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Research Article

Effects of Processing Methods on Proximate, Antinutrients, and Antioxidant Properties of Pigeon Pea (*Cajanus cajan*) Flours and Organoleptic Properties of the Puddings

***Arukwe, D. C.[1], Okereke, I. F.[2], Offia-Olua, B. I.[1], Nwanagba, N. L.[1], and Iwuanyanwu, G. C.[1]**

[1]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
[2]Department of Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
****Corresponding Author's email*: dorarukwe@gmail.com**

ABSTRACT
The effects of processing methods on proximate, antinutrients and antioxidant properties of pigeon pea flours and organoleptic properties of the puddings was investigated. Seven flours were produced using soaking, boiling and combined soaking/boiling processing methods and designated as: (So12) soaked for 12 h, (So24) soaked for 24 h, (B30) boiled for 30 min, (B60) boiled for 60 min, (S12B30) soaked for 12 h and boiled for 30 min, (S24B60) soaked for 24 h and boiled for 60 min and (RPPF) raw pigeon pea flour, which served as the control. The proximate, antinutrients, and antioxidant properties were analyzed using standard methods. The sensory properties of puddings produced from pigeon pea flours and sprouted cowpea flour were evaluated using the 9-point hedonic scale. The proximate result depicted that moisture ranged (5.45 – 9.66%), crude protein (18.85 – 24.16%), fat (1.31 – 1.80%), crude fibre (3.04 – 5.01%), ash (1.43 – 3.08%) and carbohydrate (59.55 – 65.68%). The energy value ranged (349.22 – 356 kcal). The antinutrients were significantly ($p<0.05$) reduced by all the processing treatments. The antioxidant properties ranged for total phenol (85.95 – 162.99 mg/GAE/100g), total flavonoid (44.91 – 93.31 mg/QE/100g), DPPH (39.90 – 63.23%), FRAP (6.35 – 16.93 umol Fe^{2+}/g), and ABTS (8.43 – 19.47 umol TE/g). The organoleptic results showed that the processed pigeon pea puddings recorded higher scores than the cowpea pudding and are therefore more preferred. The results revealed that flours with good nutrients, high antioxidant properties and acceptable products can be produced from pigeon pea processed by different methods, thereby enhancing the utilization of pigeon pea.

Keywords: Antinutrients; Antioxidant properties; Organoleptic; Pigeon pea; Processing methods; Puddings,

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INTRODUCTION

Pigeon pea *(Cajanus cajan L.)* is a drought-tolerant legume widely cultivated in tropical and subtropical regions for both food and income generation (Choudhary *et al*., 2021). Belonging to the *Fabaceae* family, it is one of the oldest and most important grain legumes, ranking sixth globally after common beans, chickpeas, field peas, cowpeas, and lentils (Gerrano *et al*., 2022). It is presumed to have originated in India around 2000 BC before spreading to West Africa which is regarded as its secondary center of origin (Sharma *et al*., 2011). Pigeon pea serves as a primary source of protein for billions of people across the world especially in Nigeria, while

also functioning as an essential cash crop that supports the livelihoods of resource-poor farmers (Susmitha *et al*., 2022). Nutritionally, pigeon pea is rich in protein (about 20–26%), carbohydrates, and ash, and contains low fat (Yang *et al*., 2020), making it a valuable food for combating protein energy malnutrition. Pigeon pea seeds have probiotic potential and can be used as a functional food (Arukwe *et al*., 2023). In addition, bioactive compounds in pigeon pea seeds including flavonoids, phenolic acids and tannins, have been linked to antioxidant, anti-inflammatory and hypoglycemic effects in laboratory and animal studies (Melini *et al*., 2023). Despite these benefits, the crop remains underutilized and receives limited research attention compared to other legumes such as cowpea. Raw pigeon pea seeds contain certain antinutritional factors such as phytates, tannins, oxalates, and trypsin inhibitors that can reduce nutrient bioavailability and affect palatability (Fasoyiro *et al*., 2024). To address this, some authors have utilized various processing methods such as soaking, germination, roasting, boiling, and fermentation to modify its physicochemical and functional properties before incorporation into flours and puddings (Sobowale, 2024; Atuna *et al*., 2023; Azuka *et al*., 2025).

Pudding, also known as *moi-moi,* is a steamed bean delicacy prepared from blended cowpea paste mixed with spices (Arukwe *et al*., 2023) and various optional ingredients such as fish, crayfish, minced meat, or bone marrow. It is a popular dish in eastern Nigeria, commonly eaten with pap, soaked gari, rice, or enjoyed on its own as a snack. Due to its rich protein content, *moi-moi* also serves as a complementary food (Arukwe *et al*., 2023). In Nigeria, cowpea (*Vigna unguiculata*) has traditionally been the most common legume used in preparing puddings (*moi-moi),* largely because of its soft seed coat, short cooking time, and wide consumer preference. However, the rising cost, limited availability, and high demand for cowpea have made it increasingly difficult for many households to afford, especially those in low-income communities.

To solve the challenge of protein-energy malnutrition, it is necessary to explore and promote other locally available underutilized legumes that are both rich in nutrients and cost-effective. Pigeon pea, a native but underexploited legume, presents a promising alternative due to its high levels of protein, dietary fiber, and essential minerals. Also, pigeon pea has not been fully harnessed as an ingredient in the production of functional foods despite the abundance of physiologically active components and its rich nutritional profile. Also, the commercial use of pigeon pea flour in preparation of products like pudding has remained unpopular largely because of its hard seed coat, lengthy cooking time, and the presence of antinutritional factors. Adopting suitable processing techniques, such as boiling, soaking and combined soaking and boiling, could help reduce its antinutrients and improve its nutritional, functional and sensory properties thereby making it a potential replacement for cowpea in *moi-moi* preparation. Therefore, using pigeon pea flour for pudding production would increase its utilization and decrease post-harvest losses. Moreso, this will help to address the problem of protein energy malnutrition prevalent in the society. Additionally, it will help to increase the earnings of local producers of the crop due to increased market demand and create varieties of puddings (*moimoi*). Findings from this research will provide data for effective processing and utilization of pigeon pea both on household and industrial scale. The aim of this study was to evaluate the proximate, antinutrients and antioxidant properties of pigeon pea flours as affected by processing treatments and organoleptic properties of the puddings.

