible-UV spectrophotometer. Briefly, a greenbluish complex was formed by mixing peroxidase (100 μl, 2.5 μM), hydrogen peroxide (15 μl, 1 mM H_2O_2), ABTS (100 μl, 20 mM), and water. The total volume of the reaction mixture was 1 ml. The properly diluted peanut skin extract (10 μl) was then added and the resulting color reduction was attributed to the presence of phenolics. Extracts from blanched peanut skin were diluted 2 times, while samples from non-blanched peanut skins were diluted 10 times because of their high total phenolic contents. The absorbance at 415 nm was measured by a Genesys 10 UV spectrophotometer (Spectronic Unicam, Rochester, NY). Total antioxidant activity of the extracts was calculated in two different ways. TAA was calculated as the percentage of color reduction relative to control $\text{TAA}\% = (1 - \frac{A_{\text{extract}}}{A_{\text{control}}}) \times 100$, or expressed as mM of Trolox equivalents per mM Trolox per mM of total phenolics, called Trolox Equivalent Antioxidant Capacity or TEAC, using Trolox as standard.

2.6. HPLC separation of peanut skin extracts

The identification of individual phenolics was carried out using a Waters HPLC system, based on matching retention times of standards. The HPLC system consisted of a Waters In-Line Degasser AF, Waters 717 Autosampler, Waters 1525 Binary HPLC Pump, Waters 2748 Dual Wavelength Absorbance Detector, and Waters 474 Scanning Fluorescence Detector. The column used was Nucleosil RP C_{18}(250 mm × 4.6 mm, particle size 5 μm). The compounds were eluted with a gradient elution of mobile phase A (5% acetoniltrile in 0.035% trifluoroacetic acid (TFA)) and B (80% acetonitrile in 0.025% TFA) where B increased from 10% to 20% in 10 min, to 50% by 20 min, was maintained at 50% for 5 min, then returned to initial condition (10%) in 5 min and remained for 5 min before next injection. Elutes were detected by a Waters 2487 Dual wavelength detector at wavelength of 280 nm.

2.7. Statistical analysis

The experimental design used in this study was a 3 × 3 factor factorial design. The factors were skin removal methods (direct peeling, blanching, and roasting) and extraction solvents (water, ethanol, and methanol). The effects of skin removal methods and extraction solvents on total phenolics and total antioxidant activity of peanut skin extracts were evaluated by analysis of variance (ANOVA) using SAS (SAS, 2000). Tukey Post-ANOVA test was used to compare treatment means. Difference between treatment means was judged at 5% significance level.

3. Results and discussion

3.1. Total phenolics of peanut skin as affected by skin removal methods

Peanut skin represented about 3.3% of shelled peanuts used in this study. Data in Table 1 show that peanut skin contains relatively high levels of total phenolics and skin removal methods significantly

Table 1
Total phenolics (mg GAE/gram dry skin) in peanut skin as affected by skin removal methods and extraction solvents ($n = 3$)

Skin removal method	Water extraction		80% ethanol extraction		Methanol extraction	
	Total phenolics (mg/g)[a]	Change in total phenolics%[b]	Total phenolics (mg/g)	Change in total phenolics%	Total phenolics (mg/g)	Change in total phenolics%
Direct peeling	56.7 ± 0.54	–	89.9 ± 2.20	–	90.1 ± 4.90	–
Blanching peeling	12.5 ± 0.17	−82.6	16.0 ± 0.48	− 85.9	11.6 ± 1.14	−91.2
Roasting peeling	79.0 ± 1.8	+39.5	125 ± 3.92	+39.5	96.7 ± 9.22	+7.3

[a] Total phenolics in table is expressed as means of 3 replication ± standard deviations.
[b] Value calculated using total phenolics in skin removed by direct peeling as a reference.

influenced the total extractable phenolics from the skin. Total extracted phenolics obtained from directly peeled peanut skin ranged from 56 (in water) to 90 (in ethanol or methanol) mg/g dry skin. Blanching leached out 78–91% of the extractable total phenolics compared to the skin obtained by direct hand peeling without heating. This loss was apparent through the loss of skin color in water during blanching. Roasting resulted in 39.5% higher total phenolics (in both water and ethanol) compared to directly peeled skin. This could be attributed to the degradation/ polymerization products of peanut skin polyphenols during roasting, which seem to be more soluble in water and ethanol, and could react with Folin–Ciocalteu reagent to produce the blue color under alkaline conditions. According to Nepote et al. (2002), peanut skin contains 12% protein, 16% lipid, and other compounds including carbohydrates. During roasting, products formed due to the Maillard reaction might contribute to the increase of total phenolics or phenolics like complexes that contributed to higher absorbance readings.

