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# Evaluation of The Effects of Thermal Processing Treatments on The Nutrient and Anti-nutrient Composition of Pigeon Pea (*Cajanus cajan*) Seed Flours

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**ABSTRACT:** This study was carried out to evaluate the effects of thermal processing techniques on the nutrient and antinutrient contents of pigeon pea (*Cajanus cajan*) flours. The pigeon pea seeds were sorted, cleaned and divided into five equal lots of 0.5kg each. Four lots of pigeon pea seeds were processed into blanched, boiled, roasted, and autoclaved pigeon pea flours, while the fifth lot was processed raw and used as control. The raw and thermally processed samples obtained were analysed for nutrient and antinutrient composition using standard methods. The proximate composition of the samples showed that the flours had a range of 8.61 - 11.46 % moisture, 21.13 - 23.94 % crude protein, 1.26 - 1.68 % fat, 5.12 – 6.10 % crude fibre, 1.74 – 2.97 % ash, 55.56 – 60.41 % carbohydrate and 333.45 - 342.75 kJ/100g energy, respectively. The mineral composition showed that the flours contained 86.24 – 144.72 mg/100g calcium, 137.80 – 170.33 mg/100g magnesium, 125.86 - 156.76 mg/100g potassium, 66.66 – 95.62 mg/100g sodium, 4.38 – 6.64 mg/100g iron and 130.27 – 178.29 mg/100g phosphorus, respectively. The vitamin content of the flours were 3.09 - 4.33 mg/100g ascorbic acid, 0.05 - 0.17 mg/100g thiamine, 0.03 - 0.21 mg/100g riboflavin, 0.13 - 0.28 mg/100g niacin, 3.21 - 6.25 mg/100g vitamin A and 1.10 - 2.70 mg/100g vitamin E, respectively. The antinutrient composition of the flours also showed that the levels of trypsin inhibitor, tannin, phytate, oxalate, saponin and haemagglutinin ranged from, 2.30 – 5.61 Tiu/mg, 0.81 – 1.5mg/100g, 1.12 - 4.18mg/100g, 0.48-4.01 mg/100g, 1.28 – 3.66 mg/100g and 1.30 – 7.44 Hiu/g, respectively. Therefore, the study showed that thermally processed pigeon pea flours could be used as nutrient dense ingredients in the preparation of a wide range of foods for children, adolescents and aged adults especially in developing countries where the problems of protein-energy malnutrition and micronutrients deficiencies are prevalent than the raw sample.

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**KEYWORDS:** Pigeon pea, blanching, boiling, roasting, autoclaving, proximate composition, mineral composition, vitamin composition, anti-nutrient content.

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## INTRODUCTION

Pigeon pea (*Cajanus cajan*) is one of the lesser known and underutilized grain legumes that is locally available and affordable in the tropical and subtropical regions of the world. It ranks fifth in importance among edible legumes in the world (Rachie and Wurstar, 2007). Although, India remains the major producer of pigeon pea, the interest in pigeon pea in other parts of the world including Nigeria is as a result of its nutritional, medicinal, economical and agronomic usefulness (Rao *et al*., 1986). Based on these attributes, pigeon pea is widely consumed in Africa, India and the Caribbean.

Presently, different varieties of pigeon pea are grown in Nigeria. Nutritionally, pigeon pea contains 7.9-24.3% protein, 58.7% carbohydrate, 1.2-8.10% crude fibre and 0.6-3.8% fat (Rao *et al*., 1986). Pigeon pea is also a good source of calcium, phosphorus, magnesium, iron and sulphur etc (Amarteifio *et al*., 2002). Pigeon pea is a legume that is commonly known as “fio fio” in South-eastern part of Nigeria (Osita, 2007). The seeds are cooked whole until tender and then mixed with yams, vegetables, palm oil, pepper and other spices (Enwere, 1998).

Attempts have been made to fortify protein-deficient foods with protein concentrate or to improve the limiting amino acids by the use of protein or protein concentrate of vegetable origin (Owuamanam *et al*., 2014). Due to the nutritional profile of pigeon pea, new food products derived from it can be formulated to serve as supplementary food for the nutritionally vulnerable groups and communities. Pigeon pea like other legumes is deficient in methionine but high in lysine. Inspite of its high nutritional qualities, pigeon pea is not popular in the Western and Northern parts of Nigeria.

Pigeon pea has been used for therapeutic purposes since time immemorial because it contains flavonoids, isoflavonoid and stilbenes which have beneficial effects on human health (Luo *et al*., 2008). The extracts of pigeon pea leaves are generally used for the treatment of wounds, malaria, bedsores, brain damage and alcohol induced liver damage.

## MATERIALS AND METHODS

### Procurement of Raw Material

Mature dried pigeon pea (*Cajanus cajan*) seeds used for the study were purchased from Ogbete Main Market, Enugu, Enugu State, Nigeria.

The seeds were sorted, cleaned and divided into five equal lots of 500g each. Four lots were subjected to different processing treatments (blanching, boiling, roasting and autoclaving) while the fifth batch was processed raw.

### Pre-preparation of the seed Samples

The raw pigeon pea flour was prepared according to the method described by Arukwe *et al*. (2017). Five hundred grams (500g) of Pigeon pea seeds were cleaned with 2.5 litres of potable water to remove dirt and other extraneous materials. Thereafter, the cleaned seeds were drained, rinsed and spread on the trays and hot air oven (Model DHG 9101 ISA) at 60ºC for 12 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Like most tropical grain legumes, pigeon pea especially the raw seeds contain antinutritional substances such as saponins, trypsin inhibitors, tannins, oxalates, phylates and haemagglutinins which affect their utilization. They also conatin flatulence causing oligosaccharides such as stachyose, raffinose and verbascose (Igbedioh *et al*., 1994; Akubor, 2017). In addition, the characteristic problem of hard-to-cook phenomenon also hinders the excessive use of pigeon peas as food. The dried seeds are hard and by the use of traditional processing methods, it takes almost 24 hours to prepare a meal from pigeon pea (Amartcifio *et al*., 2002; Akubor, 2017). Various methods have been used to improve the food value of pigeon pea by improving its processing, storage, preservation and utilization. These methods include simple processing techniques such as germination, fermentation, soaking, blanching, boiling, roasting, autoclaving and irradiation (Osita, 2007). These processing methods may affect the physicochemical properties of the seeds and hence, their potential food applications.

