NUTRITIVE VALUE AND INHERENT ANTI-NUTRITIVE FACTORS IN PROCESSED PEANUT (*ARACHIS HYPOGAEA)*

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Abstract
Processing conditions and even the form of the food being processed as they affect nutrient availability is critical to develop structured foods to meet the nutritional needs of end users. The effect of heat treatments (roasting, boiling and autoclaving) on the physical, nutritional and functional properties of in-shell and shelled peanut (Arachis hypogaea) was determined. Unprocessed shelled peanut served as the control. Nutrient and anti-nutrient compositions of peanut samples were determined by standard methods, while physical (colour) and functional properties were also carried out. Analysis of variance was used to analyze the treatment groups and Duncan's multiple range tests to determine significant difference at p≤0.05. The result of proximate composition revealed that raw peanut had protein (32.7%), ash (1.37%), fibre (5.15%), fat (42.9%) and carbohydrate (12.1%). However, processing methods significantly increased the fat and ash contents. Peanut is high in calcium, magnesium and potassium but low in iron and zinc; processing significantly increased the elemental concentration of peanut. Phytate, tannin, oxalate, alkaloid, trypsin inhibitor and flavonoid were determined in the peanut samples and all were significantly affected by the processing method employed. However, boiling of shelled peanut was more effective in reducing the anti-nutrients than roasting and autoclaving. The aflatoxin concentration was in a range of 2.06-8.05 ppb. Shelled peanuts subjected to the processing methods had lower aflatoxin levels compared with in-shell processed peanuts. There exist variation in bulk densities (packed and loosed), water and oil absorption capacities as a result of processing method employed. The colour of peanut was significantly affected by the processing method. In general, processing of shelled peanut resulted in flour with better nutritional quality and functionality than in-shell peanut. The findings showed that boiling has proved to be an efficient method in processing of peanut.

Key words: Peanuts, shell, colour, nutrition, aflatoxin, anti-nutrient.

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INTRODUCTION

Peanut (*Arachis hypogaea*), also known as groundnut is a legume crop from the family *Leguminosae* or *Fabaceae*, native to Mexico, South and Central America (Gibbon,1985). The list of the five largest producing countries is headed by China with a production of 33,309,998 tonnes,followed by India with 6,857,000 tonnes, Nigeria with 3,028,571 tonnes, the United States with 2,578,500 tonnes and Sudan with 1,826,000 tonnes (FAOSTAT, 2016). The leading producing state in Nigeria is Niger state and peanut has contributed extremely to Nigeria economy through the sales of seeds, cakes, oil and haulms (Olorunju *et al*., 1999). Peanuts can be boiled, roasted with or without addition of sugar and salt and may be processed into other forms such as peanut butter, groundnut soup, groundnut oil peanut flour, etc. Large number of people eat processed peanut while a few eat it raw. Peanut is an excellent source of protein and also has high fat content which contributes to their use as oil seeds. Peanut is however low in carbohydrate though high in protein, fat and fibre which contribute to their very low glycemic indexhereby making it suitable for diabetic patients (Foster-Powell *et al*., 2002). On a 100 –point scale, the glycemic index (GI) of peanuts is 14, and the glycemic load (GL) of peanuts is one. More so, research has shown that when peanuts are added to a high glycemic load meal, they actually keep the blood sugar stabilized so that it does not rise too high too quickly (Johnson *et al*., 2007). The vitamins and minerals found in peanuts

include: folate, niacin, thiamine, riboflavin, choline, magnesium, potassium, zinc, iron and selenium (Segura *et al*., 2006).
Asides, peanut contain phytochemicals such as flavonoids and antinutrients such as phytic acid, trypsin inhibitor, tannin, saponin, etc. and all these inhibit the absorption of some nutrient in the diet. Beside the anti-nutritional factors, peanuts are particularly vulnerable to contamination by fungi *Aspergillus flavus* and *Aspergillus parasiticus*. These fungi produce aflatoxins that are known to cause cancer in humans, lower immune response and impair growth in children (Wild and Yong, 2010). As a result of this, significant risk is attached to eating raw peanuts (Robert *et al*., 1968). Major process steps include processing peanuts for in-shell consumption and shelling peanuts for other uses. Peanuts are usually consumed after roasting or boiling in the shell or without the shell and are available in Nigeria throughout the year.
The knowledge of how processing conditions and even the form of the food being processed as they affect nutrient availability are critical to develop structured foods to meet the nutritional needs of end users. No comprehensive study has been reported simultaneously to show nutritional qualities of shelled and in-shell peanut growing in African tropics as affected by processing conditions. The processing of peanut in or out of shell will allow the products to be distinguished and their constituents to be checked. This study is aimed at evaluating the effect of processing conditions (roasting, boiling and autoclaving) on physical, nutritional and functional properties of shelled and in-shell peanuts.

MATERIALS AND METHODS

1. Sample collection

In-shell peanuts were purchased from Bodija market, Ibadan, Oyo State, Nigeria and transported in polyethylene bags to the laboratory.

2. Treatment of samples

In-shell peanuts were sundried and processed as follows:

2.1. Raw peanut

In-shell peanuts (300g) were shelled and the nuts collected. The nuts were oven-dried to constant weight and milled into flour. The peanut flour was then packed in plastic container and kept in freezer (-4°C) pending analysis. This served as the control sample.

2.2. Roasting of in-shell peanuts

In-shell peanuts were roasted according to Ayoola and Adeyeye (2010). About 300 g of the dried pods were put into an iron pot and mixed withclean fine sand and stirred to prevent burning of the sample and to ensure uniform distribution of heat. The peanuts pods were roasted for 30 min at 120-130°C usingGallenkamp thermostat hot plate until a characteristic brownish nutty smell seeds were obtained which indicated complete roasting. The sand was then separated from the roasted pods using a sieve and allowed to cool. Thereafter, the pods were shelled and the peanuts collected. The nuts were then milled into flour, packed inplastic container and kept in freezer (-4°C) pending analysis.