MATERIALS AND METHODS

PROCUREMENT OF RAW MATERIALS

Pigeon pea *(Cajanus cajan)* seeds were procured from Ikpa Market, Igbo-Etiti Local Government Area, Enugu State. The cowpea seeds and other ingredients were procured from Orie Ugba Market, Umuahia, Abia State, Nigeria. Sample preparation and laboratory analysis were conducted at the Food Processing Laboratory of Department Food Science and Technology, and the Biochemistry Laboratory of National Root Crops Research Institute (NRCRI), Umudike, Abia State.

Preparation of soaked pigeon pea flour samples

The method described by Adeleke *et al*. (2017) with slight modification was used. Two kilograms (2 kg) of pigeon pea seeds will be sorted and cleaned of extraneous materials. The seeds were washed with clean tap water and the water drained. The seeds were divided into two portions with codes So12 and So24 (1 kg each), and soaked in water (1:5 w/v) for 12 h and 24 h respectively. The water was changed at 6-hourly intervals during the soaking process. At the end of the soaking for each portion, the water was drained and the seeds dried in an oven (Uniscope laboratory oven model SM9023) at 70°C for 18 h (with constant turning after every 4 h) until constant weight was obtained. Then, the dried seeds were milled using attrition mill (model SK-30-SS Food Grade),

sieved with 0.4 mm sieve and packaged in polyethylene bag for further studies.

Preparation of boiled pigeon pea flour samples

The method described by Adeleke *et al*. (2017) with slight modification was used. Two kilograms (2 kg) of pigeon pea seeds were sorted and cleaned of extraneous materials. The seeds were washed with clean tap water and the water drained. The seeds were divided into two portions with codes B30 and B60 (1 kg each) and boiled for 30 min and 60 min respectively. The samples were drained and the seeds dried in an oven (Uniscope laboratory oven model SM9023) at 70°C for 18 h (with constant turning after every 4 h) until constant weight was obtained. Then, the dried seeds were milled using attrition mill (model SK-30-SS Food Grade), sieved with 0.4 mm sieve and packaged in polyethylene bag for further studies.

Preparation of soaked/boiled pigeon pea flour samples

The method described by Adeleke *et al*. (2017) with slight modification was used. Two kilograms (2 kg) of pigeon pea seeds were sorted and cleaned of extraneous materials. The seeds were washed with clean tap water and the water drained. The seeds were divided into two portions with codes S12B30 and S24B60 (1 kg each) and soaked in water (1:5 w/v) for 12 h and 24 h respectively. The water was changed at 6-hourly intervals during the soaking process. At the end of the soaking for each portion, the water was drained. Thereafter, the seeds were boiled for 30 min and 60 min respectively and the water drained, and the seeds were dried in an oven (Uniscope laboratory oven model SM9023) at 70°C for 18 h (with constant turning after every 4 h) until constant weight is obtained. Then, the dried seeds were milled using attrition mill (model SK-30-SS Food Grade), sieved with 0.4 mm sieve and packaged in polyethylene bag for further studies.

Preparation of raw pigeon pea flour

The method described by Arukwe *et al*. (2017) with slight modification was used. Two kilograms (2 kg) of pigeon pea seeds were sorted and cleaned of extraneous materials. The seeds were washed with clean tap water and the water drained. The seeds were dried in an oven (Uniscope laboratory oven model SM9023) at 70°C for 18h (with constant turning after every 4h) until constant weight was obtained. Then, the dried seeds were milled using attrition mill (model SK-30-SS Food Grade), sieved with 0.4 mm sieve and packaged in polyethylene bags for further studies.

Preparation of sprouted cowpea flour

The method described by Arukwe *et al*. (2017) with slight modification was used. Two kilograms (2 kg) of cowpea seeds were sorted and cleaned of extraneous materials. The seeds were washed with clean tap water and the water drained. The seeds were soaked in water for 10 hours and allowed to sprout for 3 days at room temperature. During the sprouting, the seeds were sprayed with water at 12-hour intervals to maintain moisture. At the end of sprouting time, the seeds were dried in an oven (Uniscope laboratory oven model SM9023) at 70°C for 18 h (with constant turning after every 4 h) until constant weight was obtained. Then, the dried seeds were milled using attrition mill (model SK-30-SS Food Grade), sieved with 0.4 mm sieve and packaged in polyethylene bag for the production of cowpea pudding.

Determination of Proximate Composition

Moisture content: Moisture content of the flours was determined according to the method described by Onwuka (2018). Two millimeters of each of the samples were weighed into different moisture cans. They were then placed in an oven at 150˚C for 3h, drying was stopped after obtaining a constant value consecutively. The flakes were cooled in a desiccator and weighed. Moisture content of the flakes was then calculated as follows:

$$\text{Moisture}(\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where: W_1 = initial weight of empty can,

W_2 = weight of empty can + sample before drying,

W_3 = final weight of empty can + sample after drying.

Crude Protein content: Crude protein of the samples was determined using the Kjedahl method as described by Onwuka (2018). One millimeter of the sample was introduced into the digestion flask. Kjedahl catalyst (selenium tablets) was added to the sample. Twenty milliliters of concentrated sulphuric acid was added to the sample and fixed to the digester for 8h until a clear solution was obtained. The cooled digest was transferred into 100ml volumetric flask and made up to the mark with distilled water. The distillation apparatus was set and rinsed for 10m after boiling. Twenty milliliters of 4% Boric acid was pipetted into conical flask. Five drops of methyl red was added to the flask as indicator and the sample was diluted with 75ml distilled water. Ten milliliters of the digest was made alkaline with 20ml of sodium hydroxide (NaOH) (20%) and distilled. The steam exit of the distillatory was closed and the change of color of boric acid solution to green was timed. The mixture was distilled for 15min. The filtrate was then titrated against 0.1N Hydrochloric acid (HCl).

The total percentage of protein was calculated:
Protein(%) = % nitrogen x conversion factor (6.25).