Solvents used for phenolics extraction also significantly affected the total phenolic concentration of peanut skin extracts at equal volume of solvent. Ethanol and methanol were more effective in extracting phenolic compounds from peanut skin than water, with 80% ethanol being the most efficient extraction solvent. The total phenolics resulting from ethanol and methanol extracts were about 90 to 125 mg/g non-defatted dry skin. These levels were compatible to the results reported by (Nepote et al., 2002) in defatted skin. Statistical analysis using ANOVA also shows that both the skin removal processes ($P < 0.0001$, $F = 1156$) and extraction solvents ($P < 0.0001$, $F = 100.9$) had significant effects on total phenolics, although the effect of solvent was less significant as shown by its smaller F value. In addition, there was interaction between skin removal method and extraction solvents ($P < 0.0001$, $F = 31.12$), which indicated that the skin removal method might enhance or reduce the extraction capability of solvent. For example, the extraction capability of ethanol was enhanced by roasting.

Peeling skin from raw peanut was difficult and time consuming, although the phenolic compounds of the skin were well preserved as shown in Table 1. In contrast, it was relatively easier to remove skin from the kernel after blanching, but the majority of phenolics were lost in the water. Roasting is the common method to remove skin from peanut in peanut butter and peanut snack manufacture. In the food industry, the skin has to be removed before peanuts are used in most peanut based products. The process of peanut skin removal is called "dry blanching". The kernels travel through warm air for a period of time to loosen the skins. Then the kernels go through a "blanching machine" where large rollers rub the surfaces of the kernels until the skins fall off. The third skin removal method (short time roasting) used in this study is very similar to "dry blanching". Since short time roasting did not result in total phenolics loss, it would be the most recommended method of skin removal. This finding is encouraging since it means that peanut skin, as a by-product of the peanut industry obtained by "dry blanching", would have its phenolic content unaffected by the prevalent skin removal method and could represent a plentiful and inexpensive source of health promoting antioxidants.

3.2. Total antioxidant activity (TAA) of peanut skin crude extracts

Plant phenolics are natural antioxidants and their antioxidant activity can be evaluated by their free radical scavenging capacity, metal chelating capacity, inhibition of lipid oxidation or inhibition of activity, of the enzyme that catalyzes the oxidation of lipids or lipoproteins. In this study, a free radical ($ABTS^{\cdot+}$) scavenging method reported by Cano et al. (1998) was used to measure the total antioxidant activity (TAA) of peanut skin extracts. The blue color due to the formation of ABTS free radicals ($ABTS^{\cdot+}$) after mixing peroxidase, hydrogen peroxide and ABTS is sensitive to the presence of antioxidants. Discoloration following sample addition indicates that ABTS radicals were quenched or reduced by the antioxidants in the sample.

TAA shown in Fig. 1 was expressed as percentage of inhibition relative to the control (with no extract added). The TAAs of peanut skin extracts were significantly affected by the methods of skin removal ($P < 0.0001$, $F = 790.4$) and extraction solvents ($P < 0.0001$, $F = 217.2$), as well as the interaction between skin removal method and extraction solvent ($P < 0.0001$, $F = 181.7$). Blanching significantly reduced the antioxidant activity of peanut skin extracts, while roasting had both positive and negative effects depending on the solvents used for extraction. The lower TAAs of extracts from blanched peanut skin compared to the extracts from directly peeled skin were consistent with the loss of total phen-