Moderate heat processing treatment improves the digestibility of plant proteins without developing toxic derivatives and inactivates several enzymes such as proteases, lipases, amylases, lipoxygenases and other oxidative and hydrolytic enzymes in foods (Arukwe *et al*., 2017). Roasting causes physical, chemical, structural and sensorial changes in foods. Roasting could promote the development of flavour, desired colour and increase the palatability of foods (Nwosu *et al*., 2013). One of the major advantages of roasting is the increase in antioxidant activity due to the formation of Maillard reaction products (Akubor, 2017). Boiling destroys protease inhibitors and cyanogens in pigeon pea. Roasting and boiling have been reported to enhance the flavour of foods (Osita, 2007). Autoclaving destroys the anti-nutrients such as protease inhibitors, tannins and saponins in pigeon pea and other legumes. It also enhances the flavour, taste and palatability in foods (Olanupelan *et al*., 2015). Blanching inactivates enzymes and destroys flatulence causing oligosaccharides in foods. However, these methods in some cases rather than improving the nutritional value of foods, they adversely affect them. The objective of the study was to evaluate the effects of thermal processing of pigeon pea flours.

### Preparation of Blanched Pigeon pea Flour

The blanched pigeon pea seed flour was prepared according to the method described by Arukwe *et al*. (2017) with slight modifications. Half kilogram (0.5kg) of pigeon pea seeds were cleaned to remove dirt and other extraneous materials. The cleaned seeds were soaked in 3 litres of potable water at room temperature (30±2ºC) for 12 h with occasional change of water at intervals of 6 h to prevent fermentation. The soaked seeds were drained, rinsed, placed in stainless pot and hot water blanched with 2.5 litres of potable water on a hot plate at 80ºC for 15 min. The blanched seeds were drained, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60ºC for 14 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with a 500-micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

**Preparation of Boiled Pigeon pea Flour**

The boiled pigeon pea seed flour was prepared according to the method described by Arukwe *et al*. (2017) with slight modifications. Half kilogram (0.5kg) of pigeon pea seeds were cleaned to remove dirt and other extraneous materials. The cleaned seeds were soaked in 3 litres of potable water at room temperature (30±2ºC) for 12 h with occasional change of water at intervals of 6 h to prevent fermentation. The soaked seeds were drained, rinsed, placed in stainless pot and boiled with 2.5 litres of potable water on a hot plate at 100ºC for 30 min. The boiled seeds were drained, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60ºC for 16 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis

**Preparation of Roasted Pigeon pea Flour**

The roasted pigeon pea flour was prepared according to the method described by Arukwe *et al*. (2017) with slight modifications. Half kilogram (0.5kg) of pigeon pea seeds were cleaned to remove dirt and other extraneous materials. The cleaned seeds were soaked in 3 litres of potable water at room temperature (30±2ºC) for 12 h with occasional change of water at intervals of 6 h to prevent fermentation. The soaked seeds were drained, rinsed, and roasted in an electric fryer at 240ºC for 1 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform roasting. The roasted seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

**Preparation of Autoclaved Pigeon pea Flour**

The autoclaved pigeon pea flour was prepared according to the method of described by Arukwe *et al*. (2017) with slight modifications. Half kilogram (0.5kg) of pigeon pea seeds were cleaned to remove dirt and other extraneous materials. The cleaned seeds were soaked in 2.5 litres of potable water at room temperature (30±2ºC) for 12 h with occasional change of water at intervals of 6 h to prevent fermentation. The soaked seeds were drained, rinsed, placed in beaker and autoclaved in an autoclave (Model 75XG) at temperature of 121ºC and pressure of 6 atmosphere for 1 h. The autoclaved seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60ºC for 14 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

**Proximate Analysis**

The moisture, crude protein, fat, ash and crude fibre contents of the samples were determined on dry weight according to the methods of AOAC (2010). Carbohydrate was determined by difference (AOAC, 2010). The energy content of the flours was calculated from the proximate composition using the At water factor 4×protein, 9×fat, and 4×carbohydrate respectively (Shumaila and Mahpara, 2009). All determinants were carried out in triplicate samples.

**Micronutrients Analyses**

The calcium, potassium, iron, phosphorus, magnesium and sodium contents of the samples were determined on dry weight basis according to the methods of AOAC (2010). The ascorbic acid and niacin contents of the samples were determined according to the methods of AOAC (2010). The thiamine and riboflavin contents of the flours were determined according to the flourimetric methods described by Onwuka (2005). The vitamins A and E contents were determined according to the methods described by Nwajagu *et al*., (2021). All determinations were carried out in triplicate samples.

**Antinutrient Analysis**

The levels of trypsin inhibitor, tannin, phytate, oxalate, saponin and haemagglutinin of the samples were determined on dry weight basis according to the spectrophotometric methods described by Onwuka (2005). All determinations were carried out in triplicate samples.

**Statistical Analysis**

The data generated after the analysis were subjected to Analysis of Variance (ANOVA) using Special Package for Social Sciences (SPSS version 20, 2013). Significant means were separated using Turkey's least significant difference (LSD) test at $p<0.05$.

## RESULTS AND DISCUSSION

### Proximate Composition of Raw and Processed Pigeon Pea Flours

The proximate composition of raw and processed pigeon pea flour samples are presented in Table 1.

**Table 1: Proximate composition (%) of raw and processed pigeon pea flour samples**

| Parameters | Raw | Blanched | Boiled | Roasted | Autoclaved |
|---|---|---|---|---|---|
| **Moisture** | $9.75^{d}$ ±0.03 | $10.77^{b}$ ±0.00 | $11.46^{a}$ ±0.03 | $8.60^{e}$ ±0.04 | $10.11^{c}$ ±0.04 |
| **Crude Protein** | $23.94^{a}$ ±0.03 | $22.40^{c}$ ± 0.02 | $21.13^{e}$ ±0.01 | $21.97^{b}$ ±0.02 | $21.58^{d}$ ± 0.01 |
| **Fat** | $1.68^{a}$ + 0.01 | $1.61^{b}$ + 0.00 | $1.53^{c}$ + 0.01 | $1.47^{d}$ + 0.03 | $1.26^{e}$ ±0.00 |
| **Crude Fibre** | $6.10^{a}$ ±0.03 | $5.27^{e}$ ±0.02 | $5.20^{d}$ ±0.03 | $5.51^{c}$ ±0.01 | $5.54^{b}$ ±0.01 |
| **Ash** | $2.97^{a}$ ±0.03 | $1.74^{e}$ ±0.05 | $1.89^{d}$ ±0.03 | $2.04^{b}$ ±0.01 | $1. .99^{c}$ ±0.05 |
| **Carbohydrate** | $55.56^{e}$ ±0.04 | $58.21^{d}$ ±0.02 | $58.79^{c}$ ±0.03 | $60.41^{a}$ ±0.02 | $59.52^{b}$ ±0.02 |
| **Energy (kJ/100g)** | $333.52^{d}$ ± 0.01 | $336.93^{b}$ ± 0.03 | $333.45^{e}$ ± 0.01 | $342.75^{a}$ ± 0.01 | $335.74^{c}$± 0.01 |

Values are mean ± SD of triplicate determinations. Means within the same row with different letters are significantly different at $p<0.05$.