Crude Fibre content: The crude fibre of the samples was determined according to the Onwuka (2018) method. Two millimeters of each of the snacks were boiled under reflux for 30min with 200ml of solution containing 1.25g of tetraxosulphate (vi) acid (H_2SO_4) per 100ml of solution. The solution was filtered through linen on a flaunted funnel and washed with water until the washing is no longer acidic. The residue was then transferred to a beaker and boiled for 30min with 100ml of solution. The final residue was filtered through a thin but closer pad of washed and ignited asbestos in a Gosh crucible. The residue was then dried in an electric oven and weighed. The residue was incinerated, cooled and weighed. Crude fibre content of the instant meal was then calculated as follows:

$$\text{Crude fibre } (\%) = \frac{W_2 - W_3}{W_1}$$

Where: W_1 = weight of sample used
W_2 = weight of crucible plus sample
W_3 = weight of sample crucible

Fat content: The fat content of the samples was determined using solvent extraction in a soxhlet apparatus as described by Onwuka (2018). Two millimeters of each of the samples were wrapped in a filter paper and placed in a soxhlet reflux flask which is connected to a condenser on the upper side and to a weighed oil extraction flask full with 200ml of petroleum ether. The ether was brought to its boiling point, the vapour condensed into the reflux flask immersing the samples completely for extraction to take place on filling up the reflux flask siphons over carrying the oil extract back to the boiling solvent in the flask. The process of boiling, condensation, and reflux was allowed to go on for four hours before the defatted samples were removed. The oil extract in the flux was dried in the oven at 60˚C for 30min and then weighed.

$$\text{Fat } (\%) = \frac{\text{Weight of fat}}{\text{Weight of sample}} \text{ x } 100$$

Ash content: The method described by Onwuka (2018) was used to determine the ash content of the samples. Porcelain crucible was dried and cooled in desiccators before weighing. Two millimeters of the samples were weighed into the crucible and the weight taken. The crucible containing the samples were placed into the muffle furnace and ignited at 550°C. This temperature was maintained for 3h. The muffle furnace was then allowed to cool; the crucibles were then brought out, cooled and weighed. The ash content was calculated as follows:

$$\text{Ash}(\%) = \frac{W_2 - W_1}{\text{Weight of sample}} \text{ x } 100$$

Where: W_2 = weight of crucible + ash,
W_1 = weight of empty crucible.

Carbohydrate content: Carbohydrate content of the samples was determined by using the formula described by Onwuka (2018).

Carbohydrate(%)=100 − % (protein + fat + fibre + ash + moisture content)

Determination of Energy value

The energy value was estimated using Atwater factors as described by Onwuka (2018). The energy value was calculated by multiplying the proportion of protein, fat and carbohydrate by their respective physiological fuel value of 4, 9, and 4kcal/g respectively and taking the sum of their products. The energy value was calculated thus:

F_e = (% CP x 4) + (% CF x 9) + (% CHO x 4)

Where: F_e = Food energy (in grain calories), CP= Crude protein, CF= Crude fat, CHO= Carbohydrate

Determination of anti-nutritional factors

Saponin: The colourimetric method of AOAC (2012) was employed to determine the saponin content. The sample (0.5g) was weighed and put into a test tube followed by the addition of 10ml of distilled water. The mixture was shaken and allowed to stand for 1h. the formation of stable foaming froth was observed. One millilitre of the mixture was pipette into another test tube with 5ml of distilled water added to the extract. This was followed by the addition of a drop of olive oil. The test tube with its content was shaken and it became cloudy. The absorbance was measured at 620nm using a spectrophotometer. The quantity of saponin contained in each cake was estimated from the standard saponin curve obtained from plotting the concentration of the standard concentration against the absorbance, and calculated as:

%Saponin = Ab x S x Df x 100

Where: Ab = absorbance, S = slope, Df = dilution factor

Tannin: The method described by Nwosu *et al*. (2014) was used to determine the tannin content of the samples. One gram of each sample was weighed into a different centrifuge tube with 2ml of distilled water. It was centrifuged at 1500rpm for 10 minutes. The centrifuge samples were then poured out into a beaker and the supernatant (extract) dispersed. One millilitre of sodium carbonate and Folin Denis reagent were added to the beaker and allowed to settle. The absorbance of the developed colour was measured at 760nm wavelength with the reagent blank at zero. The tannin content was calculated as;

$$\%\text{Tannin} = \frac{\text{AU x C x VF}}{\text{W x AS x VA}}$$

Where: W = weight of sample analyzed, AU = absorbance of the test sample, AS = absorbance of the standard solution, C = concentration of the standard in mg/ml, VF = total volume of filtrates, VA = volume of filtrates analyzed

Phytate: The spectrophotometric method described by AOAC (2012) was used to analyze the phytate content. One gram of the sample was extracted in duplicate for 4h with 20 ml of 0.1M nitric acid with constant agitation. The tubes were stoppered and placed in a boiling water bath for 20 minutes and allowed to cool. Five millilitres of amyl alcohol were added to each tube followed by 1.0ml of ammonium thiocyanate (100g/l). The tubes were shaken thoroughly and centrifuged at 2000rpm and then absorbance of the amyl alcohol layer was a spectrophotometer. One millilitre of the extract was pipette into a test tube fitted with a ground glass stopper together with 1ml of ferric solution. A ferric solution was prepared by dissolving 0.2g hydrated ammonium iron (III) sulphate in 100ml 2N HCl and made up to 1000ml with diluted water and the absorbance was measured at 519nm against distilled water using a spectrophotometer. A standard solution was also prepared for the analysis. Per cent phytic acid was then calculated using the absorbance of the test sample and that of the standard solution.

Alkaloids: The alkaline precipitation gravimetric method (Harborne, 1973) was employed. Five grams of each sample was dispersed in 100 mL of 10% acetic acid in ethanol solution. The mixture was well shaken and allowed to stand for 4 h at room temperature and shaken every 30 min. At the end of this period, the mixture was filtered through Whatman No. 42 filter paper. The filtrate (extract) was concentrated by evaporation to a quarter of its original volume. The extract was treated with drop-wise addition of concentrated NH_3 solution to precipitate the alkaloid. The dilution was done until the NH_3 was in excess. The alkaloid precipitate was removed by filtration using weighed Whatman No. 42 filter paper. The paper was dried at 60°C and reweighed after cooling in a desiccator. The weight of alkaloid was determined and expressed as a percentage of the sample.

$$\% \text{ Alkaloid} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Where: W1 = weight of empty filter paper, W2 = weight of filter paper + alkaloid precipitate

Determination of antioxidant properties

Total phenolic content: Total phenolic content was analyzed using the Folin-Ciocalteucolorimetric process (Onwuka, 2018). A portion (0.3 ml) of the samples was combined with Folin-Ciocalteuphenol reagent (2.25 ml). After 5 min, 6% sodium carbonate (2.25 ml) was added and the mixture was allowed to stand at room temperature for 90 min. The absorbance of the mixture was measured at 725 nm. Standard calibration curve for gallic acid in the range of 0-200 g/ml was prepared in the same manner and the result (total phenol) was expressed as mg/Gallic Acid Equivalent (GAE) per gram of extract (mg/GAE/100 g).