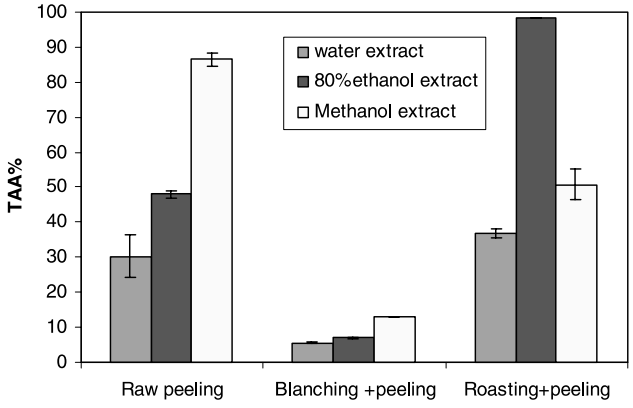

Fig. 1. Effects of skin removal methods and extraction solvent on relative TAAs of peanut skin extracts.

olics due to blanching. For directly peeled and blanched peanut skins, the order of TAA for extracts in different solvents were methanol>ethanol>water. For roasted peanut skin, the order was ethanol>methanol>water. The TAA of water and ethanol extracts obtained from roasted peanut skin were higher than the extracts derived from raw peeled peanut skin with the exception of methanol extracts.

When the concentration of total phenolics of peanut skin extract was in the range of 0.05–0.2 mg/ml, the relationship between TAA % and total phenolics was linear (Fig. 2) with R^2 above 0.98. Out of this range, the relationship became slightly curvilinear. Therefore, it was necessary to dilute the samples to obtain the right concentration of polyphenols when using the method of Cano et al. (1998). The directly proportional increase of TAA % with concentration of total phenolics indicates that the antioxidant activity of peanut skin extracts is attributable to the presence of phenolics in the tested extracts. In fact, 98% of the change in TAA of the extracts tested was explained by the concentration of total phenolics in both water (Fig. 2(a)) and ethanol (Fig. 2(b)) extracts of peanut skin.

The TAA obtained by the relative percentage of discoloration is not convenient for comparison among antioxidants on the basis of equal unit of concentration. Therefore, TEAC (Trolox equivalent antioxidant capacity) value was calculated using Trolox as the standard reference. The standard curve, which shows a linear relationship between the concentration of Trolox and the absorbance in the range of 0–4 mM is given in Fig. 3. The very small standard deviation in the figure also confirms the high reproducibility of this method, as reported by Arnao, Cano, and Acosta (1999).

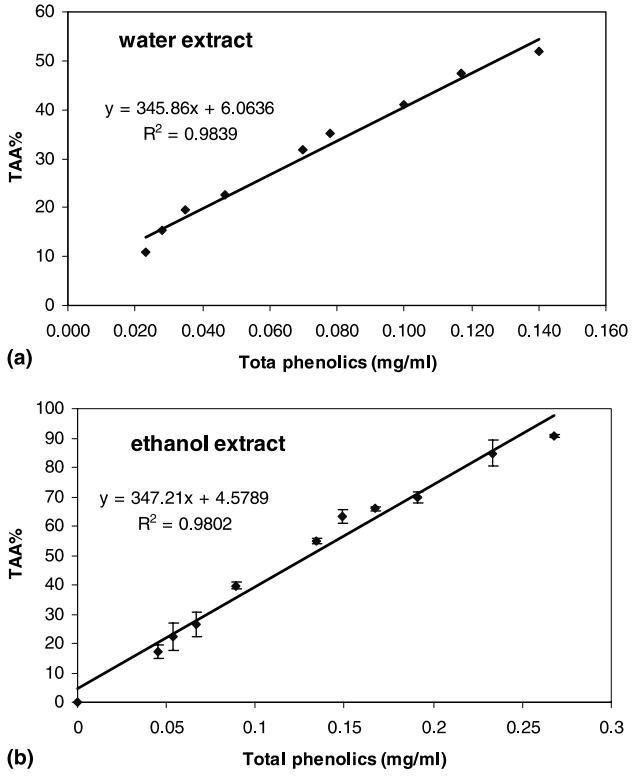

Fig. 2. Correlation between TAA and total phenolics of (a) water and (b) ethanol extracts of peanut skin.