2.3. Roasting of shelled peanuts

Shelled peanuts were roasted according to Ayoola and Adeyeye (2010). About 150 g of the shelled peanut were put into an iron pot and mixed withclean fine sand and stirred to prevent burning of the sample and to ensure uniform distribution of heat. The peanuts were roasted for 25 min at 120-130°C using Gallenkamp thermostat hot plate until a characteristic brownish nutty smell seeds were obtained which indicated complete roasting. The sand was then separated from the peanuts using a sieve. The nuts were cooled, milled into flour, packed inplastic container and kept in freezer (-4°C) pending analysis.

2.4. Boiling of in-shell peanuts

In-shell peanuts were boiled according to Ayoola and Adeyeye (2010). About 300 g of the dried peanut pods were put in aluminium pot, tap water added (peanut pods/water ratio 1:5 w/v), and cooked at 85-90°C on a Gallenkampthermostat hot plate. The peanut pods got cooked after about 2½ hr. The nuts were consideredcooked when they became soft to touch on pressing between the thumb

andfingers. At the end of cooking time, the boiling water was drained and nuts were removed from pods and oven-dried to constant weight. The nuts were then milled into flour, packed in plastic bottles and kept in freezer (-4°C) pending analysis.

2.5. Boiling of shelled peanuts

Shelled peanuts were boiled according to Ayoola and Adeyeye (2010). About 150 g of the shelled peanuts were put in aluminium pot, tap water added (peanut/water ratio 1:5 w/v), and cooked at 85-90°C on a Gallenkampthermostat hot plate. The shelled peanut got cooked after about 2 hr. The nuts were consideredcooked when they became soft to touch on pressing between the thumb andfingers. At the end of cooking time, the boiling water was drained and the nuts were oven-dried to constant weight. The nuts were then milled into flour, packed in plastic container and kept in freezer (-4°C) pending analysis.

2.6. Autoclaving of in-shell peanuts

In-shell peanuts (300g) were autoclaved using vertical autoclave at 15 lb pressure (121°C) in tap water (1:2 w/v) for 1 hr. The nuts were considered cooked when they became soft to touch on pressing between the thumb andfingers. After autoclaving, the water was drained and nuts were removed from pods and oven-dried to constant weight. The nuts were then milled into flour, packed in plastic container and kept in freezer (-4°C) pending analysis.

2.7. Autoclaving of shelled peanuts

Shelled peanuts (150g) were autoclaved using vertical autoclave at 15 lb pressure (121° C) in tap water (1:2 w/v)for 45 min. The nuts were considered cooked when they became soft to touch on pressing between the thumb andfingers. At the end of autoclaving, the water was drained and the nuts were oven-dried to constant weight. The nuts were then milled into flour, packed in plastic container and kept in freezer (-4°C) pending analysis.

3. Determination of nutritional constituents

The proximate composition of peanut samples was determined using standard procedures (AOAC, 2012). Carbohydrate content was determined by difference.

Potassium content was determined using flame photometry (Corning, UK Model 405). The other elemental contents (Ca, Mg, Fe and Zn) were determined, after wet digestion of sample ash with a mixture of concentrated nitric acid, sulphuric acid and perchloric acid (10:0.5:2, v/v) using Atomic Absorption Spectrophotometer (AAS, Hitachi Z6100, Tokyo, Japan). All the determinations were carried out in triplicates.

4. Determination of secondary metabolite constituents

Tannin content was determined by the modified method described by Trease and Evans (1989). A known quantity (0.5g) of the dry sample was boiled with 20ml of water. $FeCl_3$(0.1%) was added to observe for brownish green or blue-black colouration.

The chemical method described by Maga (1982) was used to determine the phytate content. Two grams of each finely ground sample was soaked in 20 mL of 0.2 N HCl and filtered. After filtration, 0.5 mL of the filtrate was mixed with 1mL ferric ammonium sulphate solution in a test tube, boiled for 30 min in a water bath, cooled in ice for 15 min and centrifuged at 3000 rpm for 15min. One millilitre of the supernatant was mixed with 1.5 mL of 2, 2- pyridine solution and the absorbance measured in a spectrophotometer at 519 nm. The concentration of phytic acid was obtained by extrapolation from a standard curve using standard phytic acid solution.

The titration method was used to determine the oxalate content according to Day and Underwood (1986). A known quantity (1.0g) of the sample was dissolved in 100mL of 0.75M H_2S0_4. The solution was then carefully stirred with a magnetic stirrer for 1hr and filtered. 25mL of the filtrate was pipetted and titrated hot (80-90ºC) against 0.1M $KMn0_4$ to an end point of a faint pink colour that persisted for more than 30 sec.

Trypsin inhibitor activity (TIA) was determined according to the procedure described by Prokopet and Unlenbruck (2002). One gram of the sample was extracted with 50

mL of 0.5 M NaCl and stirred for 30 min. Afterwards, it was centrifuged at 1500 rpm for 15 min, 10 mL of the filtrate was pipetted and 2 mL of trypsin inhibitor standard was added. The concentration of the trypsin inhibitor was read against a blank at wavelength of 410 nm.

Alkaloid content was determined gravimetrically as reported by Sreevidya and Mehrotra (2003). One gram of the sample was dispersed in 40 mL of 10% acetic acid in methanol. The suspension was shaken and then allowed to stand for 4 hr before it was filtered. The filtrate was evaporated to a quarter of its original volume before few drops of concentrated ammonium hydroxide was added to precipitate the alkaloid. The precipitate was filtered through a weighed filter paper and the filter paper was dried at 60ºC till constant weight. The weight of the dried filter paper was recorded. The difference in weight of filter paper before and after drying divided by initial weight of filter paper gives the alkaloid content of the sample.