Total phenol= C x $^{v}/_{W}$

Where: C = concentration of gallic acid calculated from the calibration curve in mg/ml,

V= volume of extract in ml, W= weight of plant ethanolic extract in g

Total flavonoid content: Total flavonoid content was determined colorimetrically using aluminum chloride ($AlCl_3 6H_2O$) solution and quercetin as described by Onwuka (2018). One (1) ml of sample extract was placed in a 10ml volumetric flask containing 5ml of distilled water and 0.3 ml of 5% sodium nitrite was added and mixed. After 5mins, 0.3ml of 10% aluminum chloride solution ($AlCl_3 6H_2O$) was added and the mixture was allowed to stand for another 6 min, after which 2 ml of 1 M sodium hydroxide was added and properly mixed. Absorbance of the mixture was read at 510 nm after 15-30 min, with a spectrophotometer. Quercetin (10-750 µg/ml) was used to plot a standard curve. Total flavonoid content was expressed as milligram quercetin equivalent per gram of sample mg QE/100 ml.

$$\% \text{ flavonoid} = \frac{W_3 - W_2}{W_1} \times \frac{100}{1}$$

Where: W_1= Weight of sample, W_2= Weight of empty flask, W_3= Weight of flask and residue

Antioxidant capacity by FRAP assay

The antioxidant activity by FRAP assay was determined using the modified method of Ruslan *et al.* (2018). FRAP solution was prepared in acetate buffer (pH 3.6). The sample extract (2 ml) was added to 2 mL of FRAP solution. After incubation at 50°C for 30 min, the absorbance was read using spectrophotometer (Bosch Mode 752N UV/vis, Germany) at 593 nm. Ascorbic acid was used as the standard, FRAP (50 µg/mL) as the control, and acetate buffer as the blank. The antioxidant capacity was presented as EC_{50} of FRAP capacity by determining the 50% exhibitory concentration using the calibration curve.

Antioxidant activity by DPPH assay

The antioxidant activity by DPPH assay was determined using the modified method of Ruslan *et al.* (2018). The sample extract (2 ml) was added to2 mL of DPPH solution (50 µg/mL) to initiate the

reaction for obtaining a calibration curve. The absorbance at 515 nm was measured after incubation at 50℃ for 30 min by using an ultraviolet (UV)–Vis spectrophotometer (Beckman Coulter DU 720, China). DPPH (50 µg/mL) was used as the control, ascorbic acid as the standard, and methanol as the blank. Analysis was conducted in duplicate for the standard and the samples. The antioxidant activity was revealed as IC_{50} of DPPH scavenging activity by observing the 50% inhibitory concentration for the sample using the calibration curve.

Determination of ABTS

ABTS radical scavenging activity Analysis of 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical scavenging activity of the yoghurt was conducted using Chen and Tengku-Rozaina, (2020) method. ABTS+ radical solution was prepared by incubating the mixture of 3 mL of 7 mM ABTS stock solution (Sigma-Aldrich, USA) and 3 mL of 2.45 mM potassium persulfate (EMSURE, Germany) at room temperature for 16 hrs in darkness. The mixture was diluted with 80% ethanol (HmbG Chemical, Malaysia) to obtain absorbance of 0.70±0.005 at 734 nm using UV Vis spectrophotometer (Interscience, Malaysia). A total of 0.3 mL of a series of lotus rhizome extract solution (0.5 to 3.0 mg/mL) was mixed with 2.7 mL of ABTS+ radical solution and incubated for 30 min. The absorbance was measured at 734 nm using UV-Vis spectrophotometer with methanol as blank. The scavenging ability (%) and IC50 values were determined as previously described for DPPH.

Recipe for puddings production from pigeon pea and cowpea flours

The recipe for puddings production using the pigeon pea flours processed with different treatments and cowpea flour is shown in Table 1. Cowpea flour pudding served as the control. **Production of puddings from pigeon pea and cowpea flours**

Production of the puddings was according to the method described by Ilesanmi and Nkama (2017) with slight modification. The foil used to wrap the pudding was prepared and set aside. Approximately 500g of each flour sample was put in a clean bowl, and 500ml of warm water was added and mixed to form a fluffy paste. Twenty grams (10g) of onions, 50g of cayenne pepper, 50g of red paprika, and 50g of crayfish were ground using a Kenwood food blender and added to the fluffy paste and stirred using a wooden spatula until properly mixed. Vegetable oil (60ml), 4g of seasoning cubes, and 10g of salt were added and mixed properly. About 100ml of the fluffy paste (pudding mix) was scooped into the foil with a spoon, wrapped properly and steamed at 100°C for 40 min to form a hard gel. The puddings (plate 1) were allowed to cool before serving for sensory evaluation.

Sensory evaluation of the pigeon peas and cowpea puddings

The method described by Iwe (2014) was employed to determine the sensory properties of the puddings. The samples were assessed by 30 pre-trained panelists selected from Michael Okpara University of Agriculture, Umudike. The pre-trained panelists were instructed prior to the exercise. All samples were put on different plates and served to the panelists with portable water to rinse their mouths after each testing so as not to interfere with the taste of the preceding samples. Quality attributes such as appearance, taste, aroma, texture, and general acceptability of the products were scored on a 9-point hedonic scale. The degree of likeness was expressed as; 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. Like extremely to like slightly constitute good while dislike slightly to dislike extremely constitutes poor. Neither like nor dislike indicates that the product was neither good nor bad.

Table 1: Recipe for production of puddings

Ingredients	Quantity
Flour	500g
Vegetable oil	60ml
Cayenne pepper	50g
Red paprika	50g
Crayfish	50g
Onion	20g
Salt	10g
Seasoning cubes	4g
Water	500ml