The moisture content of the raw sample was 9.75 %, while that of the processed samples ranged between 8.60 to 11.46% with the roasted and boiled samples having the least (8.60 %) and highest values (11.46%), respectively. There were significant differences ($p<0.05$) in the moisture content of the flour samples. The moisture content was higher in boiled and blanched samples compared to the samples processed by autoclaving and roasting treatments. The increase could be attributed to the penetration of large quantity of water into the seeds as a result of boiling and blanching treatments during processing. The variation in the moisture content observed in this study is in agreement with the findings of Akubor (2017) who reported that roasting lead to decrease in moisture content of pigeon pea flour whereas boiling increases the moisture content of the flour sample. In addition, the result obtained in this study is also in agreement with the report of Nsa and Ukachukwu (2009) who stated that boiling increases the moisture content of castor oil seed (*Ricinus communis*) flour, while roasting decreases its moisture content. The high moisture affects the storage stability of legume and other flour products. The values (8.60 – 11.46%) obtained in this study were lower than the maximum level (14 %) of moisture that is compatible with proper packaging and storage of legume flours (Oraka and Okoye, 2017). The moisture content of food is used as a measure of its stability and susceptibility to microbial deterioration and spoilage during storage.

The crude protein content of the raw sample was 23.94%, while that of the processed samples ranged between 21.13 and 22.40 % with the boiled sample having the least value (21.13 %), while the blanched sample had the highest value (22.40 %). There were significant ($p<0.05$) differences in the crude protein content of the flour samples. The crude protein content of the flours was significantly ($p<0.05$) reduced by boiling and autoclaving treatments compared to roasting and blanching techniques. The reduction in the protein contents of boiled and autoclaved samples could be attributed to the scorching effects of heat followed by double degradation which might have led to the leaching of some soluble proteins into the boiling water during processing (Akinmutimi, 2004a; Obasi and Wogu, 2008). The result also showed that blanching and roasting treatments might have led to an increase in the concentration of proteins in the pigeon pea seed flours. The reduction in the crude protein contents observed in this present study as a result of boiling and autoclaving treatments is in line with the findings of Eburuaja (2010) and Ekwe (2012) who reported that boiling and autoclaving treatments reduced the crude protein content values of African yam bean and *Mucuna sloanei* seed flours, respectively. The crude protein values (21.13 – 22.40%) obtained in this present study were relatively lower than the protein contents (22.83 and 25.88%) reported by Akinmutimi (2004b) and Anya and Ozung (2019) for boiled sword bean and roasted African yam bean flours, respectively. Dietary proteins are needed for the synthesis of new cells, enzymes and hormones that are required for the development of the body (Okaka *et al.*, 2006).

The fat content of the raw sample was 1.68 % and that of the processed samples ranged between 1.26 to 1.61 % was significantly ($p<0.05$) lower in autoclaved and roasted samples compared to the samples processed by blanching and boiling treatments which had the fat content of 1.53 and 1.16%, respectively. The observed decrease in fat contents of autoclaved and roasted flour samples could be due to the oxidation of fat as a result of heat penetration during processing. The values (1.26 – 1.61%) obtained in this study were lower than the fat contents (2.26 -2.88 %) and (2.46-3.18%) reported by Nsa and Ukachukwu (2009) and Onunkwo *et al*. (2017) for roasted castor oil and boiled velvet bean flours respectively. Fat is important in human diets because it is a high energy-yielding nutrient. It also supplies fat soluble vitamins and essential fatty acids to the body (Okaka *et al*., 2006).

The crude fibre content of the raw sample was 6.10%, while that of the processed samples ranged between 5.20 and 5.51% with the boiled sample having the least value (5.20%), while that of the roasted sample had the highest value (5.51 %). There were significant ($p < 0.05$) differences in the crude fibre content of the flour samples. All the processing treatments employed slightly decreased the crude fibre contents of the pigeon pea seed flours when compared to the raw sample. Roasting and autoclaving treatments concentrated the crude fibre contents of the flours due to loss of moisture. The crude fibre content values (5.20 – 5.51%) obtained in this present study were comparable to the crude fibre content (5.19 – 5.52%) reported by Ahamefule and Odoemelam (2006) for boiled and roasted *Canavalia plagiosperma* seed flours. The nutritional significance of fibre in human foods cannot be underestimated. The normal peristaltic movements of the intestine tract are dependent, in part, on internal distention which is provided by food residue (crude fibre) that is not attacked by digestive enzymes. Some of the crude fibres are hydrophilic and so help maintain a moist, soft condition of the faecal mass that facilitates the easy passage of the stool through the large intestine (colon). Fibre is also important in the diets of humans because it acts as a diluent and its absence in the diets leads to incidence of a wide range of diseases which include cancer of the colon, diabetes mellitus, obesity and coronary heart diseases (Okaka *et al*., 2006; Anya and Ozong, 2019).

The ash content showed significant ($p < 0.05$) differences between the raw and processed flour samples. The ash content of the raw sample was 2.97%, while that of the processed samples ranged from 1.74 to 2.04%. The low ash contents observed in blanched and boiled flour samples compared to the samples processed by roasting and autoclaving treatments could be attributed to the leaching of some mineral elements into the boiling and blanching media during processing. The observations are in agreement with the reports of Ukachukwu and Obioha (2000) and Anya and Ozung (2017) for blanched and boiled *Mucuna cochinchinensis* and African yam bean flours, respectively. This trend is also line with the findings of Okoye and Mazi (2012) who reported that roasted groundnut flour had higher ash content than the blanched and boiled samples. The results also showed that the increase in the ash contents of the roasted and autoclaved flours could be due to loss of greater amount of water as a result of the application of dry heat during processing. The high ash content recorded by roasted sample is an indication that the roasting technique is a good for the extraction of minerals than the boiling and blanching techniques.