Total flavonoid content was determined by Boham and Kocipal-Abyazan (1994). One gram of the sample was weighed into a beaker, 10 mL of 80% methanol was added and it was extracted for 2 hr at room temperature. The mixture was filtered into a weighed petri dish and the filtrate was dried at 40ºC to constant weight. The difference in weight of petri dish and the filtrate after drying and weight of empty petri dish gives the flavonoid content of the sample.

Total aflatoxin (B_1, B_2, G_1 and G_2), were determined according to the method described by CSAN (2015) using an ELISA (Enzyme Linked Immuno-Sorbent Assay) test kit. Fifty grams of the sample was extracted with a sachet of the extraction powder and 150 mL of distilled water was added. The mixture was stirred properly for 30 sec to extract and centrifuged at 4000 rpm for 1½ min. 300 µL of the supernatant was pipetted using a micropipette into a clean tube containing 600 µL of Aflatoxin dilution buffer. 300 µL of the mixture was then pipetted and plated on the test strip in the reader. The reader incubates the sample in the test strip at 45±1ºC for 5 min and displays the result in parts per million (ppm)

5. Determination of functional properties

The loose and packed densities were determined using the gravimetric method as described by Ikpeme *et al*. (2010). Water and oil absorption properties of the peanut flour were determined following methods of Adebayo *et al*. (2013). Flour sample (1g) was mixed with10mL distilled water for water absorption and 10mL of oil for oil absorption in a Philips laboratory blender (HR2811 model) at high speed for 30 sec. Samples were allowed to stand for 30min at room temperature then centrifuged (Uniscope, England) at 2000rpm for 30 min. The volume of supernatant in a graduated cylinder was noted. Density of water was taken to be 1g/mL and that of oil was determined to be 0.993g/mL. Analysis was performed in triplicate.

6. Colour value measurement

The surface colour trichromatic characteristics of peanut flour was measured using a Chroma Meter CR-400 (Konica Minolta Sensing Inc., Japan) and expressed in terms of lightness (L*), red-green characteristics (a*), blue–yellow characteristics (b*).

7. Statistical analysis

Determinations were carried out in triplicates and the error reported as standard deviation from the mean. Analysis of Variance (ANOVA) was performed and the least significant differences were calculated with the SPSS software for window release 16.00; SPSS Inc., Chicago IL, USA. Significance was accepted at $p \leq 0.05$ levels.

RESULTS AND DISCUSSION

1. Effect of processing on nutritional constituents of peanut flour

The proximate composition of peanut samples is as presented on Table 1. Processing methods were observed to significantly ($p \leq 0.05$) affect the nutrient composition when compared with the raw seeds. Results showed that, the moisture content of raw peanut (control) was 5.68%. The moisture levels in processed samples were: boiled in-shell (5.94%), boiled

shelled (6.53%), roasted in-shell (3.15%), roasted shelled (1.49%); autoclaved in-shell (6.32%), and autoclaved shelled (8.40%). The moisture of in-shell nuts decreased during roasting though the most substantial water losses were observed in shelled nuts. The lower values reported for roasted peanut compared to raw sample could be attributed to the fact that the nuts were in direct contact with dry heat at very high temperature. The significantly higher moisture level of boiled and autoclaved peanut flour respectively compared to raw sample could be attributed to absorption of moisture from processing water medium. Moreso, the moisture content value increased in boiled shelled sample compared to in-shell peanut possibly due to the direct absorption of water into the nuts during moist cooking. Increased moisture content could also be due to water absorption by fibre and other natural chemical component (Mittal *et al.*, 2002). A similar relationship exists between autoclaved shelled peanut and autoclaved in-shell peanut (8.40% and 6.32%, respectively).

The ash content of peanut was significantly ($p \leq 0.05$) increased by all treatments. This may be attributed to the heat employed during processing which led to greater reduction in anti-nutrients binding to the mineral elements. Moreso, the ash content of the in-shell processed peanut samples was significantly lower than shelled samples. This could be explained by the fact that there are anti-nutritional factors such as phytic acid in peanut shell (Sim *et al.*, 2012). Similar observation was reported by Nwafor *et al.* (2016) on food tree (*Adenanthera pavonina*) seeds. The fat content in control sample (42.87%) was the least, followed in ascending order by boiled in-shell (45.79%), roasted in-shell (47.43%), autoclaved in-shell (47.53%), boiled shelled (47.60%), autoclaved shelled (47.76) and roasted shelled (49.37%), respectively. This shows that processing enhances the fat content of peanuts. The effect of direct heat on shelled peanut samples resulted in better release of fat from the nuts due to higher disintegration of inherent complex organic compounds at high temperatures to release more free fat molecules (Makinde and Oladunni, 2016) compared with processed in-shell peanuts.

Raw sample had the lowest protein content (32.72%). Generally, the protein value significantly increased after boiling, autoclaving and roasting, respectively. The increase in protein content of processed peanut is attributed to a positive effect of heat treatment on proteins due to the reduction in the level of anti-nutrients such as phytate which bind to them and subsequently reduce their availability and digestibility through the formation of phytic-protein complexes. However, processed shelled peanut samples had higher protein contents than processed in-shell samples. This could be attributed to the direct contact of the nuts with the heat employed in the processing leading to the disruption or breakdown of inherent organic compounds binding to the proteins and hence, further release of protein molecules. The protein content of peanut is generally high and hence suitable for therapeutic aids (Segura *et al.*, 2006). The fibre content of peanut was significantly ($p \leq 0.05$) affected by all treatments. Moreso, processed in-shell peanuts had significantly higher fibre than processed shelled peanuts. The observed higher fibre content could be attributed to high level of crude fibre in peanut shells (Sim *et al.*, 2012) which permeate into the nuts during processing.