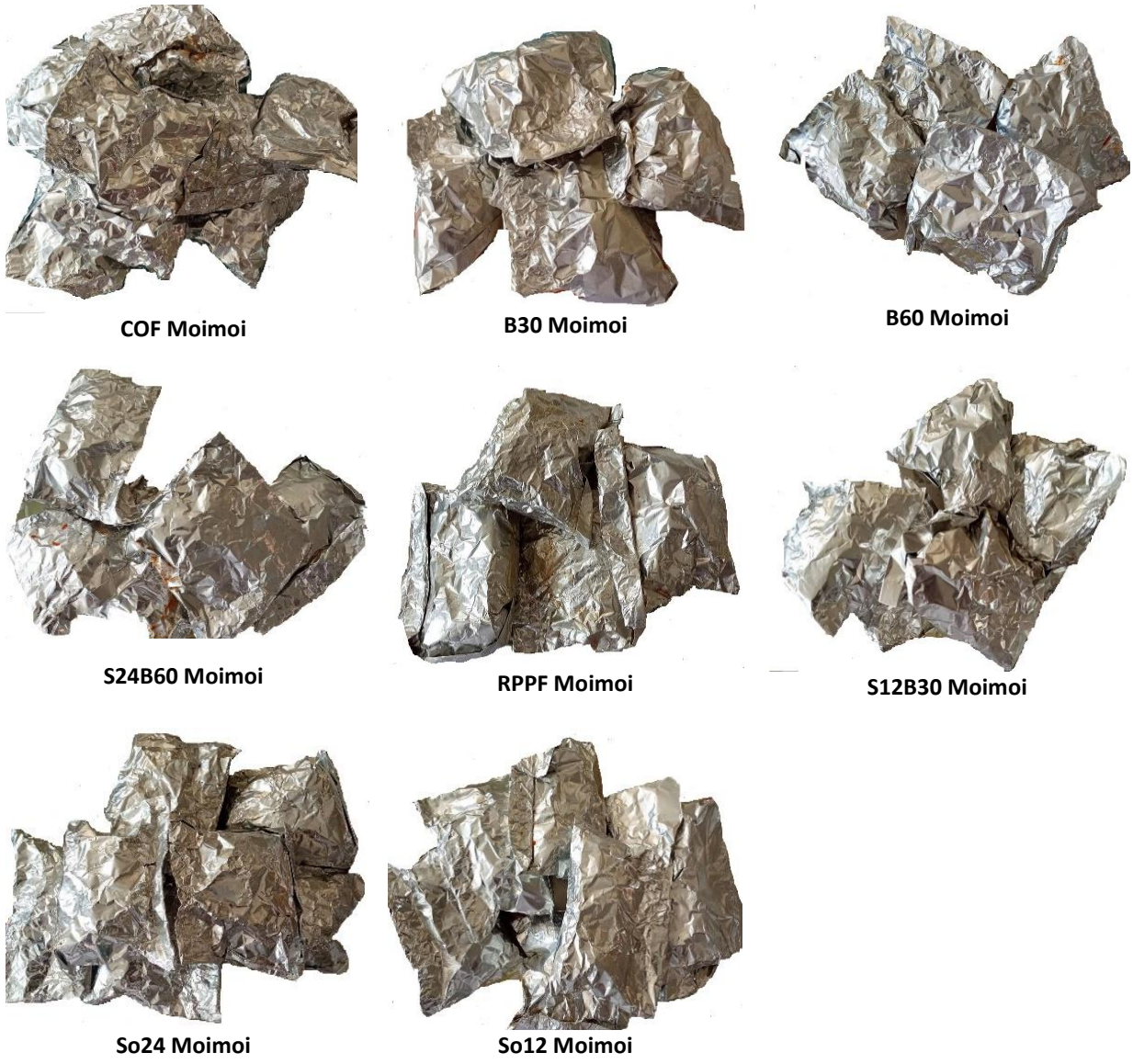

Plate 1: Samples of moimoi (puddings) produced from pigeon pea flours and cowpea flour

Experimental Design

Completely Randomized Design (CRD) will be used for this study.

Statistical Analysis

The data obtained were subjected to analysis of variance using the SPSS procedure version 16 for personal computers, while treatment means were separated using Duncan's multiple range test (DMRT) at 95% confidence level ($p<0.05$). The analyzed data were expressed as mean ± SD (standard deviation).

RESULTS AND DISCUSSION

Effect of different processing methods on proximate composition and energy value of pigeon pea flours

Table 2 shows the effects of different processing methods on the proximate composition and energy value of pigeon pea flours. The moisture content of the pigeon pea flours ranged from 5.45 - 9.66%. The moisture content increased for all the treated flour samples with sample S24B60 (soaked for 24 h and boiled for 60 min) having the highest value (9.66%). This increase in moisture content of the treated samples is expected since all the treatments involved soaking and boiling which caused the flours to imbibe more water, could be due to water absorption. However, results of moisture content were within the safe moisture level (≤10%) for long term storage of flour (Akinoso *et al.,* 2016). Arukwe (2021) reported

that low moisture content is advantageous for storage stability and enhanced shelf life of products.

The highest crude protein contents of the pigeon pea flours ranged from 18.85-24.16%. The protein content of all the treated samples significantly ($p<0.05$) decreased except for the sample So12 (soaked for 12 h) which was not significantly different from the untreated pigeon pea flour. This suggests that soaking for 12 hours does not significantly reduce the protein content of pigeon pea. It was observed that soaking for 24 hours reduced the protein content to a level higher than the sample boiled for 30 min (B30) followed by the sample boiled for 60 min (B60). The least protein content (18.85%) was recorded in sample S24B60. The decrease in protein content could be attributed to the leaching of soluble proteins into soaking and boiling water. The decrease in protein could be because the soluble proteins in pigeon pea leached into the boiling water during boiling and soaking water during soaking. This observation is corroborated by the report of Akubor (2017). Leaching occurs when proteins dissolve and migrate into the surrounding liquid.

The fat content of the pigeon pea flours processed by different methods ranged between 1.31% and 1.80%. The fat content significantly ($p<0.05$) decreased for the processed samples except for sample So12. Boiling and soaking can leach fat into water. The low-fat content of the processed flours is advantageous because it might lead to increase in the keeping quality of the products, since high fat increases the chances of rancidity.

The crude fibre content of the pigeon pea flours ranged from 3.04 - 5.05%. The fibre content reduced for all the treated samples except for sample So12 which was not significantly ($p<0.05$) different from the raw samples. This implies that soaking for a shorter period does not significantly deplete pigeon pea nutrients. Fibre is important in the diet due to its beneficial role in increasing faecal bulk, lowering serum cholesterol, improving glucose tolerance and enhancing insulin sensitivity (Michael *et al*., 2013; Arukwe and Arukwe, 2021).

The ash content of the pigeon pea flours ranged from 1.43 - 3.08%. The ash content reduced for all the treated samples except for sample So12 which was not significantly ($p<0.05$) different from the raw samples. Boiling and soaking can leach minerals into water, further lowering ash levels. Ash content depicts total minerals content in foods.

