ADAN J. Agric. 2024, 5: 95-104 **DOI:10.36108/adanja/4202.50.0111**

ISSN 2736-0385

Effect of processing on nutritional content of Peanut (*Arachis hypogaea*) skin waste as functional food and feed

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Abstract
This study assessed the nutritional content of peanut skin (PS) (Arachis hypogaea) using different processing methods. Roasted Peanut Skin (RoPS) were collected from peanut vendors, Boiled Peanut Skin (BPS) obtained by cooking peanut to boiling temperature 100˚C and PS hand peeled, while Raw Peanut Skin (RaPS) were obtained by air drying and skin hand peeled. Samples were milled to finesse and analysed for proximate, anti-nutritional factors (ANF), mineral content, amino acid and fatty acid profile of PS according to standard methods. The result showed that BPS had high protein (21.85%). Application of heat on RoPS significantly increased ash content (20.44%) and BPS reduced significantly ether (1.60%) and crude fibre content (1.39%). Variations in mineral content was noticed in the samples with significant difference. The ANF were present in appreciable quantities while boiling reduced the ANF significantly in PS except in alkaloids. The amino acid profile level was enhanced by boiling PS while roasting reduced some of the amino acid content. The fatty acid profile indicated that RoPS had a high percent of fatty acids and lowered by boiling in BPS sample. This study noted that PS possess valuable nutritional qualities. The boiling process could be an effective method to reduce the levels of ANF and increase the protein content while roasting is adopted for improvement of the fatty acid content.

***Keywords:** Arachis hypogaea, By-product, Peanut skin, Waste.*

Introduction

Processed peanut consumption is relished as snacks either boiled or roasted with the hull and eaten in roasted form with or without the peanut skin. Peanut skins protect the testa and peanut skin waste is used in different products as food, feed, drinks and beverage (NPRL 2009, American Peanut Council 2010, Davis *et al.*, 2010). Peanut skin are by-products of low value from the peanut processing industry whose rate of disposal has increased presently (NPRL 2009). In terms of commercial value PS have no adduced price (Lee, 2002; Toomer *et al.*, 2021). Processing methods have resulted in different quantification of chemical and nutritional contents of PS. Nepote *et al.*, (2002b) noted that defatting increase PS content, while Yu *et al.*, (2005) reported that non-defatted PS revealed decreased content in phenolic compounds. The peanut industry generated enormous waste of PS worldwide to the tune of over 754,000 metric ton from 29 million tons of groundnut (Sobolev and Cole, 2004). World production of peanut skins is estimated to reach as much as 1mmt annually (Davis *et al.*, 2010). While Arya *et al.*, (2016) reported

that 31mmt of PS has no economic value and therefore discarded as waste annually. Toomer *et al.,* (2021) further noted that PS contain beneficial nutrients that can enhance functional food and feed of human and livestock. The addition of 5% (w/w) of PS into peanut based products improved the nutritional profile of these product and higher concentration reduced flavor and acceptability (Hathorn and Sanders, 2012). Nepote *et al.,* (2002a) reported that peanut skins contain higher source of phenolic compounds than the hulls, while Elsorady and Ali (2018) confirmed PS as sources of phytochemicals. This study assessed the nutritional content of peanut *Arachis hypogaea* skin using different processing methods. The samples were analysed for proximate, anti-nutritional factors, mineral content, amino acid and fatty acid profile.