Moist heating (boiling or autoclaving) significantly decrease the carbohydrate content of peanut. This is due to the flow of free sugar (leaching) to the water during processing. Considering dry heat treatment (roasting), the reduction in carbohydrate content could be due to Maillard reaction in which the simple sugar forms complexes with protein molecules. In addition, the observed the lower carbohydrate content in processed shelled peanut samples compared to its in-shell counter-part could be attributed to direct contact with heat which results in higher decrease in simple sugars as reported by Nwafor *et al.* (2016).

Table 2 depicts the effect of boiling, autoclaving and roasting on mineral content of peanut flours. Flour prepared from raw nuts

had significantly ($p \leq 0.05$) lower Ca, Mg, K, Fe and Zn contents than the values obtained for flours prepared from boiled, autoclaved and roasted nuts. This may be attributed to the fact that the phytic acid in the raw sample is higher and it binds to inherent minerals in the nuts. Generally, boiled and autoclaved samples had the higher mineral concentration than roasted peanut. This implies that moist heat is more effective than dry heat in the release of mineral from the nuts. In all the samples, processed shelled peanuts had greater mineral concentrations than in-shell peanuts counterpart due to better release of minerals in shelled peanuts than encapsulated peanuts. The report from this study supports the claim of Mustapha *et al*. (2015).

Table 1: Proximate composition of raw and processed peanut flours (%)

Parameter	Samples						
	Raw	Boiled shelled	Boiled in-shell	Roasted shelled	Roasted in-shell	Autoclaved shelled	Autoclaved in-shell
Moisture	5.677^{c}±0.02	6.527^{f}±0.02	5.937^{d}±0.02	1.490^{a}±0.01	3.150^{b}±0.01	8.400^{g}±0.01	6.327^{e}±0.02
Ash	1.370^{a}±0.02	2.297^{b}± 0.02	1.840^{f}±0.01	1.750^{e}±0.01	1.707^{d}±0.02	1.650^{c}±0.01	1.530^{b}±0.02
Fat	42.873^{a}±0.03	47.603^{e}±0.02	45.790^{b}±0.02	49.370^{g}±0.01	47.427^{c}±0.02	47.760^{f}±0.01	47.533^{d}±0.02
Protein	32.717^{a}±0.02	34.707^{g}±0.02	33.240^{b}±0.01	33.513^{d}±0.02	33.313^{c}±0.02	33.950^{f}±0.01	33.607^{e}±0.02
Fibre	5.150^{e}±0.01	3.730^{b}±0.01	5.900^{g}±0.01	5.070^{d}±0.02	5.527^{f}±0.01	3.630^{a}±0.02	4.207^{c}±0.02
***CHO**	12.143^{g}±0.01	5.177^{b}±0.07	7.303^{d}±0.05	8.360^{e}±0.03	9.340^{f}±0.06	4.610^{a}±0.04	6.877^{c}±0.11

*CHO- Carbohydrate
Key a-g: Means with the same superscripts within each column are not significantly different ($p \geq 0.05$)

Table 2:Mineral composition of raw and processed peanut flours (mg/kg)

Parameter	Samples						
	Raw	Boiled shelled	Boiled in-shell	Roasted shelled	Roasted in-shell	Autoclaved shelled	Autoclaved in-shell
***Ca**	63.49^{a}±0.09	127.10^{g}±0.40	125.97^{f}±3.37	69.58^{c}±0.39	65.36^{b}±0.06	107.85^{e}±0.06	72.57^{c}±0.11
***Mg**	2007.86^{a}±0.42	2200^{f}±1.09	2106.88^{d}±0.12	2108.11^{e}±0.72	2008.24^{a}±0.10	2099.71^{c}±0.28	2098.60^{b}±0.33
***K**	6505.27^{c}±2.34	6771.47^{e}±1.06	6593.58^{d}±0.40	7772.32^{g}±0.92	7505.39^{f}±1.10	6317.96^{b}±0.08	6225.28^{a}±0.36
***Fe**	30.94^{a}±0.10	66.02^{g}±0.08	46.57^{e}±0.36	37.50^{d}±0.32	36.46^{c}±0.07	53.55^{f}±0.27	32.35^{b}±0.11
***Zn**	31.95^{a}±0.44	39.54^{f}±0.74	35.40^{c}±0.20	36.14^{d}±0.07	34.59^{b}±0.09	37.43^{e}±0.08	34.69^{b}±0.31

*Ca = Calcium, *Mg = Magnesium, *K = Potassium, *Fe = Iron, *Zn = Zinc.
Key a-g: Means with the same superscripts within each column are not significantly different ($p \geq 0.05$)