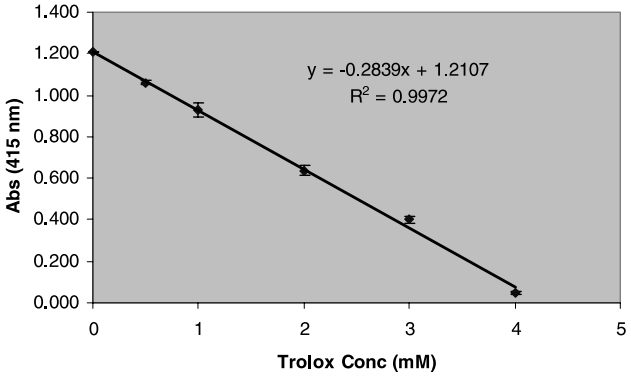

Fig. 3. Standard curve showing linear relationship between absorbance at 415 nm and the concentration of Trolox standard.

Table 2
Comparison of total antioxidant activity (TAA)[a] of peanut skin and green tea extracts

	Water extracts[b]	Ethanol extracts [b]
Directly peeled skin	3.39 ± 0.25	4.10 ± 0.43
Roasted skin	3.30 ± 0.30	3.72 ± 0.15
Green tea	1.91 ± 0.03	2.46 ± 0.03

[a] TAA expressed as trolox equivalent antioxidant capacity (mM Trolox per mM of total phenolics).
[b] Values are means of 3 replications ± standard deviations.

TAAs of peanut skin extracts were calculated using the standard curve in Fig. 3 and compared to that of tea infusions calculated using the same standard curve (Table 2). Water extracts of directly peeled and roasted peanut skins had TEAC value of 3.39 and 3.30, respectively, but the water extract of tea had much lower TEAC value (1.91). The TEAC value of ethanol extract of directly peeled peanut skin (4.10) was higher than that of roasted peanut skins (3.72), and they were both higher than the TEAC value of tea extract (2.46). Table 2 also shows that roasting had a negligible effect on TAA of water extract but lowered the TAA of ethanol extract from 4.10 to 3.72 mM Trolox equivalent per mM total phenolics. This might relate to the degradation/isomerization of some phenolics in peanut skin due to heat. Under the same extraction condition, ethanol extracts had slightly higher TAA than water extracts at equivalent concentration of total phenolics. This may be attributed to the extraction power of ethanol, which is able to extract some compounds that have very low water solubility.

Table 2 shows that regardless of the solvent used for extraction, the TAAs of peanut skin extracts were higher than green tea extracts at equal concentration of total phenolics (1 mM). This indicates that peanut skin extract may contain antioxidants that are more potent than those found in green tea extract. According to Lou et al. (1999), peanut skin contains six A-type procyanidins that were not reported as present in green tea. These A-type procyanidins have the same molecular weights as B-type procyanidins found in grape seeds and wine. These procyanidin dimers might have higher antioxidant activity than monomers such as tea catechins. In addition, peanut skin is rich in resveratrol (Sanders et al., 2000). Although it was reported that the antioxidant activity of resveratrol was mainly due to its higher metal chelating capacity, resveratrol also possesses free radical scavenging capacity (Fremont, 2000). The potential synergistic effect of non-flavonoid resveratrol and flavonoids such as procyanidins may contribute to the higher antioxidant activity observed in peanut skin extracts.

However, antioxidant activity measured by the chemical approach in this study can only give the relative ranking of extracts based on their reduction potential. It does not necessarily indicate that their biological/physiological effects are in the same order. Thus a biological approach/assay will be needed to determine/confirm the in vitro and in vivo antioxidant activity of peanut skin extracts. Furthermore, the study of the contribution of individual phenolic compound in peanut skin extract to the TAA is also needed.