Materials and Methods

Raw groundnut seeds of 2kg was purchased from local market. The method of Van Ha *et al.,* (2007) for PS removal was adopted. The PS was removed by hand peeling 1 kg of air-dried raw groundnut to obtain RaPS, boiling 1kg of raw groundnut to obtain BPS and collection of RoPS from vendors of roasted peanut. The PS obtained were milled and samples were analysed in the laboratory. Proximate analysis was determined according to the methods of AOAC (2005). Mineral content was analysed using Model NV 210/211 Buck Scientific Atomic Absorption Spectrophotometer machine, UK and JENWAY Instrument Flame Spectrophotometer, Ontario Canada Flame Photometer machine using wet ashing method with perchloric and nitric acid at the Department of Agronomy, University of Ibadan. The determination of phytochemical properties was according to the procedure described by Harbone (1973); Marcano and Hasenewa (1991). The phytochemical studied were tannin, saponin, phytate, alkaloid, oxalate and hydrogen cyanide content. Amino acid determination was by spectrophotometric using ninhydrin chemical reaction. The different wavelengths of amino acid from the hydrolysate was calculated from the formula of sample absorbance, gradient factor and dilution factor. Fatty acid was determined by thin layer chromatography plus spectrophotometric of fatty acids in oil and oil product according to the methods of Baker (1964), Lowry and Tinsley (1976) at the Department of Animal Science, University of Ibadan.

Statistical Analysis

Data were analysed using SPSS 20 Analysis of variance and results presented as means while significance was tested at 95% level using Duncan Multiple Range Test.

Results and Discussion

Processing methods and proximate composition

The analysed parameters of PS processed differently is presented in Table1. The proximate content parameters differed significantly ($P<0.05$) among the treatment methods. The crude protein of PS was improved by boiling over RaPS while roasting decrease the protein content. Ash content analysis in RoPS was significantly different ($P<0.05$) from BPS and RaPS. Roasting increased ether extract in RoPS while there was no significant difference in ether extract of both RaPS and BPS. The crude fibre was increased by roasting while boiling decreased fibre content when compared to RaPS. Boiling in water made the moisture content of BPS to increase due to the absorption of water from the medium, while roasting decrease the moisture content over RaPS. The level of carbohydrate content was significantly affected by

roasting as it reduced it to the least among the treatments.

The processing methods applied in this study conformed with previous studies. Van Ha *et al.,* (2007) studied 3 samples of peanuts which were peeled by hand and finely powdered in laboratory research, denoting low cost peeling method used to optimize research conduct. Dry blanching has been used to separate skins from peanut kernels (Sobolev and Cole, 2004). While, Yu *et al.,* (2006) confirmed that roasting is a practice in peanut industry used to achieve the removal of PS, and also confirmed processing PS by 3 methods: peeling raw peanut with hand, peeled after wet blanching and after roasting. Cloviece (2011) also subjected PS to 3 different heat treatment methods when PS are to be incorporated into dietary peanut butter. From literature the protein content was within the range of 16-18% (Ahmed and Young, 1982); 19.8% West *et al.,* (1993). Heuze *et al.,* (2017) protein ranged for PS 13.1-21.4%; Min *et al.,* (2019) 19.4%; Nepote *et al.,* (2002b) 12% for peanut skins. However, Abdulrazak *et al.,* (2014) noted low protein (4.43%) in PS. Varying protein for PS also reported by Mostafa *et al.,* (2022) 5.59% for roasted PS; De Camargo *et al.,* (2021) 4.66% for dry blanched PS; Munoz-Arrieta *et al.,* (2021) 8.88-12.7% for raw frozen PS and Sulieman *et al.,* (2014) 9.2% for washed oven dried PS respectively.

The ash content was noted to be affected by different methods of processing used in enhancing the functionality of PS in food and feed. Ash content in RoPS was highest and least in RaPS. Nepote *et al.,* (2002); Abdulrazak *et al.,* (2014); De Camargo *et al.,* (2021); Munoz-Arrieta *et al.,* (2021); Mostafa *et al.,* (2022) reported low ash content 2.83%; 2.5%; 2.89%; 2.07-2.13%; 1.87%, while Sulieman *et al.,* (2014) reported high ash content 9.42% which was within the range for this study. Heuze *et al.,* (2017) ash was within range (2.4-11.8%) for this study except in RoPS.