2. Effect of processing on secondary metabolite constituents

Data on anti-nutrient concentrations in raw and processed peanut samples is presented in Table 3. The level of phytate in raw peanut was 0.006g/kg and a significant reduction ($p \leq 0.05$) was observed after all heat treatments. Boiling, autoclaving and roasting of the nuts led to significant ($p \leq 0.05$) reductions in oxalate, phytate, tannin, alkaloid, flavonoid and trypsin inhibitors, respectively in the flour when compared with their values in the flour from the raw nuts. However, boiling of the nuts was more effective in reducing the anti-nutrients than autoclaving and roasting of the nuts. The apparent decrease in phytate content during thermal processing may be partly due either to the formation of insoluble complexes between phytate and other components, such as phytate-protein and phytate-protein-mineral complexes or to the inositol hexaphosphate hydrolyzed to penta- and tetraphosphate (Siddhuraju and Becker, 2003). On the other hand, some authors reported that phytic acid contents were unaffected or increased after heat treatments (Martin-Cabrejas *et al*., 2009; Embaby, 2010). Similarly, processing significantly ($p \leq 0.05$) reduced the oxalate content of the samples. Boiled peanut samples had the lowest oxalate content and hence, it can be said that it is the most effective processing method in reducing oxalate content in peanuts. In peanut, most tannin is located in seed coats (skin) while fruit (meat nut) are practically tannin free (Shahidi and Naczk, 2004). In the present study, tannins were determined in the raw and processed peanuts without removal the skin. Edible parts of the peanut consist of the kernel and the protective skin/testa. This could explain the reported higher levels of tannins (20.49-56.03g/kg**)** in peanut samples. There was significant reduction in tannin concentration in processed peanut compared to raw peanut. The loss of tannin may be due to the degradation or interaction with other components of seeds, such as proteins, to form insoluble complexes (Embaby, 2010). The tannin content of the boiled shelled sample was the lowest and this implies that boiling has greater diminishing effect on this compound compared to other processing methods. This is sequel to the fact that tannins are water soluble in nature resulting in their leaching out during boiling into the cooking medium especially when the water is discarded after boiling.

The result indicated higher trypsin inhibitor activity in raw (5.6 mg/g) compared to processed peanut samples. Significant reduction of trypsin inhibitor activity was noted in all heat treated peanut samples. Cooking of the nuts brought about highest reduction in trypsin inhibitor activity and this could be attributed to the faster and more efficient heat transfer (into the core of the nuts) than other treatments. Similar inactivation of trypsin inhibitor activity was reported by others in cooked, autoclaved and microwave cooked legumes (Embaby, 2010). Processing significantly ($p \leq 0.05$) reduced the alkaloid content of the samples. Boiling of peanut resulted in the most significant reduction of alkaloids. This is due to leaching out of this toxic substance into the processing water. Also, apart from the raw sample, the alkaloid content of all the samples are less than 10% and this implies better taste or improved palatability (McCurdy, 2008). Processing also significantly ($p \leq 0.05$) reduced the flavonoid content of the samples. Aside the significant reduction in anti-nutrient concentration in peanut subjected to boiling, autoclaving or roasting, it was noted that in-shell processed samples had significantly higher concentration of anti-nutrients compared to the shelled samples. Turner *et al*. (1975) found out that there are various anti-nutritional factors present in peanut shells, cotyledons and skin such as phenols, tannins and related pigment. Similarly, Sim *et al*. (2012) reported that anti-nutrients are present in peanut shell.

3. Effect of processing on aflatoxin concentration of peanut flour

The total aflatoxin content (B_1, B_2, G_1 and G_2) of peanut samples in increasing levels were as follow: boiled shelled (2.06 ppb), boiled in-shell (2.27 ppb), autoclaved shelled (3.10 ppb), roasted shelled (4.12 ppb), autoclaved in-shell (4.14 ppb), roasted in-shell (5.19 ppb) and raw

(8.05 ppb) as indicated in Figure 1. Aflatoxins are secondary metabolites produced by fungi in the genus *Aspergillus*, including *A. Flavus* and *A. Parasiticus* (Yu *et al*., 2004). The four major naturally produced aflatoxins are known as aflatoxins B_1, B_2, G_1 and G_2. 'B' and 'G' refer to the blue and green fluorescent colours produced by these compounds under ultra-violet light on thin layer chromatography plates, while the subscript numbers1 and 2 indicate major and minor compounds, respectively (Pitt, 2000).
Processing significantly ($p \leq 0.05$) reduced the aflatoxin content of the samples. This may be due to the removal of mould-damaged kernels, seeds or nuts physically from food commodities before processing which as stated by Park (2002) reduces aflatoxin by 40-80%. However, the efficacy and extent of reduction depends on several factors, including aflatoxin concentration, extent of binding between aflatoxin and food constituents, heat penetration, moisture content, pH, ionic strength, processing conditions and source of contamination (naturally or artificially) as reported by Hussain *et al*.(2011). Increases in moisture content noted in boiled and autoclaved peanut samples justify the significant reduction compared to dry heat (roasting) treatment. The relationship between moisture content of foods and reduction of aflatoxin has been demonstrated (Mendez-Albores *et al*., 2004). According to this report, by increased moisture content, the reduction of aflatoxin is increased during processing. Moreso, it has been suggested that the presence of water helps opening the lactone ring in aflatoxin B_1 (by the addition of water molecule to the ring) to form a terminal carboxylic acid that subsequently undergoes heat-induced decarboxylation (Kabak *et al*., 2006).
The level of aflatoxin contamination differs in the shelled and in-shell samples respectively. The aflatoxin concentration was lower in shelled nuts after processing compared to in-shell nuts. This can be explained by the fact that shelled batches are composed of nuts from which unacceptable parts were withdrawn (e.g. fungi, stains) and thus the probability of presence of aflatoxin would be lower compared to encapsulated (in-shell) nuts. In fact, the contamination seems to be more associated with the shell and not in the nut, and after its removal the aflatoxin concentration can be reduced to levels below the lowest LOD value (CAC, 2010). However, in this study, the aflatoxin content of the shelled and in–shell processed peanuts ranged from 2.06 to 8.05 ppb and these values are below the European standard (10 ppb) for permissible limit of aflatoxin in food (EFSA, 2009).