The carbohydrate content of the raw sample was (55.56 %), and that of the processed samples ranged from 58.21 to 60.41%. The raw sample had the least value (55.56%), while the roasted sample had the highest value (60.41 %). There were significant ($p<0.05$) differences in the carbohydrate content of the flour samples. All the processing treatments slightly increased the carbohydrate contents of the pigeon pea seed flours when compared to the raw sample. The carbohydrate content of the flours was significantly ($p<0.05$) lower in the boiled and blanched flours compared to the samples processed by roasting and autoclaving treatments. The decrease could be attributed to thermal decomposition of carbohydrate into carbonic acid and carbon dioxide by boiling and blanching treatments during processing (Obasi and Wogu, 2008).

The energy content of the raw flour sample was 333.52KJ/100g and that of the processed samples ranged from 333.45 to 342.75KJ/100g with the boiled sample having the least value (333.45 kJ/100g), while the roasted sample had the highest value (342.75 kJ/100g). There were significant ($p<0.05$) differences in the energy content of the flour samples. The energy content of the flours was lower in boiled and autoclaved samples whereas roasting and blanching treatments relatively increased the energy content of the samples. The increase in energy content of the roasted and blanched samples could be a reflection of their high protein and fat contents. The energy content values (333.45-342.74KJ/100g) obtained in this study for the processed flours were higher than the energy content (296.3 – 312.4KJ/100g) reported by Ahamefula and Odoemelam (2008) for soaked and boiled *Canavalia plagiosperma* seed flours. The result showed that the processed flours could generally serve as good energy supplements when compared to the raw pigeon pea flour.

Generally, boiling and blanching treatments had greater reductive effects on protein, fat, crude fibre, ash and carbohydrate contents of processed pigeon pea flour samples than the autoclaving and roasting methods when compared with the raw pigeon pea flour.

**Mineral Composition of Raw and Processed Pigeon Pea Flours**

The mineral composition of raw and processed pigeon pea flour samples are presented in Table 2.

**Table 2: Mineral composition (mg/100g) of raw and processed pigeon pea flour samples**

| Parameters | Raw | Blanched | Boiled | Roasted | Autoclaved |
|---|---|---|---|---|---|
| **Calcium** | $144.72^a \pm 0.01$ | $102.24^d \pm 0.00$ | $86.24^e \pm 0.00$ | $132.76^b \pm 0.00$ | $116.83^c \pm 0.02$ |
| **Magnesium** | $170.33^a \pm 0.01$ | $145.80^d \pm 0.03$ | $137.80^e \pm 0.01$ | $169.74^b \pm 0.00$ | $153.73^c \pm 0.01$ |
| **Potassium** | $156.76^a \pm 0.01$ | $125.86^d \pm 0.00$ | $125.86^d \pm 0.00$ | $148.32^b \pm 0.00$ | $142.30^c \pm 0.01$ |
| **Sodium** | $95.62^a \pm 0.02$ | $68.66^d \pm 0.04$ | $66.66^e \pm 0.02$ | $94.45^b \pm 0.03$ | $88.36^c \pm 0.01$ |
| **Iron** | $6.64^a \pm 0.00$ | $4.38^d \pm 0.13$ | $4.38^e \pm 0.05$ | $6.31^b \pm 0.01$ | $5.42^c \pm 0.00$ |
| **Phosphorus** | $178.29^a \pm 0.03$ | $132.27^d \pm 0.05$ | $130.27^e \pm 0.03$ | $175.30^b \pm 0.01$ | $158.78^c \pm 0.02$ |

*Values are mean ± SD of triplicate determinations. Means within the same row with different letters are significantly different at p<0.05.*

The calcium content of the raw pigeon pea flour was 144.72mg/100g and that of processed samples ranged between 86.24 and 132.76mg/100g with the boiled sample having the least value (86.24 mg/100g), while the roasted sample had the highest value

(132.76 mg/100g). There were significant ($p<0.05$) differences in the calcium content of the flour samples. The roasting and autoclaving treatments slightly increased the calcium content of the pigeon pea seed flours than blanching and boiling when compared with the raw sample. This could be due to the ability of roasting and autoclaving methods to concentrate the calcium. The decrease in the calcium contents could be caused by leaching of the mineral element into the boiling and blanching water during processing (Akubor, 2016). This is in agreement with the results obtained by Oraka and Okoye (2017) and Anya and Ozung (2019) for boiled and blanched lima bean and African yam bean flours, respectively. However, the values (86.24 – 102.24mg/100g) obtained in this present study were relatively lower than the calcium content (90.26 – 112.42mg/100g) reported by Ekwe (2012) and Onunkwo *et al*. (2017) for blanched and boiled *Mucuna pruriens* and *Mucuna sloanei* seed flours, respectively. Calcium helps in bone formation. It is also important in blood clotting and muscle contraction, Calcium is involved in enzyme reaction, hormonal signal transmission, glucose metabolism, release of neuro transmitters and maintenance of membrane integrity and excitability. It also helps in the regulation of buffer balance of the blood, aids in hormone secretion and cell division. Calcium is closely bound to phospholipids in the cell membrane where it controls the permeability of membrane and regulates the uptake of nutrients by the cell (Okaka *et al*., 2006; Obizoba, 2008). The study generally showed that all the treatments reduced the calcium contents of pigeon pea flours when compared to the raw flour sample which had higher calcium content than the processed flour samples.

The magnesium content of the raw flour sample was 170.33mg/100g and that of the processed samples ranged from 137.80 to 169.74 mg/100g. All the treatments decreased the levels of magnesium in the processed pigeon pea flours but boiling and blanching methods had greater reductive effects on the magnesium content of the samples. There were significant ($p<0.05$) differences in the magnesium content of the flour samples. The decrease in the magnesium content due to boiling and blanching treatments was probably caused by degradation and leaching of the mineral element into the boiling and blanching media during processing (Akubor, 2016b). The observation is in agreement with the reports of Akinmutimi (2004) and Nsa and Ukachukwu (2009) for cooked sword bean and boiled and blanched castor oil seed flours, respectively. Magnesium helps in the maintenance of electrical potential in nerves. Magnesium is also needed for the synthesis of proteins, muscle contraction, nerve transmission and maintenance of the immune system. Magnesium is beneficial for the maintenance of blood pressure and it also helps to prevent sudden heart attack, cardiac arrest and stroke. Magnesium is also an important component of bone which contributes to its structural development (Jacob *et al*., 2015). Magnesium deficiency results in the uncontrolled twisting of muscles which may lead to convulsion in some individuals and this is common with people with chronic alcoholism (Etong *et al*., 2013).