Peanut seed is noted to be rich in oil hence its use in production of cooking oil. West *et al.,* (1993) noted high ether extract (24.34%) in PS. Nepote *et al.,* (2002a; 2002b) reported 16% fat for defatted peanut skins. Heuze *et al.,* (2017) 3.3-27.3%; Toomer, (2020) 19%; Munoz-Arrieta *et al.,* (2021) 9.59-10.2%; Mostafa *et al.,* (2022) 20.68% revealed high concentration which contradicts our findings. The low level of ether extract in BPS can be as a result of the loss of oil into the medium of boiling, while roasting released some of the oil in it to the RoPS due to heat treatment. This low lipid was inline with the findings of Abdulrazak *et al.,* (2014) 0.50%. Cultivar variation also affected the ether content in peanut kernels and PS (Mahatma *et al.,* 2016; Munoz-Arrieta *et al.,* 2021). Fibre content was increased by roasting in this study but lower to values in literature. Abdulrazak *et al.,* (2014) noted high fibre (59.0%); Heuze *et al.,* (2017) (11.6-44.8%); Toomer (2020) (12%); Munoz-Arrieta *et al.,* (2021) 39-43% which were higher than values in this study.

Moisture in food is a precursor to spoilage. Roasting reduced the moisture content in PS. Although, Mostafa *et al.,* (2022) moisture content (2.34%) in PS is very low, which is similar to the low value reported in this study, while this corroborated Munoz-Arrieta *et al.,* (2021) of a longer shelf for the PS to be used as functional food. Moisture content in food and feed need to be reduced to the barest minimum which will inhibit growth of spoilage organisms. The CHO content was within the range reported by Nepote *et al.,* (2002) 69.8% and Mostafa *et al.,* (2022) 55.33%. However, Yu *et al.,* (2005) reported much higher value of 72% CHO for defatted peanut skins while Abdulrazak *et al.,* (2014)

noted lower CHO 25.57%. This study revealed that boiling improved the protein content and roasting denatured the protein due to heat treatment, while roasting increased the ash content as a result of the heat applied to the PS.

Table 1: Proximate composition of differently processed peanut skin

Parameters	RaPS %	RoPS %	BPS%
Crude protein	19.65±0.05^{b}	16.67±0.05^{c}	21.85±0.05^{a}
Ash content	2.09±0.03^{c}	20.44±0.66^{a}	7.08±0.28^{b}
Ether extract	1.69±0.02^{b}	2.95±0.21^{a}	1.60±0.14^{b}
Crude fibre	1.81±0.02^{b}	2.86±0.06^{a}	1.39±0.05^{c}
Moisture content	8.40±0.01^{b}	7.47±0.04^{b}	9.82±0.15^{a}
Nitrogen free extract	66.36±0.21^{a}	49.61±0.44^{c}	58.26±0.17^{b}

Row means values (±SE) with different superscripts are different significantly (P<0.05)

Mineral Content of differently processed peanut skin

The mineral content analysis (Table 2) differed significantly (P<0.05) except with phosphorus which compared among treatments. In BPS Ca, Mg, K, Mn and Cu were high in values. In RaPS the values of Fe and Zn were highest, while it was only Na that was highest in RoPS. The Ca, P, K, Na, Mg and Cu in this study were higher than range values in Heuze *et al.,* (2017); Fe was within the range value 262-269 mg/kg; while Mn and Zn values were high than our study, except for the Zn value in RaPS which was within the range reported. The values for mineral were higher than reported values of Abdulrazak *et al.,* (2014) except for Zn 38mg/kg and Mn 45mg/kg. According to Abdelrahim *et al.,* (2012) the mineral composition of PS will depend on the peanut variety. Sulieman *et al.,* (2014) reported values for Fe (1004 ppm), Cu (143 ppm) and Zn (4 ppm). Munoz-Arrieta *et al.,* (2021) noted the predominance of copper and zinc in PS while K>Mg>P for PS from three cultivars. Processing was noted to reduce the Fe content while the high Na RoPS was as a result of the addition of NaCl salt to add taste to the peanut to enhance eating quality.