Table 3: Secondary metabolite concentration of raw and processed peanut flours

Parameter	Samples						
	Raw	Boiled shelled	Boiled in-shell	Roasted shelled	Roasted in-shell	Autoclaved shelled	Autoclaved in-shell
Tannin (g/kg)	$56.030^{g}\pm0.07$	$20.489^{a}\pm0.00$	$27.851^{b}\pm0.02$	$44.937^{e}\pm0.08$	$46.156^{f}\pm0.01$	$37.369^{c}\pm0.01$	$38.491^{d}\pm0.01$
Trypsin inhibitor (mg/L)	$235.90^{g}\pm0.07$	$8.605^{a}\pm0.00$	$9.354^{b}\pm0.01$	$17.487^{c}\pm0.01$	$20.080^{d}\pm0.00$	$85.449^{e}\pm0.01$	$92.158^{f}\pm0.00$
Phytate (g/kg)	$0.006^{c}\pm0.00$	$0.004^{a}\pm0.00$	$0.005^{ab}\pm0.00$	$0.005^{b}\pm0.00$	$0.005^{b}\pm0.00$	$0.007^{d}\pm0.00$	$0.007^{d}\pm0.00$
Flavonoid (mg/100g)	$0.446^{d}\pm0.05$	$0.063^{c}\pm0.00$	$0.032^{abc}\pm0.001$	$0.022^{ab}\pm0.00$	$0.026^{ab}\pm0.00$	$0.051^{bc}\pm0.00$	$0.012^{a}\pm0.00$
Oxalate (mg/100g)	$15.027^{g}\pm0.03$	$8.040^{a}\pm0.04$	$10.313^{c}\pm0.03$	$9.213^{b}\pm0.05$	$12.167^{f}\pm0.38$	$11.033^{d}\pm0.15$	$11.433^{e}\pm0.15$
Alkaloid(%)	$12.530^{g}\pm0.03$	$4.337^{a}\pm0.03$	$4.783^{b}\pm0.04$	$6.883^{c}\pm0.04$	$7.943^{d}\pm0.05$	$8.693^{e}\pm0.04$	$9.717^{f}\pm0.03$

Key a-g: Means with the same superscripts within each column are not significantly different ($p \geq 0.05$)

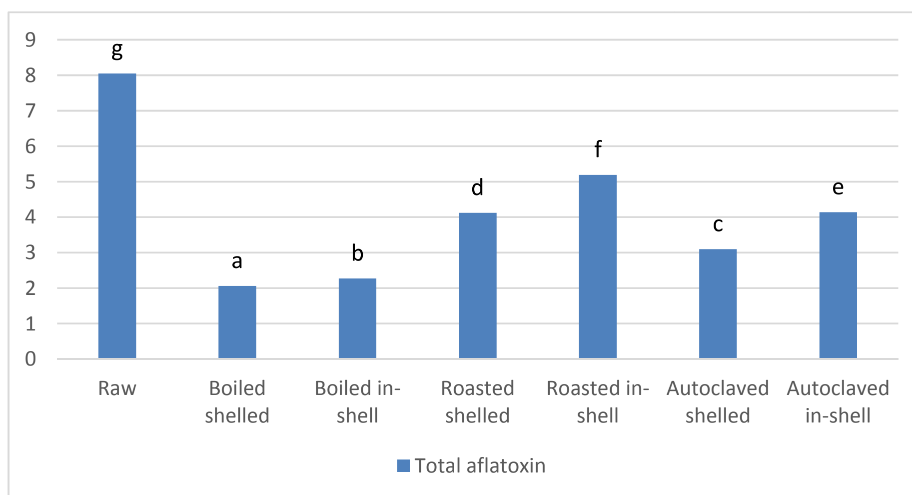

Figure 1: Total aflatoxin (B_1+B_2+G_1+G_2)content of raw and processed peanut flour (ppb)

4. Effect of processing on functional properties of peanut flour

The functional properties of the samples of peanut flour are as presented in Table 4. The loosed bulk density (LBD), which is the lowest attainable density without compression, was higher in processed peanut than raw sample. The increase in loosed bulk density of boiled and autoclaved samples may be due to the fact that the nuts were conditioned by water used in processing and later dried back and this affected the size of the particles during milling as they could not be milled enough to achieve fine texture due to the absorbed water components (Odimegwu *et al*., 2015). Loosed bulk density value in roasted shelled peanut and in-shell roasted peanut was 0.39 g/mL and 0.40 g/mL, respectively. It is revealed from the results that roasting significantly increased the bulk density. In contrast; packed bulk density was lower in processed peanut than raw sample. The reduction in packed bulk density in processed peanut samples makes the products suitable as functional ingredient for weaning formula production.

Water absorption capacity was higher in processed peanut than raw sample. Higher water absorption capacity noted in processed peanut may be due to the high polar amino acid residues of their proteins which have strong affinity for water molecules. Similarly, oil absorption capacity was higher in processed peanuts than raw sample. Boiling, autoclaving and roasting increased the oil absorption capacity of the peanut samples and this implies that there will be high interactions among the hydrophobic/ lipophilic lipoprotein and oil and hence they could be a good thickener in food systems. Generally, bulk densities, water and oil absorption capacities of processed shelled peanut were found significantly different from processed in-shell samples. The variation in functionality of raw, processed shelled and in-shell peanuts could be due to the existing differences in the conformational characteristics of their proteins.

5. Effect of processing on colour attributes of peanut flour

The measured values of the colour dimensions, $L*$, $a*$ and $b*$ for raw and processed peanut flour are presented in Table 5. The lightness ($L*$), of processed peanut samples decreased significantly compared with raw peanut. The lower the L* value of a sample is, the darker the product becomes. The decrease in lightness of processed samples may be due to Maillard reactions and other chemical reactions that affect the colour of food during heat processing. Similarly, parameter $a*$ significantly decreased in boiled, autoclaved

and roasted peanut samples compared with raw peanut. In terms of b* values, there are variations depending on the processing condition. Also it is worth noting that processed shelled peanuts presented higher L* values compared to processed in-shell peanut. In view of this it is possible to suggest that various processing methods accelerated the decrease in L* value noted in-shell samples. However, the colour of autoclaved in-shell sample was the most affected as indicated by lowest L* value. The lower L* values in processed in-shell samples reported in the present work suggested that peanut shells could have played a role in protecting the kernel, however the shells were not efficient in preventing the changes to the colour of the skins. Similar observation was reported by Costa de Camargo *et al*. (2012) on effect of gamma irradiation on in-shell and blanched peanuts.