3.3. Total antioxidant activity of peanut skin extract fractions

Two portions were obtained by the purification procedure of Hara (2001) as described in Section 2.3. Total phenolics and total antioxidant activity of ethyl acetate and water soluble portions were determined (Table 3). Data shows that water portions had higher total phenolics concentration than ethyl acetate portions for all extracts. Another important finding shown in Table 3 is that the TEAC values of water layers (11.0–15.9) were over two-folds higher than the TEAC values of ethyl acetate layer (4.33–4.86). Therefore, the difference between ethyl acetate layer and water layer was not only in the quantity of total phenolics, but also the composition/potency of phenolics. Based on the polarity of water (polarity index 9) and ethyl acetate (polarity index 4.4), phenolic compounds in the water layer are more polar than those that would preferentially dissolve in ethyl acetate. Thus, water would favorably dissolve more polar plant polyphenols with higher antioxidant activity. Because the higher polarity means more hydroxyl groups on the ring of polyphenols, this conclusion is in agreement with the results of Cao, Sofic, and Prior (1997) and Lien, Ren, Bui, and Wang (1999) who reported that the antioxidant activity of flavonoids was generally determined by the number and location of hydroxyl groups on the flavonoid ring structure, the more hydroxyl substitutions, the stronger the antioxidant activity.

This finding is also encouraging since functional ingredients used in the formulation of health promoting foods and dietary supplements need to be water soluble for optimal physiological benefits.

3.4. HPLC separation of peanut skin extracts

Preliminary separation and identification of individual phenolic compounds in peanut skin extract was conducted by HPLC. Sample peaks were identified by matching against retention time of known phenolic standards under the same chromatography conditions. Fig. 4 shows typical chromatograms of standards, water and ethanol extracts of peanut skins removed by three different methods. Eight peaks were successfully identified based on retention time. The compounds identified can be divided into three classes: (1) phenolic acids including chlorogenic acid, caffeic acid, coumaric acid, and ferulic acid; (2) flavonoids including epigallocatechin (EGC), epicatechin, catechin gallate (CG), epicatechin gallate (ECG), and (3) stilbene (resveratrol).

It can be seen from Fig. 4(b)–(d) that the same number of peaks (corresponding to same retention times) were observed in the chromatograms of peanut skin extracts from directly peeled and roasted peanut skins. The chromatogram of blanched peanut skin

Table 3
Total phenolics and total antioxidant activities (TEAC) of different fractions of peanut skin extracts

Method of peeling	Fractions	Total phenolics[a](mg/ml)	TEAC (mM Trolox/mM)[a]
Raw peeling and freeze dried	EtOAC layer	0.28 ± 0.00	4.33 ± 0.16
	Water layer	0.47 ± 0.02	11.0 ± 0.51
Blanched peeling and freeze dried	EtOAC layer.	0.03 ± 0.00	3.85 ± 0.07
	Water layer	0.03 ± 0.00	15.9 ± 0.50
Roasting and peeling	EtOAC layer	0.32 ± 0.02	4.86 ± 0.03
	Water layer	0.56 ± 0.00	11.2 ± 0.07

[a] Values are means of 3 replications ± standard deviations.