The potassium content of the raw flour sample was 156.76mg/100g and that of the boiled, blanched autoclaved and roasted pigeon pea flour samples were 125.86mg/100g, 125.86mg/100g; 142.30mg/100g and 148.32mg/100g, respectively. There were significant ($p<0.05$) differences in the potassium content of the flour samples. The result showed that boiling and blanching treatments had more reductive effects on potassium content than autoclaving and roasting methods when compared to the raw pigeon pea flour. The decrease in the potassium content due to boiling and blanching treatments could be probably caused by degradation and leaching of the mineral element into the boiling and blanching water during processing (Akubor, 2016b). This is in agreement with the results obtained by Akinmutimi (2004), Oraka and Okoye (2017) and Anya and Ozung (2019) for boiled and blanched lima bean and cooked and roasted African yam bean flours, respectively.

Potassium is essential in blood clotting and muscle contraction. Potassium is needed for proper fluid and electrolyte balance, nerve transmission, muscle contraction and maintenance of cell integrity (Eze *et al*., 2019). Potassium in combination with sodium chloride has the main function of maintaining the acid-base and ionic balance (osmotic pressure regulation) of the blood fluid (Omoikhoje *et al*., 2006).

The sodium content of the raw pigeon pea flour was 95.62mg/100g and that of the processed samples ranged from 66.66 to 94.45 mg/100g with the boiled sample having the least value (66.66 mg/100g), while the autoclaved sample had the highest value (94.45 mg/100g). There were significant ($p<0.05$) differences in the sodium content of the flour samples. All the treatments significantly ($p<0.05$) decreased the sodium content of the flour samples when compared to the raw sample but boiling and blanching methods had more reductive effects than the autoclaving and roasting treatments. The decrease in the sodium contents of boiled and blanched pigeon pea flours could be attributed to degradation and leaching of the mineral element into the boiling and blanching water during processing (Akubor, 2016). The values (66.66 – 94.45mg/100g) obtained in this study were higher than the calcium content (76.46 – 96.48mg/100g) reported by Olanipekun *et al*. (2015) for boiled and roasted kidney bean flours. Sodium is the principal cation in extracellular fluids. It regulates plasma volume and acid-base balance. It is also involved in the maintenance of osmotic pressure of the body fluids. It equally preserves normal irritability of muscles and cell permeability, activates nerve and muscle function. In addition, sodium is involved in $Na^+/K^+$-ATPase, maintenance of membrane potentials, transmission of nerve impulses. It also helps in the absorption of monosaccharides, amino acids, pyrimidines, and bile salts. The changes in osmotic pressure are largely dependent on sodium concentration. Its metabolism is regulated by aldosterone (Soetan *et al*., 2010). The increase in the level of sodium in the serum is called hypernatraemia and this occurs in Cushion's disease, administration of adrenocorticotropic hormone (ACTH), administration of sex hormones and diabetes insipidous (Okaka *et al*., 2006).

The iron content of the raw pigeon pea flour was 6.64mg/100g and that of the processed samples ranged from 4.38 to 6.31mg/100g with the boiled sample having the least value (4.38 mg/100g), while the autoclaved sample had the highest value (6.31 mg/100g). There were significant (p<0.05) differences in the iron content of the flour samples. The iron content of the samples processed by autoclaving and roasting was higher than that of the boiled and blanched pigeon pea flours when compared to the control (raw flour sample). The decrease in the iron contents of boiled and blanched flour samples could be probably caused by degradation and leaching of the mineral element into the boiling and blanching water during processing (Oraka and Okoye, 2017). The result obtained in this present study is in agreement with the reports of Oraka and Okoye (2017) and Nwajagu *et al*. (2021) for boiled and roasted lima bean and boiled and roasted *Mucuna flagellipes* flours, respectively. Iron is also an essential element that is needed by humans and plants. It occurs predominantly in plants in the form of phytate complexes. It may also occur in the form of inorganic iron salts such as ferric hydroxides. Iron is among the mineral elements that WHO is strongly advocated that it should be in everyday meal. Iron is an important component of haemoglobin which is an oxygen carrying pigment in the blood (Potter and Hotchkiss, 2006).

The phosphorus content of the raw sample was 178.29mg/100g and that of the boiled, blanched, autoclaved and roasted samples were 130.27mg/100g, 132.27mg/100g, 158.78mg/100g and 175.30mg/100g, respectively with the boiled sample having the least value (130.27mg/100g), while the roasted sample had the highest value (175.30mg/100g). There were significant (p<0.05) differences in the phosphorus content of the flour samples. All the treatments drastically reduced the levels of phosphorus in the processed samples but boiling had more reactive effect than the other treatments. The decrease in the phosphorus content due to boiling was probably caused by degradation and leaching of the mineral element into the boiling water during processing (Arukwe *et al*., 2017). The observation is in agreement with the results obtained by Oraka and Okoye (2017) and Anya and Ozung (2019) for boiled and roasted lima bean and African yam bean flours, respectively. Phosphorus enhances the quick release of energy in the body and it may combine with calcium for the development of bones and teeth in human body. The deficiency of phosphorus is rare because of the prevalence of phosphorus in foods and is generally observed only in the case of starvation (Etong *et al*., 2013).

Generally, autoclaving and roasting had greater effect on the enhancement of the mineral contents of pigeon pea flours than the boiling and blanching treatments when compared to the raw sample.

**Vitamin Composition of Raw and Processed Pigeon Pea Flours**

The vitamin composition of raw and processed pigeon pea flour samples are presented in Table 3.