The carbohydrate content of the pigeon pea flours ranged from 59.44 - 65.69%. The carbohydrate content of all the be due to softening of cellulose. Carbohydrate refers to the starch and sugar component of flour. They are the body's preferred sources of energy because they are easily digested into glucose or blood sugar (Appiah *et al.,* 2011).

The energy value ranged from 349.22 - 356.56 kcal, with sample B30 (boiled for 30 min) having the highest value and sample So24 (soaked for 24 h) having the least value. The differences in energy values of the samples could be due to differences in the protein, fat and carbohydrate contents of the samples as both constitute major source of energy.

Effect of different processing methods on antinutrient content of pigeon pea flours

The antinutrients content of pigeon pea as affected by different processing methods is shown in Table 3. There were significant differences in the antinutrients content of the pigeon pea flour samples. The saponin content ranged from 0.20 – 3.76 mg/100g with the raw sample (RPPF) recording the highest value and sample S24B60 (soaked for 24 h and boiled for 60 min) having the lowest value. It was observed that all the processing methods significantly ($p<0.05$) reduced the saponin content of pigeon pea, but the highest decrease was observed in the combined soaking and boiling treatments. This could be attributed to leaching of saponin into the soaking and boiling water and some may have been broken down by heat. The saponin content obtained in this study are lower than the values (1.09 – 20.43 mg/100g) reported by Okoye and Ene (2018). Saponin lowers blood lipids, cancer risks, and blood glucose response.

The tannin content ranged between 0.03 mg/100g and 1.92 mg/100g. Sample RPPF had the highest value while sample S24B60 had the least value. All the processing methods caused significant reduction in the tannin content. Tannins are water soluble complexes and may have been destroyed by heat and some leached into the soaking and boiling water. This decreased tannin is beneficial because tannins decrease the digestibility and palatability of proteins and carbohydrates by forming insoluble complexes with them. Tannins also reduce bioavailability of minerals (Arukwe and Arukwe, 2021).

The phytate content ranged from 1.08 – 6.06 mg/100g. Sample RPPF (control) had the highest value while sample S24B60 (soaked for 24 h and boiled for 60 min) had the least value of phytate. During boiling, the reduction in phytate can be as a result of heat treatment, which not only causes thermal degradation of these compounds but also facilitates their diffusion into the boiling water. Soaking contributes to the leaching of soluble antinutritional factors into the soaking water, further

decreasing their content. Phytate values obtained from this study were lower than the values (0.13 – 2.55 mg/100g) reported by Ukom *et al*. (2023). Phytate is the main storage form of phosphorus in many plant tissues which help the body calcify and form kidney stones and reduce blood glucose and lipids. It forms complexes with metals or proteins thereby reducing the bioavailability.

Alkaloid content ranged between 0.96 mg/100g and 7.04 mg/100g. All the processing methods employed significantly ($p<0.05$) reduced the alkaloid content, with the highest reduction recorded in the sample S24B60 (soaked for 24 h and boiled for 60 min). There were significant differences between the processing treatments. Alkaloid contents also reduced during soaking and boiling because of their water solubility and heat-sensitive nature (Abeshu and Kefale, 2017). These reductions in antinutrients improve the nutritional value of pigeon pea, checking the limiting effects of these compounds on protein utilization and mineral absorption.

As a result, treated pigeon pea becomes a viable food source, contributing to better health outcomes by enhancing nutritional content and digestibility.

Effect of different processing methods on the antioxidant properties pigeon pea flours

Table 4 shows the antioxidant properties of the pigeon pea flours processed by different methods. The total phenol content ranged from 85.95 - 162.94 mg/GAE/100g and there were significant variations ($p<0.05$). The highest value was recorded in sample RPPF (control) while the lowest value was recorded in sample S24B60 (soaked for 24 h and boiled for 60 min). The phenolic content was reduced by all the processing treatments employed, but the sample So12 (soaked for 12 h) was the least affected. These reductions could be attributed to leaching into soaking and boiling water and thermal degradation by heat during boiling (Roy *et al*., 2021; Ukom *et al*., 2023). Phenolic compounds are natural plant metabolites used to protect plants from biotic stresses, diseases, insects and environmental predators. Phenol derivatives have been found to possess antimicrobial, analgesic, anti-inflammatory, antioxidant, anticonvulsant, anticancer, anesthetic, antiseptic and disinfectant, antituberculosis and antiparkinsonian activities (Ukom *et al*., 2023).

Table 2: Effect of different processing methods on proximate composition and energy value of pigeon pea flours

Sample	MC (%)	CP (%)	FAT (%)	CF (%)	ASH (%)	CHO (%)	EV (Kcal)
RPPF	$5.45^{g} \pm 0.08$	$24.16^{a} \pm 0.02$	$1.80^{a} \pm 0.01$	$5.05^{a} \pm 0.01$	$3.08^{a} \pm 0.04$	$59.58^{f} \pm 0.07$	$354.34^{a} \pm 0.43$
B30	$6.14^{f} \pm 0.03$	$22.40^{c} \pm 0.02$	$1.62^{c} \pm 0.01$	$3.97^{c} \pm 0.02$	$2.78^{c} \pm 0.01$	$63.09^{d} \pm 0.01$	$356.56^{a} \pm 0.43$
B60	$7.25^{d} \pm 0.04$	$21.02^{d} \pm 0.01$	$1.54^{d} \pm 0.01$	$3.66^{d} \pm 0.01$	$2.32^{d} \pm 0.03$	$64.22^{c} \pm 0.00$	$355.80^{a} \pm 0.99$
So12	$6.93^{e} \pm 0.06$	$24.04^{a} \pm 0.02$	$1.79^{a} \pm 0.01$	$4.99^{a} \pm 0.03$	$3.02^{a} \pm 0.02$	$59.44^{g} \pm 0.03$	$355.83^{a} \pm 0.99$
So24	$7.89^{c} \pm 0.03$	$23.19^{b} \pm 0.03$	$1.70^{b} \pm 0.00$	$4.10^{b} \pm 0.01$	$2.83^{b} \pm 0.01$	$60.29^{e} \pm 0.06$	$349.22^{c} \pm 0.11$
S12B30	$8.78^{b} \pm 0.04$	$20.12^{e} \pm 0.04$	$1.38^{e} \pm 0.01$	$3.33^{e} \pm 0.02$	$2.03^{e} \pm 0.02$	$64.47^{b} \pm 0.02$	$350.05^{b} \pm 0.99$
S24B60	$9.66^{a} \pm 0.06$	$18.85^{f} \pm 0.04$	$1.31^{f} \pm 0.02$	$3.04^{f} \pm 0.03$	$1.43^{f} \pm 0.04$	$65.69^{a} \pm 0.02$	$350.47^{b} \pm 0.11$

Values presented are means ± standard deviation of replicate determinations. Means with different superscripts within the same column differ significantly ($p<0.05$).