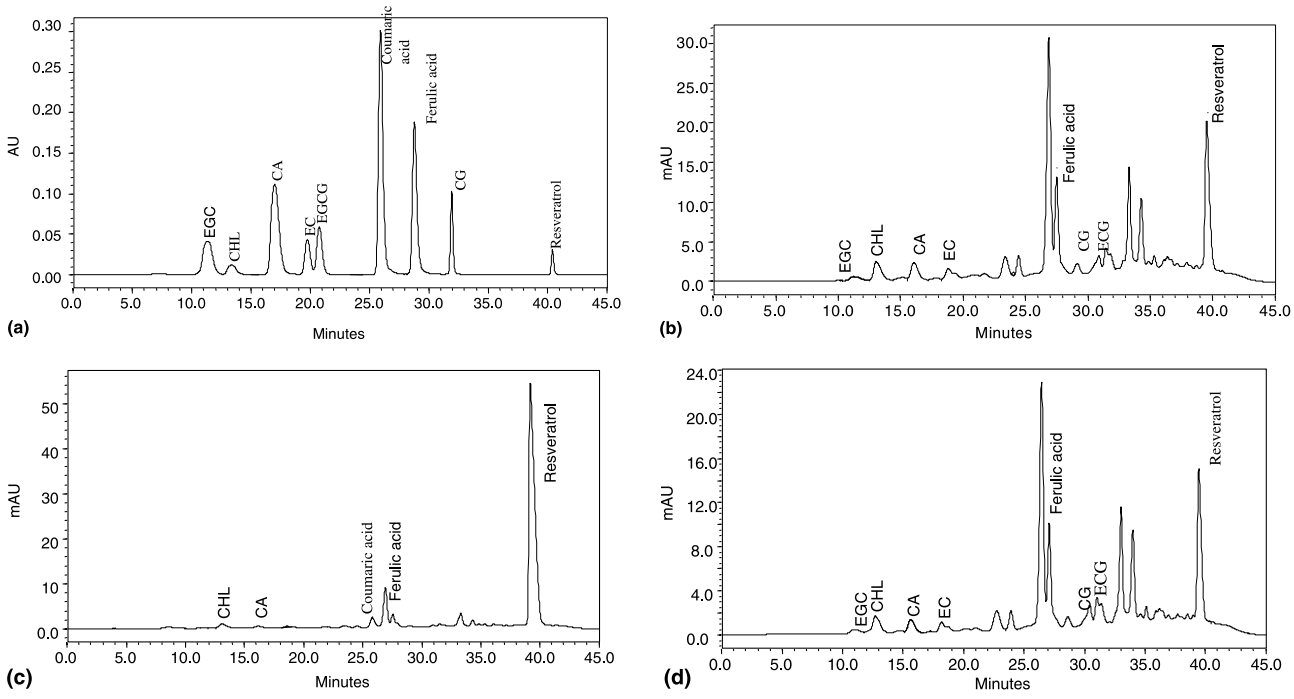

Fig. 4. HPLC chromatograms of (a) polyphenol standards and water extracts from (b) raw skin, (c) blanched skin and (d) roasted peanut skin, where EGC = epigallocatechin, CHL = chlorogenic acid, CA = caffeic acid, EC = epicatechin, EGCG = epigallocatechin gallate, CG = catechin gallate and ECG = epicatechin gallate.

extract (Fig. 4(c)) was different from that Fig. 4(b) and (d). The major compound in blanched peanut skin extract was resveratrol. This HPLC profile is consistent with the pattern observed in total phenolic concentration and total antioxidant activity where blanched peanut skin extract was significantly different from the extracts of peanut skins removed by directly peeling and roasting. Phenolic acids, although their antioxidant activity were not studied as extensively as flavonoids, are important antioxidants of fruits and beverages because of their high concentrations. An example is chlorogenic acid in apples and apple juice. Flavonoids found in peanut skin extracts are present in green tea and grape seeds and are major components that have been demonstrated to have multiple human health benefits, such as lower LDL level of serum/liver, inhibition of LDL oxidation thus preventing cardiovascular diseases, protection of DNA from free radical attack leading to lower the risk of cancer, inhibition of the release of histamine thereby preventing inflammation.

4. Conclusions

The results of this study indicate that peanut skin is very rich in phenolics and its total phenolics content was as high as 90–125 mg per gram dry skin, depending on how the skin was removed from peanut kernels. Compared to direct peeling, blanching caused significant loss of total phenolics in peanut skin, while roasting resulted in higher total phenolic concentration in the extracts. Solvents used for extraction also affected the concentration of total phenolics in extracts. Ethanol was proven to be a more efficient solvent for phenolic extraction from peanut skin. Total antioxidant activity of peanut skin extract was linearly proportional to the concentration of total phenolics. TAAs of peanut skin extracts ranged from 3.39 to 4.10 TEAC. The compounds found in peanut skin are considered potent antioxidants, particularly, flavonoids and resveratrol. The comparative study of total antioxidant activities of peanut skin extracts and green tea infusions demonstrates that peanut skin extracts had chemically higher antioxidant potential than green tea infusions. Catechins that give green tea the capability to lower LDL in human serum and liver, and to lower the risk of cardiovascular disease and cancer, procyanidins and resveratrol that are present in grape and red wine, are all found in peanut skin in different levels. This makes peanut skin a good and an inexpensive source of those bioactive compounds. More work is needed to identify and quantify phenolic compounds in peanut skin extracts, to test their antioxidant activity in biological systems, and to test the contribution of each individual compound to the total antioxidant activity. Furthermore, positive confirmation of phenolics in peanut skin via LC-MS is also needed.

References

Alper, C. M., & Mattes, R. D. (2002). Effects of chronic peanut consumption on energy balance and hedonics. *International Journal of Obesity, 26*, 1129–1137.