**Table 3: Vitamin composition (mg/100g) of raw and processed pigeon pea flour samples**

| **Parameters** | **Samples** | | | | |
|---|---|---|---|---|---|
| | **Raw** | **Blanched** | **Boiled** | **Roasted** | **Autoclaved** |
| **Ascorbic acid** | $4.33^{a} \pm 0.05$ | $3.17^{d} \pm 0.00$ | $3.09^{e} \pm 0.00$ | $4.02^{b} \pm 0.00$ | $3.51^{c} \pm 0.00$ |
| **Thiamine** | $0.17^{a} \pm 0.00$ | $0.07^{d} \pm 0.00$ | $0.05^{e} \pm 0.00$ | $0.12^{b} \pm 0.00$ | $0.09^{c} \pm 0.00$ |
| **Riboflavin** | $0.21^{a} \pm 0.00$ | $0.04^{d} \pm 0.00$ | $0.03^{e} \pm 0.00$ | $0.17^{b} \pm 0.00$ | $0.12^{c} \pm 0.00$ |
| **Niacin** | $0.28^{a} \pm 0.00$ | $0.17^{d} \pm 0.00$ | $0.13^{e} \pm 0.00$ | $0.26^{b} \pm 0.01$ | $0.24^{c} \pm 0.00$ |
| **Vitamin A** | $6.25^{a} \pm 0.00$ | $3.55^{d} \pm 0.01$ | $3.21^{e} \pm 0.01$ | $5.89^{b} \pm 0.00$ | $4.70^{c} \pm 0.04$ |
| **Vitamin E** | $2.70^{a} \pm 0.00$ | $1.37^{d} \pm 0.03$ | $1.10^{e} \pm 0.03$ | $2.40^{b} \pm 0.05$ | $1.68^{c} \pm 0.00$ |

*Values are mean ± SD of triplicate determinations. Means within the same row with different letters are significantly different at p<0.05.*

The ascorbic acid contents of the raw, boiled, blanched, autoclaved and roasted pigeon pea flour samples were 4.33mg/100g, 3.09mg/100g, 3.17mg/100g, 3.51mg/100g, and 4.02mg/100g, respectively with the boiled sample having the least value (3.09 mg/100g), while the raw sample had the highest value (4.33 mg/100g). There were significant (p<0.03) differences in the ascorbic acid content of the flour samples. Boiling and blanching treatments significantly (p<0.05) reduced the ascorbic acid content of the pigeon pea seed flours than the autoclaving and roasting methods when compared to the raw sample. The decrease in the ascorbic acid contents of boiled and blanched flour samples could be attributed to degradation and leaching out of the vitamin C into the boiling and blanching water during processing (Fasoyiro *et al*., 2010). The result of this present study is in agreement with the findings of Oraka and Okoye (2017) and Arukwe *et al*. (2017) who reported that boiling reduced the ascorbic acid content of processed lima bean and pigeon pea flours, respectively. Ascorbic acid plays an important role in the prevention of scurvy. It also promotes the wound healing, healthy immune system and prevents cardiovascular diseases. Vitamin C (ascorbic acid) is an antioxidant vitamin which helps to mitigate scavenge free radicals in the cells. Vitamin C is very vital in iron metabolism; hence, it helps to against iron deficiency anaemia (Soetan *et al*, 2010). Olanipekun *et al*. (2015) also reported that vitamins A and C which are commonly used antioxidants help in the prevention of certain diseases such as cancer and diabetes mellitus in the human body.

The thiamine content of the raw pigeon pea flour was 0.17mg/100g and that of the processed pigeon pea flour samples ranged from 0.05 to 0.12 mg/100g with the boiled sample having the least value (0.05 mg/100g), while the roasted sample had the highest value

(0.12 mg/100g). There were significant (p<0.05) differences in the thiamine content of the flour samples. Autoclaving and roasting treatments recorded higher thiamine content values (0.09mg/100g and 0.12mg/100g) than the boiling (0.05mg/100g) and blanching (0.07mg/100g) methods when compared to the raw sample which had the thiamine content of 0.17mg/100g. The decrease in thiamine contents as a result of boiling and blanching treatments could be probably caused by degradation and leaching of the thiamine into boiling and blanching media during processing (Olanipekun *et al*., 2015). The observation is in close agreement with the findings of Arukwe *et al*. (2017) and Eze *et al*. (2019) who reported that boiling and blanching reduced the thiamine contents of processed pigeon pea and soybean flours, respectively. Thiamine functions as a coenzyme in energy metabolism. It also helps in the proper functioning of peripheral nerves and in the treatment of beriberi (Potter and Hotchkiss, 2006). Thiamine helps in the maintenance of healthy mental attitude in infants and young children (Okaka *et al*., 2006). Autoclaving and roasting methods had lesser reductive effects on the thiamine content of processed pigeon pea flours than the boiling and blanching treatments.

The riboflavin content of the raw sample was 0.21mg/100g and that of the boiled, blanched, autoclaved and roasted samples were 0.03mg/100g, 0.04mg/100g, 0.12mg/100g and 0.17mg/100g, respectively. There were significant (p<0.05) differences in the riboflavin content of the flour samples. The result showed that boiling and blanching treatments had greater reductive effects on the riboflavin content of the pigeon pea seed samples than the autoclaving and roasting methods when compared to the raw sample. The decrease in the riboflavin contents of boiled and blanched flour samples compared to the autoclaved and roasted samples could be due to degradation and leaching of the vitamin into boiling and blanching media during processing (Oraka and Okoye, 2017). The result of the present study is in agreement with the findings of Anya and Ozung (2019) who reported that boiling and blanching reduced the riboflavin contents of processed African yam bean flours. Riboflavin functions as part of a group of enzymes called flavoproteins, flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) which assist in the respiratory chains of cellular metabolism particularly in the oxidation-reduction reaction involving the release of energy. More so, the presence of this vitamin improves growth, reproduction and also prevents anaemia and abnormal gait in the human body (Potter and Hotchkiss, 2006).

The niacin content of the raw pigeon pea flour was 0.28mg/100g and that of the processed pigeon pea flour samples ranged from 0.13 to 0.26 mg/100g with the boiled sample having the least value (0.13 mg/100g), while the roasted sample had the highest value (0.26 mg/100g). There were significant (p<0.05) differences in the niacin content of the flour samples. All the treatments employed reduced the niacin content of the pigeon pea flours. However, boiling and blanching treatments significantly (p<0.05) decreased the niacin content of the samples than the autoclaving and roasting methods when compared to the raw sample. The decrease in the niacin content due to boiling and blanching could be probably attributed to degradation and leaching of this vitamin into the boiling and blanching water during processing (Akubor, 2016). The niacin content values (0.13-0.26mg/100g) obtained in this study were lower than the niacin content (1.12 – 2.08mg/100g) reported by Okoye and Mazi (2012) for boiled and roasted groundnut flours. Niacin which is equally a member of the B-complex vitamin functions as a co-enzyme (NAD and NADP) in the body. It also has specific effect on the growth and plays an important role in reducing the levels of blood cholesterol in the body (Potter and Hotchkiss, 2006).