KEY: MC: Moisture Content**,** CP: Crude Protein**,** FAT: Fat**,** CF: Crude Fiber**,** ASH: Ash Content**,** CHO: Carbohydrate**,** EV: Energy Value, RPPF: raw pigeon pea flour**,** B30: pigeon pea flour boiled for 30 min, B60: pigeon pea flour boiled for 60 min**,** So12: pigeon pea flour soaked for 12 h, So24: pigeon pea flour soaked for 24 h, S12B30: pigeon pea flour soaked for 12 h and boiled for 30 min, and S24B60: pigeon pea flour soaked for 24 h and boiled for 60 min.

Table 3: Effect of different processing methods on antinutrient content of pigeon pea flours

Sample	Saponin (mg/100g)	Tannin(mg/100g)	Phytate (mg/100g)	Alkaloid (mg/100g)
RPPF	$3.77^{a} \pm 0.02$	$1.92^{a} \pm 0.01$	$6.07^{a} \pm 0.05$	$7.04^{a} \pm 0.04$
B30	$1.72^{d} \pm 0.02$	$0.58^{d} \pm 0.03$	$4.73^{d} \pm 0.02$	$5.31^{d} \pm 0.03$
B60	$1.25^{e} \pm 0.04$	$0.31^{e} \pm 0.01$	$3.40^{e} \pm 0.01$	$4.51^{e} \pm 0.02$
So12	$2.55^{b} \pm 0.03$	$1.21^{b} \pm 0.01$	$5.83^{b} \pm 0.03$	$6.85^{b} \pm 0.04$
So24	$2.02^{c} \pm 0.01$	$1.01^{c} \pm 0.02$	$4.96^{c} \pm 0.01$	$6.05^{c} \pm 0.03$
S12B30	$0.59^{f} \pm 0.04$	$0.16^{f} \pm 0.01$	$1.99^{f} \pm 0.05$	$2.23^{f} \pm 0.03$
S24B60	$0.20^{g} \pm 0.04$	$0.03^{g} \pm 0.01$	$1.90^{g} \pm 0.04$	$0.96^{g} \pm 0.03$

Values presented are means ± standard deviation of replicate determinations. Means with different superscripts within the same column differ significantly ($p<0.05$) according to Duncan multiple range test.

Key: RPPF: Raw pigeon pea flour, B30: Pigeon pea flour boiled for 30 minutes, B60: Pigeon pea flour boiled for 60 minutes, So12: Pigeon pea flour soaked for 12 hours, So24: Pigeon pea flour soaked for 24 hours, S12B30: Pigeon pea flour soaked for 12 hours and boiled for 30 minutes, S24B60: Pigeon pea flour soaked for 24 hours and boiled for 60 minutes.

Table 4: Effect of Processing Methods on Antioxidant Properties

SAMPLES	TPC (mg/GAE/100g)	TFC (mg/QE/100g)	DPPH (%)	FRAP (umol Fe^{2+}/g)	ABTS (umol TE/g)
RPPF	$162.94^{a} \pm 0.01$	$93.31^{a} \pm 0.01$	$63.23^{a} \pm 0.04$	$16.93^{a} \pm 0.04$	$19.47^{a} \pm 0.01$
B30	$129.45^{d} \pm 0.04$	$66.56^{d} \pm 0.01$	$57.21^{c} \pm 0.02$	$13.00^{d} \pm 0.03$	$14.08^{d} \pm 0.02$
B60	$110.04^{f} \pm 0.04$	$54.47^{f} \pm 0.03$	$45.95^{f} \pm 0.04$	$8.24^{f} \pm 0.01$	$9.11^{f} \pm 0.04$
So12	$149.68^{b} \pm 0.02$	$88.66^{b} \pm 0.03$	$60.01^{b} \pm 0.03$	$15.15^{b} \pm 0.03$	$18.52^{b} \pm 0.01$
So24	$141.24^{c} \pm 0.03$	$71.30^{c} \pm 0.03$	$56.85^{d} \pm 0.03$	$13.89^{c} \pm 0.01$	$16.76^{c} \pm 0.02$
S12B30	$112.74^{e} \pm 0.01$	$59.93^{e} \pm 0.03$	$53.10^{e} \pm 0.02$	$9.94^{e} \pm 0.01$	$10.77^{e} \pm 0.03$
S24B60	$85.95^{g} \pm 0.03$	$44.91^{g} \pm 0.02$	$39.90^{g} \pm 0.02$	$6.35^{g} \pm 0.04$	$8.43^{g} \pm 0.04$

Values are mean ± standard deviation of duplicate determinations. Means with different superscripts within the same column differ significantly ($p<0.05$).

Key: TPC: TFC: Total phenolic content**,** Total flavonoid content**,** DPPH: 2,2-diphenyl-1-picrylhydrazyl**,** FRAP: Ferric reducing antioxidant power**,** ABTS: 2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid), RPPF: raw pigeon pea flour**,** B30: pigeon pea flour boiled for 30 min, B60: pigeon pea flour boiled for 60 min**,** So12: pigeon pea flour soaked for 12 h, So24: pigeon pea flour soaked for 24 h, S12B30: pigeon pea flour soaked for 12 h and boiled for 30 min, and S24B60: pigeon pea flour soaked for 24 h and boiled for 60 min.

The total flavonoid ranged from 44.91 - 93.31 mg/QE/100g. Sample RPPF had the highest value while sample S24B60 had the least value. The result of this study is – compared to the values reported by Ukom *et al*. (2023). Flavonoids are powerful antioxidant agents that help to regulate cellular activity and fight free radicals that cause oxidative stress in the body.

The DPPH antioxidant capacity ranged from 39.90 - 63.23%. The highest value was recorded in sample RPPF while the least value was observed in sample S24B60. Boiling and soaking significantly reduced DPPH capacity due to reduced phenolic content, though soaked for 12 h sample (So12) retained higher DPPH levels than the other treatments. The combined soaking and boiling treatments for longer hours and time respectively had the highest reductive effect on the antioxidant activity. The values for DPPH observed in this study are within the range (52.1 - 73.02%) reported by Uchegbu and Ishiwu (2016).