Table 2: Mineral content of differently processed peanut skin

Parameters	RaPS	RoPS	BPS
Calcium (%)	9.80±0.03^{c}	12.70±0.31^{b}	19.10±0.53^{a}
Magnesium (%)	32.90±0.92^{a}	27.40±0.51^{b}	34.10±0.74^{a}
Potassium (%)	47.50±0.65^{b}	49.60±0.76^{b}	81.30±0.89^{a}
Sodium (%)	14.10±0.22^{c}	697.50±10.14^{a}	24.20±0.34^{b}
Phosphorus (%)	3.10±0.02	3.30±0.02	2.90±0.10
Manganese (mg/kg)	17.70±0.17^{a}	16.10±0.41^{b}	18.25±0.73^{a}
Iron (mg/kg)	439.25±15.21^{a}	318.95±11.04^{c}	333.75±13.01^{b}
Copper (mg/kg)	48.10±0.83^{b}	51.70±0.51^{a}	52.90±0.47^{a}
Zinc (mg/kg)	30.95±0.46^{a}	24.05±0.31^{b}	22.55±0.13^{b}

Row means values (±SE) with different superscripts are different significantly (P<0.05)

Phytochemical content of differently processed peanut skin

The phytochemical analysis (Table 3) differed significantly ($P<0.05$) noting that boiling has effect on reducing phytochemical except in alkaloids. Oxalate, saponin, tannin, phytate and HCN were highest in RaPS and decreased due to the effect of roasting and boiling PS. Alkaloids was highest in BPS and least when PS is roasted. The values obtained were higher to the studies of West *et al.,* (1993) for tannin 18.17mg/kg except in BPS. Van Ha *et al.,* (2007) did not detect tannins in PS when hexane was used to extract, while with the use of ethyl acetate (av. 2.83) and methanol extract (av. 22.56) were obtained. Tannin in the form of tannic acid (94.0 mg/kg-238.0 mg/kg) (Heuze *et al.,* 2017) was high when compared with this study. Abdulrazak *et al.,* (2014) discovered oxalate 220mg/100g, phytate 362.1mg/100g at higher concentrations over this study. The HCN in this study for BPS was similar to Abdulrazak *et al.,* (2014) 1.6 mg/100g. The view of Heuze *et al.,* (2017) that tannin in PS can be high is hereby corroborated by this study.

Table 3: Phytochemical content of differently processed peanut skin

Parameters mg/kg	RaPS	RoPS	BPS
Oxalate mg/kg	25.06 ± 1.04^{a}	18.02 ± 0.57^{b}	8.41 ± 0.22^{c}
Alkaloid mg/kg	10.31 ± 0.06^{b}	8.65 ± 0.03^{c}	11.38 ± 0.04^{a}
Saponin mg/kg	18.42 ± 0.27^{a}	16.74 ± 0.30^{b}	14.21 ± 0.16^{c}
Tannin mg/kg	58.05 ± 0.31^{a}	24.22 ± 0.25^{b}	14.01 ± 0.40^{c}
Phytate mg/kg	60.04 ± 1.02^{a}	40.42 ± 0.85^{b}	20.01 ± 0.01^{c}
HCN mg/kg	8.89 ± 0.17^{a}	3.56 ± 0.05^{b}	1.69 ± 0.06^{c}

Row means values (±SE) with different superscripts are different significantly ($P<0.05$)

Amino acid profile of differently processed peanut skin

The amino acid profile (Table 4) revealed observable difference with highest values in BPS (isoleucine, leucine, lysine, threonine, histidine, phenylalanine, valine, alanine, arginine, aspartic acid, glutamic acid, glycine, proline); followed RoPS (methionine, tryptophan, cysteine, ornithine, pyrolysine) while RaPS have highest values in serine and tyrosine.

The methionine in this study was higher than 0.4% reported by Heuze *et al.,* (2017) for PS. The reason for the difference has been reported by Elsorady and Ali (2018) that in peanut roasting, soluble proteins and amino acids are changed as a result of moisture losses and formation of derivatives as a result of Millard reaction. Munoz-Arrieta *et al.,* (2021) noted that variety affected the concentration of EAA which ranged 5.78 to 11.1 mg/g, whereas the concentration of NEAA ranged from 10.0–21.7 mg/g for then three PS. These values are low and contradicts our findings.