The vitamin A content of the raw sample was 6.25mg/100g and that of processed pigeon pea flour samples ranged from 3.21 to 5.89 mg/100g. There were significant (p<0.05) differences in the vitamin A content of the flour samples. The result showed that all the treatments employed significantly (p<0.05) decreased vitamin A content of the pigeon pea flours but boiling and blanching methods were found to have greater reductive effects than the autoclaving and roasting treatments when compared to the raw sample. The result of this study is in agreement with the findings of Okoye and Mazi (2012) who reported that heat processing of legumes led to reduction in their vitamin A content. The reduction in vitamin A contents of boiled and blanched pigeon pea flours compared to the samples processed by autoclaving and roasting treatments could be due to the sensitivity of this vitamin to oxidation and leaching into the water-soluble media during processing (Audu and Aremu, 2011; Okoye and Mazi, 2012). Vitamin A helps in the maintenance of normal vision of the eyes. It is also an antioxidant that plays a major role in fighting against diseases like glycoma and diabetes and slows down the natural aging process (Olanipekun *et al*., 2015). Vitamin A deficiency leads to blindness and failure of normal bone and tooth development in the young children (Potter and Hotchkiss, 2006).

The vitamin E content of the raw sample was 2.70mg/100g and that of the processed pigeon pea flour samples ranged from 1.10 to 2.40 mg/100g with the boiled sample having the least value (1.10 mg/100g), while the autoclaved sample had the highest value (2.40 mg/100g). There were significant (p<0.05) differences in the vitamin E content of the flour samples. The result showed that autoclaving and roasting increased the vitamin E content of the samples than the boiling and blanching methods when compared to the raw sample. The observation is in close agreement with the findings of Okoye and Mazi (2012) who reported that boiling and blanching treatments reduced the vitamin E content of groundnut flour than roasting. Olanipekun *et al*. (2015) stated that the observed increase in loss of vitamin E as a result of boiling and blanching treatments could be due to its high sensitivity to oxidation and leaching of the vitamin into water soluble media during processing. Vitamin E is a strong antioxidant which plays a major role like vitamin A in fighting against diseases like cancer and diabetes mellitus in humans. It also has the ability to spare carotene and vitamin A from oxidative destruction in human body (Okaka *et al*., 2006). Generally, boiling and blanching greatly reduced the vitamin contents of processed pigeon pea flours than the autoclaving and roasting treatments when compared to the raw pigeon pea flour sample.

**Antinutrient Composition of Raw and Processed Pigeon Pea Flours**

The anti-nutrient composition of raw and processed pigeon pea flour samples are presented in Table 4.

**Table 4: Anti-nutrient composition of raw and processed pigeon pea flour samples**

| Parameters | Raw | Blanched | Boiled | Roasted | Autoclaved |
|---|---|---|---|---|---|
| **Trypsin inhibitor (Tiu/mg)** | $5.61^a \pm 0.01$ | $3.54^b \pm 0.01$ | $2.30^d \pm 0.01$ | $3.37^c \pm 0.01$ | $1.00^e \pm 0.01$ |
| **Tannin (mg/100g)** | $1.54^a \pm 0.01$ | $1.25^b \pm 0.01$ | $1.06^d \pm 0.01$ | $0.81^e \pm 0.01$ | $1.17^c \pm 0.01$ |
| **Phytate (mg/100g)** | $4.18^a \pm 0.01$ | $2.33^c \pm 0.01$ | $1.12^d \pm 0.03$ | $1.10^e \pm 0.01$ | $3.28^b \pm 0.01$ |
| **Oxalate (mg/100g)** | $4.01^a \pm 0.01$ | $3.40^b \pm 0.01$ | $1.19^d \pm 0.01$ | $0.48^e \pm 0.01$ | $2.69^c \pm 0.01$ |
| **Saponin (mg/100g)** | $3.66^a \pm 0.01$ | $2.89^b \pm 0.01$ | $1.92^d \pm 0.01$ | $1.28^e \pm 0.01$ | $2.63^c \pm 0.01$ |
| **Haemaglutinin (Hui/g)** | $7.44^a \pm 0.01$ | $4.31^b \pm 0.01$ | $2.23^d \pm 0.01$ | $1.30^e \pm 0.01$ | $4.23^c \pm 0.01$ |

*Values are mean ± SD of triplicate determinations. Means within the same row with different letters are significantly different at p<0.05.*

The trypsin inhibitor activity of the raw, boiled, blanched, roasted and autoclaved pigeon pea flour samples were 5.61, 2.30, 3.54, 3.52 and 2.38 Tiu/mg, respectively. The result showed that the trypsin inhibitor activity values for boiled (2.30 Tiu/mg) and autoclaved (2.38 Tiu/mg) flour samples were significantly (p<0.05) lower than the values obtained for the samples processed by roasting (3.32 Tiu/mg) and blanching (3.54 Tiu/mg) treatments when compared to the raw sample which had the value of 5.61 Tiu/mg. This implied that the boiled and autoclaved pigeon pea flours were better detoxified than the roasted and blanched flour samples. The reduction in the trypsin inhibitor activities of boiled and autoclaved samples could be due to the thermal breakdown of these compounds and subsequent leaching of the soluble components into boiling water during processing (Akubor, 2017; Oraka and Okoye, 2017). The findings of this present study collaborate with the views of Adegunwa *et al* (2013) and Anya and Ozung (2019) who reported that wet or moist heat treatment is an effective means of reducing or inactivating trypsin inhibitors than the dry heat treatment. Trypsin inhibitors are natural organic compounds which have the ability to interact with proteolytic enzymes particularly trypsin and chemotrypsin thereby rendering them unavailable for protein digestion in man and other monogastric animals (Mosha and Gaga, 1999). Trypsin inhibitors are widely distributed in plants such as beans, tubers and leaves and they do not exert any adverse effect in ruminant animals because they are degraded in the rumen (Torres *et al*., 2007; Sharma *et al*., 2011). Trypsin inhibitors are generally inactivated by heat and this results in improvement in the nutritive value of proteins.