The FRAP antioxidant capacity ranged between 6.35 umol Fe^{2+}/g and 16.93 umol Fe^{2+}/g. The raw sample (RPPF) had the highest value while sample S24B60 had the least value. The second highest value (60.01 umol Fe^{2+}/g) was observed in sample So12. There were significant differences in the values. The soaking, boiling, and combined soaking and boiling treatments induced leaching of phenolic compounds.

The ABTS antioxidant activity ranged from 8.43 - 19.47 umol TE/g. Sample RPPF had the highest value while sample S24B60 had the lowest value. The ABTS values observed in this study are lower than (20.91 – 141.10 umTrolox/g) reported by Ukom *et al*. (2023).

The results generally revealed that the antioxidant properties decreased in all the processing methods used, but the sample S24B60 (soaked for 24 h and boiled for 60 min) recorded the lowest value. with all samples recording decrease compared to the raw sample (RPPF). Sample So12 (soaked for 12 h) had the highest (149.67) value among the processed samples. It was observed that soaking for 12h and 24 h has the least effect on total phenols and flavonoids followed by boiling treatment. The highest decreasing effect for both parameters was recorded for the combined treatments of soaked for 24 h and boiled for 60 min, and soaked for 12 h and boiled for 30 min, i.e., samples S24B60 and S12B30 respectively.

This result suggests that pigeon pea flours processed with different treatments apart from the nutritional composition have the capacity to scavenge free radicals and thereby contribute positively to the health of the consumers. Free radicals are highly reactive unstable metabolites usually produced during various cellular metabolic activities in the body. They cause oxidative functional damages in human body with significant health implications. However, dietary antioxidants have the capacity to check the free radicals and other reactive oxygen species thereby reducing the risks of degenerative chronic diseases (Gamel and Abdel-Aal, 2012).

Organoleptic acceptability of pigeon pea and cowpea puddings

Table 5 presents the sensory acceptability of pigeon pea puddings produced from pigeon pea flours processed by different methods, and cowpea puddings served as the control. There were significant ($p<0.05$) differences in the sensory scores of the puddings. The results for the appearance of the puddings ranged from 4.67 - 7.53 with sample CoF (cowpea) having the lowest value and sample So12

(soaked for 12 h) had the highest value (7.53) followed by sample So24 (soaked for 24 h) with the second highest value of 7.50. Appearance is the visual quality of a sample.

Table 5: Sensory acceptability of pigeon pea and cowpea puddings

Samples	Appearance	Taste	Aroma	Texture	General Acceptability
RPPF	6.70^{f} ±1.12	5.80^{e} ±1.77	6.30^{e} ± 0.92	6.37^{d} ± 1.03	6.29^{e} ± 0.88
B30	7.20^{c} ± 1.21	7.23^{a} ± 1.70	6.77^{c} ± 1.17	6.57^{b} ± 1.14	6.94^{c} ± 0.93
B60	6.90^{e} ± 1.03	6.87^{c} ± 1.04	6.57^{d} ± 1.28	6.57^{b} ± 1.07	6.73^{d} ± 0.86
So12	7.53^{a} ± 0.86	6.80^{d} ± 0.85	6.87^{b} ± 1.19	6.47^{c} ± 0.68	6.92^{b} ± 0.61
So24	7.43^{b} ± 1.07	7.07^{b} ± 1.28	6.90^{a} ± 1.29	6.90^{a} ± 1.12	7.10^{a} ± 0.81
S12B30	5.40^{g} ± 2.25	4.37^{g} ± 1.65	5.70^{g} ± 0.84	5.70^{f} ± 1.06	5.29^{g} ± 0.95
S24B60	7.00^{d} ± 1.20	4.70^{f} ± 1.56	5.83^{f} ± 0.87	6.03^{e} ± 1.35	5.89^{f} ± 0.71
CoF	4.67^{h} ± 1.68	2.67^{h} ± 1.45	4.37^{h} ± 1.61	5.00^{g} ± 1.34	4.18^{h} ± 0.84

Values presented are means ± standard deviation of replicate determinations. Means with different superscripts within the same column differ significantly ($p<0.05$) according to Duncan multiple range test.

Key: RPPF: Raw pigeon pea flour, B30: Pigeon pea flour boiled for 30 minutes, B60: Pigeon pea flour boiled for 60 minutes, So12: Pigeon pea flour soaked for 12 hours, So24: Pigeon pea flour soaked for 24 hours, S12B30: Pigeon pea flour soaked for 12 hours and boiled for 30 minutes, S24B60: Pigeon pea flour soaked for 24 hours and boiled for 60 minutes.

The scores for taste ranged from 2.67 - 7.23. Sample B30 (boiled for 30 min) recorded the highest value followed by sample So24 With the second highest value of 7.07, while sample CoF (control) had the least value. The aroma ranged from 4.37 – 6.90. Sample So24 had the highest score while the cowpea pudding had the lowest value. The sensory attributes of taste and aroma notably influence consumers' preference for a particular food (Arukwe *et al*., 2025). The score for texture ranged between 5.00 and 6.90. Sample So24 recording the highest value while sample CoF had the least value. Texture is a sensory characteristic that is use for feeling the smoothness or roughness of a food.

General acceptability is used to declare the rate at which the panellists accept the samples. The general acceptability results ranged from 4.18 – 7.10. The sample, So24 (soaked for 24 h) had the highest score while the cowpea pudding (CoF) had the least score. This implies that all the samples of pigeon pea puddings were preferred to the cowpea pudding by the panellists. It is also important to note that many of the processed pigeon pea flour puddings recorded higher scores in the sensory attributes than the raw sample pudding.

CONCLUSION

The proximate composition results showed that the processing treatments decreased the crude protein, fat, crude fibre and ash, but increased the moisture and carbohydrate contents. However, soaking for 12 hours did not significantly ($p<0.05$) reduce the crude protein, fat, crude fibre nd ash contents. Moreover, the values obtained for protein in this study were still very high (18.85% to 24.97%). This implies that consumption of foods made with processed pigeon pea flours will contribute to eradicating protein energy malnutrition. All the processing methods decreased the antinutrients, but the most decrement was observed in the sample soaked for 24 hours and boiled for 60 minutes. This study has also revealed that pigeon pea flours contain appreciable total phenols and flavonoids, and have free radical scavenging potential.

The sensory acceptability of puddings produced from the processed pigeon pea flours revealed that they were more acceptable than the cowpea puddings used as control. This suggests that production of puddings from processed pigeon pea flours will increase the utilization of pigeon pea and enhance the earnings of the farmers.

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