The ratio of EAA/AA of 52.66% was greater than 34 % reported by Munoz-Arrieta *et al.,* (2021).

In our study, leucine and threonine were more predominant than lysine and phenylalanine EAA, whereas glutamic acid and arginine more predominant than glycine and glutamine NEAA of Munoz-Arrieta *et al.,* (2021). The EAA/NEAA ratio is twice that reported by Munoz-Arrieta *et al.,* (2021) although they opined that this low level is the best based on literature for models used in nutritional studies. This study ascertain that higher levels of this ratio reported will be beneficial to human and animals due to the processing and low level of anti-nutritional factors.

Table 4: Amino acid profile of differently processed peanut skin

Essential amino acid	RaPS %	RoPS %	BPS%
Isoleucine	1.36±0.01^{b}	1.26±0.01^{c}	2.65±0.01^{a}
Leucine	2.91±0.01^{c}	3.83±0.01^{b}	4.05±0.00^{a}
Lysine	1.77±0.01^{b}	1.47±0.01^{c}	2.65±0.01^{a}
Methionine	1.57±0.02^{b}	2.27±0.01^{a}	1.91±0.01^{b}
Threonine	2.20±0.01^{b}	2.03±0.01^{c}	2.68±0.01^{a}
Tryptophan	1.18±0.01^{b}	1.48±0.01^{a}	1.27±0.01^{b}
Histidine	1.26±0.01^{c}	1.35±0.01^{b}	1.43±0.01^{a}
Phenylalanine	1.73±0.01^{b}	1.27±0.00^{c}	2.04±0.01^{a}
Valine	0.64±0.01^{b}	0.54±0.01^{c}	0.80±0.01^{a}
Non- Essential amino acid			
Alanine	0.10±0.01^{c}	0.17± 0.01^{b}	0.83±0.27^{a}
Arginine	1.72±0.01^{b}	1.60±0.02^{c}	2.17±0.01^{a}
Aspartic acid	1.04±0.01^{b}	0.73±0.04^{c}	1.35±0.00^{a}
Cysteine	0.26±0.01^{b}	0.34±0.01^{a}	0.22±0.01^{b}
Glutamic acid	3.59±0.01^{c}	4.16±0.01^{b}	5.93±0.25^{a}
Glycine	1.47±0.01^{b}	1.41±0.01^{c}	1.63±0.01^{a}
Ornithine	0.13±0.01^{c}	0.40±0.01^{a}	0.24±0.01^{b}
Pyrolysine	0.30±0.01^{b}	0.54±0.01^{a}	0.32±0.01^{b}
Proline	1.50±0.01^{b}	1.37±0.01^{c}	1.82±0.01^{a}
Serine	1.87±0.01^{a}	1.66±0.01^{c}	1.77±0.01^{b}
Tyrosine	1.49±0.01^{a}	1.11±0.01^{c}	1.38±0.01^{b}
Total AA	28.09	28.99	37.14
Total EAA	14.62	15.50	19.48
Total NEAA	13.47	13.49	17.66
EAA/AA ratio	0.52	0.54	0.53
EAA/NEAA ratio	1.09	1.15	1.10

Row means values (±SE) with different superscripts are different significantly ($P<0.05$) n = 2 samples determination

Fatty acid profile of differently processed peanut skin

The fatty acid profile (Table 5) noted difference with RoPS>RaPS>BPS. The effect of roasting was able to release the oil content more which was also evident in the ether extract value of RoPS. The values for lauric, myristic, palmitic in this study were higher than obtained by West *et al.*, (1993) lauric 0.02, myristic 0.16, palmitic 10.25; while the values for stearic 1.85, oleic 43.29, linoleic 43.99 were higher than in this study. According to Kris-Etherthorn *et al.*, (1999) the mono and poly-unsaturated fatty acids in PS makes it a product to be used as a functional food. Sobolev and Cole, (2004) studied the fatty acids in total oil in PS and kernels used in processed dietary products. The values in this study were low compared to Sobolev and Cole, (2004) for palmitic 8.45-17.33; stearic 2.10-3.76; oleic 36.24-52.86; linoleic 12.71-37.54, while in RoPS behenic and ligoleric were within the range (1.13-8.81; 1.30-3.70) reported in their study. Sobolev and Cole, (2004) further reported that increased temperature has effect on oil released from PS. The reasons for the variations in fatty acid could be as a result of the factors (cultivar, stage of harvest, environmental condition) reported by Sekhon *et al.*, (1973) cited in Sobolev and Cole, (2004). The values of oleic and linoleic

acid were low to Davis and Dean (2016) who affirmed that variations in oil content was as a result of varietal differences of peanut cultivar.