Table 4: Functional properties of raw and processed peanut flours

Parameter	Samples						
	Raw	Boiled shelled	Boiled in-shell	Roasted shelled	Roasted in-shell	Autoclaved shelled	Autoclaved in-shell
*LBD (g/mL)	$0.332^{a}\pm0.01$	$0.378^{b}\pm0.01$	$0.510^{e}\pm0.01$	$0.389^{bc}\pm0.01$	$0.394^{c}\pm0.01$	$0.395^{c}\pm0.01$	$0.495^{d}\pm0.01$
*PBD (g/mL)	$0.566^{e}\pm0.01$	$0.495^{c}\pm0.01$	$0.534^{d}\pm0.01$	$0.436^{a}\pm0.01$	$0.470^{b}\pm0.01$	$0.521^{d}\pm0.01$	$0.480^{b}\pm0.01$
*WAC (%)	$103.107^{a}\pm$ 0.74	$129.763^{d}\pm0.10$	$120.787^{c}\pm0.42$	$120.843^{c}\pm0.56$	$106.893^{b}\pm0.85$	$154.720^{e}\pm0.44$	$157.940^{f}\pm0.73$
*OAC (%)	$44.700^{a}\pm$ 0.70	$90.003^{g}\pm0.30$	$67.947^{d}\pm0.60$	$81.813^{f}\pm0.27$	$77.987^{e}0.76$	$60.030^{b}\pm0.60$	$63.940^{c}\pm0.78$

*LBD = Loose Bulk Density,*PBD = Packed Bulk Density,*WAC = Water Absorption Capacity,*OAC = Oil Absorption Capacity.
Key a-f: Means with the same superscripts within each column are not significantly different ($p\geq0.05$)

Table 5:Colour values of raw and processed peanut flours

Parameter	Samples						
	Raw	Boiled shelled	Boiled in-shell	Roasted shelled	Roasted in-shell	Autoclaved shelled	Autoclaved in-shell
L*	61.45^{g} ±0.37	$54.63^{f}\pm0.20$	$37.33^{b}\pm0.03$	$49.05^{e}\pm0.27$	$44.50^{c}\pm0.29$	$47.69^{d}\pm0.31$	$28.37^{a}\pm0.28$
a*	$4.79^{a}\pm0$ .19	$5.24^{b}\pm0.04$	$8.41^{c}\pm0.04$	$8.77^{d}\pm0.03$	$9.01^{d}\pm0.15$	$8.86^{d}\pm0.05$	$9.41^{e}\pm0.44$
b*	$13.30^{e}\pm$ 0.05	$10.27^{c}\pm0.03$	$8.52^{a}\pm0.03$	$19.86^{g}\pm0.11$	$17.03^{f}\pm0.14$	$10.99^{d}\pm0.11$	$8.97^{b}\pm0.47$

Key a-g: Means with the same superscripts within each column are not significantly different ($p\geq0.05$)

CONCLUSION

Peanut is one of the most nutritive plant produce because of its high protein and lipid content. Processing methods (boiling, roasting and autoclaving) have been shown to greatly affect the nutritional quality and functionality of peanut. Most importantly, shelling prior to processing of peanut resulted in superior quality products compared to in-shell processed peanut.

REFERENCES

[1] Adebayo, W.A., Ogunsina, B.S. & Gbadamosi, S.O. (2013). Some physic-chemical and functional properties of kariya (*Hildegardia baterii*) kernel flour.Ife Journal of Science. 15(3), 477-488.

[2] AOAC (2012). Association of Official Analytical Chemists. Official methods of analysis, 19th Ed. AOAC International, Suite 500,481 North Frederick Avenue, Gaithersburg, Maryland, USA.

[3] Ayoola, P.B. & Adeyeye, A. (2010). Effects of heating on the chemical composition and physicochemical properties of *Arachis hypogea* (groundnuts) seed flour and oil. Pakistan Journal of Nutrition, 9(8), 751-754.

[4] Boham, B.A. & Kocipai-Abyazan, R. (1994). Medicinal and Poisonous Plant of Southern and Eastern Africa. 2nd ed. Livingstone, Edinburgh and London.

[5] CAC (2010).Codex Alimentarius Commission. Report of the Fourth Session of the Codex Committee on Contaminants in Foods. Izmir, Turkey, CL 2010/13-CF.

[6] Costa de Camargo, AC., De Souza Vieira, T.M., Regitano-d'Arce, M.A., De Alencer, S.M., Calori-Domingues, M.A., Spoto, M.H. & Canniatti-Brazaca, S.G. (2012).Gamma irradiation of in-shell and blanched peanuts protects against mycotoxic fungi and retains their nutraceutical components during long-term storage. International Journal of Molecular Sciences, 13, 10935-10958.

[7] CSAN (2015). Charm Sciences Application Note, ROSA FAST (Rapid One Step Assay) Aflatoxin Quantitative Test'. Test kit instructions: LF-AFQ-FAST Revision 1. United State Department of Agriculture Grain Inspection, Packers and Stockyards Administration Technology and Science Division.

[8] Day, R.A. & Underwood, A.L. (1986). Qualitative Analysis. Prentice Hall Publications, New Delhi, India.1986.

[9] EFSA (2009). European Food Safety Authority. Effects on public health of an increase of the levels for aflatoxin total from 4 µg/kg to 10 µg/kg for tree nuts other than almonds, hazelnuts and pistachios. The EFSA Journal, 1168, 1-11.