The tannin content of the raw, blanched, boiled, roasted and autoclaved pigeon pea flours ranged from 0.81 to 1.5mg/100g. The boiled pigeon pea flour had the lowest value (0.81mg/100g) followed by the autoclaved (1.04mg/100g), roasted (1.06 mg/100g) and blanched (1.25 mg/100g) flour samples compared to the raw sample which had the tannin content value of 1.54 mg/100g. The result showed that boiling had a greater reductive effect on the tannin content of the flour samples than the other treatments. Osita (2007) reported that tannins are water soluble compounds which may be either destroyed or inactivated by the application of heat or the leaching of the compounds into boiling water during processing. Tannins decrease the digestibility and palatability of proteins and carbohydrates by forming insoluble complexes with them. They also reduce the bioavailability of minerals (Osagie, 1998). Tannins are naturally occurring plant polyphenols and their main characteristic property is to bind and precipitate protein by interfering with its digestion and absorption (Sharma *et al*., 2011). The tannin content (0.81 – 1.25mg/100g) obtained in this study for processed pigeon pea flours was higher than the values (0.31 – 0.33 %) reported by Anya and Ozung (2019) for boiled and toasted African yam bean flours. Tannins are water soluble phenolic compounds with a high molecular weight (> 500) that have the capacity to precipitate protein particularly pepsin (Kumar, 1991; Oraka and Okoye, 2017). The low tannin content recorded by the boiled pigeon pea flour compared to the other processed samples is an indication of better digestibility of protein when the boiled flour is used in food formulations. This is because tannic acid has been known to adversely affect protein digestibility (Okaka *et al*., 2006).

The phytate content of the raw flour sample was 4.18mg/100g and that of the processed samples ranged from 1.12 to 2.33 mg/100g with the boiled sample having the least value (1.12 mg/100g), while the blanched sample had the highest value (2.33 mg/100g). The result revealed that boiled pigeon pea flour had significantly (p<0.05) lower phytate content compared to the other processed and raw flour samples. Phytates are known to increase the requirements for certain minerals, especially, phosphorus and zinc, which form insoluble complexes with this metal ion and zinc (Sharma *et al*., 2011). The findings of this present study is in agreement with the report of Nwosu *et al*. (2013) who stated that boiling led to the leaching of the phytate present in pigeon pea seeds into boiling water during processing.

The oxalate content of the raw pigeon pea flour was 4.01mg/100g and that of the processed samples ranged between 0.48 to 3.40 mg/100g with the boiled sample having the least value (0.48 mg/100g), while the blanched sample had the highest value (3.40 mg/100g). There were significant ($p<0.05$) differences in the oxalate content of the flour samples. The result showed that boiled and autoclaved pigeon pea flours had lower oxalate contents (0.48 and 0.98mg/100g) than the roasted (2.48mg/100g) and blanched (3.40mg/100g) samples which suggest that the boiled and autoclaved flour samples were better detoxified than the other processed samples. The reduction in the oxalate contents of boiled and autoclaved flours could be due to degradation of oxalate by heat and the leaching of this anti-nutrient into boiling water during processing (Nwosu *et al*., 2013; Uche *et al*., 2013). Oxalates affect calcium and magnesium metabolism and react with proteins to form complexes which have an inhibitory effect in peptic digestion (Akande *et al*., 2010). Oxalates produce irritation in the mouth and prevent the absorption of calcium and iron in foods.

The saponin content of the raw, blanched, boiled, roasted and autoclaved pigeon pea flours were 3.66, 2.89, 1.29, 1.92 and 1.63 mg/100g, respectively. There were significant ($p<0.05$) differences in the saponin content of the samples. Boiling and autoclaving significantly ($p<0.05$) decreased the saponin content of the pigeon pea flours than the blanching and roasting treatments when compared to the raw sample. The values (1.28 – 2.89mg/100g) obtained for the processed samples in this present study were lower than the saponin content (1.34 – 2.92mg/100g) reported by Eburuaja (2010) for boiled and roasted African yam bean flours. Saponins are glycosides that are composed of a lipid-soluble aglycone that consists of sterol. Saponins are toxins found as non-cardiac steroid glucosides that produce foam, have taste and are characterized by their ability to homolyze red blood cells (Onyeike and Omubo-Dede, 2002). In man and other monogastric animals, saponin toxicity causes growth retardation as a result of reduction in food or feed intake (Okaka *et al*., 2006). Generally, all the treatments reduced the saponin content of processed pigeon pea flours compared to the raw sample.

The haemaglutinin content of the raw pigeon pea flour was 7.44 Hiu/g and that of the processed samples ranged from 1.30 – 2.36 Hui/g with the boiled sample having the least value (1.30Hiu/g), while the blanched sample had the highest value (4.31Hiu/g). There were significant ($p<0.05$) differences in the haemaglutinin content of the flour samples. All the treatments significantly ($p<0.05$) reduced the level of haemaglutinin in processed pigeon pea flours but boiling had a greater reductive effect than the other treatments. The observation is in agreement with the report of Egbe and Akinyele (1990) for cooked and toasted lima bean flours. The reduction in the haemaglutinin content observed in all the processed samples could be attributed to the increase in the amount of heat applied which helped in the leaching of this antinutrient into water soluble media during processing (El-Moneim *et al*., 2012; Uche *et al*., 2013). Generally, dehulling in combination with heat treatment (blanching, boiling, roasting and autoclaving) resulted in a higher reduction in the antinutrient contents of the pigeon pea seed flours when compared to raw sample. The reduction in the levels of these antinutrients due to heat processing is of considerable economic and practical importance to processors and producers of food especially in Nigeria and other sub Saharan African countries and this enhances the utilization of pigeon pea and other lesser known legumes as good sources of nutrients especially proteins, carbohydrates and crude fibre.

## CONCLUSION

Autoclaving followed by boiling generally resulted in reduction in the protein, ash, fat, crude fibre, niacin and riboflavin contents of the products. The use of roasting in the processing of pigeon pea yielded product with slight increase in carbohydrate, energy, thiamin, ascorbic acid, vitamins A and E contents. Furthermore, of all the heat processing treatments used, boiling drastically reduced the anti-nutrient contents of pigeon pea flour than the blanching, autoclaving and roasting treatments. It is therefore recommended that any of these processes can be used for processing pigeon pea seeds, however, due to the fact that autoclaves are quite expensive and may not be affordable by the local producers or manufacturers of pigeon pea products, boiling and roasting can be easily employed.

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