Awad, A. B., Chan, K. C., Downie, A. C., & Fink, C. S. (2000). Peanuts as a source of B-sitosterol, a sterol with anticancer properties. *Nutrition and Cancer, 36*, 238–241.

Arnao, M. B., Cano, A., & Acosta, M. (1999). Methods to measure the antioxidant activity in plant material. A comparative discussion. *Free Radical Research, 31*, 589–596.

Cano, A., Herandez-Ruiz, J., Garcia-Canovas, F., Acosta, M., & Arnao, M. B. (1998). An end-point method for estimation of the total antioxidant activity in plant material. *Phytochemical Analysis, 9*, 196–202.

Cao, G., Sofic, E., & Prior, R. L. (1997). Antioxidant and prooxidant behavior of flavonoids: Structure–activity relationship. *Free Radical Biology and Medicine, 22*, 749–760.

Engelhardt, U. (2001). Flavonoids-Analysis. *Critical Review in Food Science and Nutrition, 41*, 398–399.

Feldman, E. B. (1999). Assorted monounsaturated fatty acids promote healthy hearts. *American Journal of Clinical Nutrition, 70*, 953–954.

Fremont Lucie (2000). Minireview: Biological effects of reveratrol. *Life Science, 66*, 663–673.

Hara, Y. (2001). Methods of extracting polyphenolic constitutes of tea leaves. In *Green tea – health benefits and application* (pp. 22–25). New York (Basel): Marcel Dekker, Inc..

Jane, M. S., Cai, E. N., Udeani, G. O., Slowing, K. V., Thomas, C. F., Beecher, C. W. W., et al. (1997). Cancer chemopreventive activity of resveratrol, a natural product derived from grapes. *Science, 275*, 218–220.

Kris-Etherton, P. M., Pearson, T. A., Wan, Y., Hargrove, R. L., Moriarty, K., & Fishell, V. (1999). High-monounsaturated fatty acid diets lower both plasma cholesterol and triacylglycerol concentration. *American Journal of Clinical Nutrition, 70*, 1009–1015.

Lee, J. 2002. USDA Press Release.

Lien, E. J., Ren, S., Bui, H., & Wang, R. (1999). Quantitative structure–activity relationship analysis of phenolic antioxidants. *Free Radical Biology and Medicine, 26*, 285–294.

Lou, H. X., Yamazaki, Y., Sasaki, T., Uchida, M., Tanaka, H., et al. (1999). A-type procyanidins from peanut skin. *Phytochemistry, 51*, 297–308.

Miller, N. J., & Rice Evans, C. A. (1995). Antioxidant activity of resveratrol in red wine. *Clinical Chemistry, 41*, 1789.

Miller, N. J., Diplock, A. T., & Rice-Evans, C. A. (1995). Evaluation of total antioxidant activity as a marker of the deterioration of apple juice on storage. *Journal of Agricultural and Food Chemistry, 43*, 1794–1801.

Nepote, V., Grosso, N. R., & Guzman, C. A. (2002). Extraction of antioxidant components from peanut skins. *Grasas Y Aceites, 54*(4), 391–395.

Peanut-Institute, 2002. Antioxidants from food sources, like peanuts and peanut butter, may protect against Alzheimer disease. June 26, Press Release.

Renaud, S., & de Lorgeril, M. (1992). Wine, alcohol, platelets, and the French paradox for coronary heart disease. *The Lancet, 339*, 1523–1526.

Sanders, T. H., McMichael, R. W., & Hendrix, K. W. (2000). Occurrence of resveratrol in edible peanuts. *Journal of Agricultural and Food Chemistry, 48*, 1243–1246.

SAS, 2000. Release 8.02e SAS Institute, Cary, NC, USA.

Sanders, T. H. (2001). Non-detectable levels of *trans*-fatty acids in peanut butter. *Journal of Agricultural and Food Chemistry, 49*, 2349–2351.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphotungstic acid reagents. *American Journal of Enology Viticulture, 16*, 2349–2351.

Sobolev, V. S., & Cole, R. J. (1999). *Trans*-Resveratrol content in commercial peanuts and peanut products. *Journal of Agricultural and Food Chemistry, 47*, 1435–1439.