[10] Embaby, H.E. (2010) Effect of soaking, dehulling and cooking methods on certain anti-nutrients and in vitro protein digestibility of bitter and sweet lupin seeds. Food Sci. Biotechnol., 19, 1055- 1062.

[11] FAOSTAT (2016) Food and Agricultural Organization Statistics. Agriculture Data. Available: http://www.fao.org/faostat/en/#home. Accessed: 11/03/19.

[12] Foster-Powell, K., Holt, S.H. & Brand-Miller, J.C. (2002). International table of glycemic and glycemic load values. American Journal of Clinical Nutrition, 76(1), 5-56.

[13] Gibbon, D. & Pain, A. (1985).Crops of the Drier Regions of the Tropics. Longman Press, London, pp.23-407.

[14] Hussain, A., Ali,J., Akther , S. & Shafqatullah (2011). Degradation of aflatoxins by roasting in contaminated peanuts. Pak. J. Biochem. Mol. Biol., 44(2), 56-59.

[15] Ikpeme, C.A., Osuchukwu, N.C. & Oshiele, L. (2010). Functional and sensory properties of wheat (*Aestium triticium*) and taro flour (*Colocasia esculenta*) composite bread.African Journal of Food Science, 4 (5), 248-253.

[16] Johnston, C.A., Poston,W.S.& Haddock, C.K. (2007). Weight loss in overweight Mexican American children: a randomized, controlled trail.Paediatrics, 120(6), e1450-e1457.

[17] Kabak, B., Dobson, A.D.W. & Var, I. (2006). Strategies to prevent mycotoxins contamination of food and animal feed. A review, Crit. Rev. Food Sci. Nutr., 46(8), 593-619.

[18] Maga, J.A. (1982). Phytates: Its chemistry, occurrence, food interactions. Nutritional significance and method of analysis. Journal of Agricultural and Food Chemistry, 30(1), 1-7.

[19] Makinde, F.M. & Oladunni, S.S. (2016). Effects of processing treatments on nutritional quality of raw almond (*Terminalia catappa* Linn.) kernels. Advances in Applied Science Research, 7(1), 1-7.

[20] Martín-Cabrejas, M.A., Aguilera, Y., Pedrosa, M.M., Cuadrado, C., Hernandez, T., Diaz, S. &Esteban, R.M. (2009). The impact of dehydration process on antinutrients and protein digestibility ofsome legume flours. Food Chem., 114, 1063-1068.

[21] McCurdy, C.R. (2008). Book Review of Modern Alkaloids: Structure, Isolation, Synthesis and Biology. Journal of Medicinal Chemistry, 51(14), 4356.

[22] Mendez-Albores, A., De Jesus-Flores, F., Castaneda-Roldan, E., Arambula-Villa, G. &Moreno-MartiNez, E. (2004).The effect of toasting and boiling on the fate of B-aflatoxins during pinole preparation. Journal of Food Engineering, 65(4), 585-589.

[23] Mittal, R., Nagi, H., Sharma, P. & Sharma, S. (2002).Effect of processing on chemical

composition and anti-nutritional factors in chickpea flour. Journal of Food Science, 2, 180-186.
[24] Mustapha, S. Mohammed, U.M., Adeosun, N.O., Mathew, T.J., Muhammed, S.S. & Ibn-Aliyu, A. (2015).Nutritional and functional characterization of undecorticated groundnut (*ArachishypogeaeL.*) seeds from Bosso Market, Minna, Nigeria. American Journal of Food Science and Technology, 3(5), 126-131.
[25] Nwafor, F, I., Egonu, S.N., Nweze, N.O. &Ohabuenyi, N. (2016). Effects of processing methods on the nutritive values and anti-nutritive factors of *Adenanthera pavonina* L. (Fabaceae) seeds. African Journal of Biotechnology, 16(3),106-112.
[26] Odimegwu, E.N., Nwosu, J.N., Umelo, M.C., Olawuni, I.A., Akajiaku, L.O.& Oga, B.N.(2015). Effect of processing on the proximate and functional properties of akparata (*Afzeliaafricana)* flour. European Journal of Food Science and Technology, 3(1), 48-60.
[27] Olorunju, P.E., Alabi, O. & Tanimu, B. (1999). Priorities and strategies for groundnut research in Nigeria. A paper presented at the national workshop on groundnut rehabilitation in Nigeria, Kano, pp. 15.
[28] Park, D.L. (2002). Effect of processing on aflatoxin. Adv. Exp. Med. Biol. 504, 173-179.
[29] Pitt, J.J. (2000). Toxigenic fungi and mycotoxins.British Medical Bulletin, 56(1),184-192.
[30] Prokopet, G. &Unlenbruck, K.W. (2002). Protectine eine nen kalsse anti-kowperahlich verbindungen dish. Ges. Heit., 23, 318.
[31] Robert, E., Pettit, T. & Ruth, T.A. (1968). Factors influencing aflatoxin accumulation in peanut kernels and the associated mycoflora.Journal of Applied Microbiology, 16(8), 1230 - 1234.
[32] Segura, R., Javierre, C., Lizarraga, M.A. &Ros, E. (2006). Other relevant components of nuts, phytosterols, folate and minerals. British Journal of Nutrition, 96, S36-S44.
[33] Shahidi, F. & Naczk, M. (2004). Phenolics in food and nutraceuticals. CRC Press, pp. 17-82.
[34] Siddhuraju, P. & Becker, K. (2003). Antioxidant properties of various extracts of phenolic constituents from three different agroclimatic origins of drumstick tree (*Moringa oleifera* L.) leaves. J. Agric. Food Chem., 51, 2144-2155.