According to Munoz-Arrieta *et al.*, (2021) nutritional value can be estimated by PUFA/SFA content. A range >0.45 has been noted for the prevention of cardiovascular health and below this value blood cholesterol may increase. The low values of PUFA/SFA in this study may be the cause health related problems of cardiovascular and cholesterol of the blood in people as more peanut will need to be consumed to meet up the difference of >0.25 PUFA/SFA.

Table 5: Fatty acid profile of differently processed peanut skin

Saturated fatty acid (SFA)	**RaPS %**	**RoPS %**	**BPS%**
Acetic acid C2:0	0.65±0.01^{b}	1.24±0.01^{a}	0.32±0.00^{c}
Propionic C3:0	0.35±0.01^{b}	0.67±0.01^{a}	0.17±0.00^{c}
Butyric C4:0	0.26±0.01^{b}	0.51±0.01^{a}	0.13±0.00^{c}
Valeric C5:0	0.31±0.01^{b}	0.59±0.00^{a}	0.15±0.00^{c}
Caprylic C8:0	0.43±0.01^{b}	0.83±0.01^{a}	0.22±0.00^{c}
Lauric C12:0	0.60±0.01^{b}	1.15±0.01^{a}	0.28±0.00^{c}
Myristic C14:0	0.68±0.01^{b}	1.31±0.01^{a}	0.34±0.00^{c}
Palmitic C16:0	1.77±0.02^{b}	4.48±0.01^{a}	1.38±0.00^{c}
Margaric C17:0	0.81±0.02^{b}	1.56±0.01^{a}	0.40±0.01^{c}
Stearic C18:0	0.85±0.02^{b}	1.64±0.14^{a}	0.42±0.01^{c}
Behenic C22:0	1.02±0.02^{b}	1.96±0.01^{a}	0.51±0.01^{c}
Lignoceric C24:0	1.11±0.02^{b}	2.12±0.02^{a}	0.55±0.01^{c}
Mono Unsaturated fatty acid (MUFA)			
Palmitoleic C16:1n7	0.76±0.02^{b}	1.46±0.01^{a}	0.38±0.00^{c}
Oleic C18:1n9	1.85±0.02^{b}	2.63±0.01^{a}	1.42±0.01^{c}
Poly Unsaturated fatty acid (PUFA)			
Linoleic C18:2n6	0.84±0.02^{b}	1.61±0.01^{a}	0.42±0.01^{c}
Arachidonic C20:4n6	0.91±0.02^{b}	1.75±0.01^{a}	0.45±0.01^{c}
Total SFA	8.84	18.06	4.87
Total MUFA	2.61	4.09	1.8
Total PUFA	1.75	3.36	0.87
PUFA/SFA ratio	0.197	0.186	0.178
MUFA/SFA ratio	0.29	0.23	0.36

Row means values (±SE) with different superscripts are different significantly ($P<0.05$). n =2 samples determination

Conclusion and Recommendation

This study noted that processing by boiling and roasting has effect on the nutritional content of peanut skin. Boiling improved the protein content while roasting denatured the protein and carbohydrate, while increasing the ash, fibre and ether extract. Mineral content was improved by processing in calcium, potassium, sodium and copper. Similar trend was observed with phytochemicals as raw peanut skin were higher in values. Boiling was found to improve amino acid content of peanut skin, while the fatty acid profile was more in the roasted peanut skin. This study hereby recommends boiling and roasting of peanut in other to take full advantage of the nutrient embedded in peanut skin.

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