



Research Article

Variations in Antioxidant Activity, Physical, Chemical and Selected Antinutritional Factors of Two Pigeon Pea (*Cajanus cajan* (L)) Varieties as Affected by Processing Methods

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Abstract: This study evaluated the variations in antioxidant activity, physical, chemical and antinutritional properties of two pigeon pea varieties (white and brown) as affected by processing methods (boiling, roasting and sprouting). The processing methods revealed significant ($p < 0.05$) variations in the results of tested parameters. The unprocessed white pigeon pea variety had the highest gelatinization temperature (84 °C), trypsin inhibitor (9.04 Tiu/ng), polyphenols (137.05 mgGAE/100 g) and ABTS (141.10 μ mTrolox/g), while the unprocessed brown variety retained higher concentrations of bulk density (0.71 g/g), phytate (2.55%), tannin (0.94 mg/100 g), FRAP (7.86 mmol/100 g) and total flavonoid (1.02 mgQE/100 g) contents, respectively. Boiled white pigeon pea variety had the highest moisture (11.60%), fat (5.19%), oil absorption capacity (2.97 mg/ml), DPPH (103.25%), and magnesium (80.65 mg/100 g), whereas roasted white pigeon pea variety showed significantly ($p < 0.05$) higher concentrations in water absorption capacity (2.25 g/ml), swelling index (3.51%), and wettability (59.70%). Roasted brown pigeon pea variety exhibited greater ash (5.04%), fiber (5.31%), protein (24.36%), and oil absorption capacity (2.97 mg/ml) than other treatments, respectively. On the other hand, the sprouted white pigeon pea variety had the highest carbohydrate (60.09%), calcium (124.00 mg/100 g) and iron (11.38 mg/100 g) content. From the variety and processing methods, the study shows that the white variety of pigeon pea was a good source of proximate, minerals and functional values, while the brown variety had the highest antinutrients and antioxidant activities. Hence, pigeon pea is a good source of nutrients and that differences in nutrient values are due to variety and processing treatments.

Keywords: pigeon pea varieties, processing treatments, chemical properties, phenolic contents, scavenging power

1. Introduction

Pigeon pea (*Cajanus cajan* (L)) is a legume that belongs to the family of *Leguminosae* [1]. Pigeon pea is grown as an annual or perennial crop and is consumed either as decorticated or as green seed vegetables [2]. It is cultivated in many tropical and sub-tropical countries of the world like India, Myanmar, Nepal, Nigeria, Kenya, Malawi, Uganda, Mozambique and Tanzania and they produce considerable amounts of pigeon pea [2]. Being high in protein, energy,

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vitamin and mineral content, pigeon pea has been recognized for its nutritional importance. It is a good source a food crop for the production of protein, energy and fiber-fortified foods [3], and it ameliorates energy-protein malnutrition, especially among the vulnerable groups. Pigeon pea contains fatty acids, mainly the saturated fatty acid like palmitic acid [4]. Pigeon pea is a good source of minerals like phosphorus, magnesium, iron, calcium, sulphur and potassium but low in sodium [5]. Pigeon pea also has abundant antioxidant potentials, hypocholesterolemic, antimicrobial, anti-inflammatory and hepatoprotective effects [6]. It is observed that pigeon pea is economically an important legume among the rural poor population and in spite of its nutritional importance, pigeon pea is under-utilized crop.

Pigeon pea like other legumes contains nutritive value that is bound by antinutritional factors: trypsin inhibitors, haemagglutinin, saponin, tannin, and some oligo-saccharides such as stachyose, raffinose, and verbascose [7]. Processing of pigeon pea is a crucial step for the inactivation of enzymes to enable the preservation of nutritive content, colour, flavour or texture during processing and storage. Processing of food crops is, therefore, a crucial step that is aimed at generating products that are stable in terms of shelf-life, nutrition and palatability [8]. The methods involved in food processing vary widely, and the nutritive value of food may be improved or diminished depending on the methods employed [9]. Pigeon pea seeds like other legumes are usually consumed after processing either through boiling, roasting etc. Processing of this crop using appropriate methods is vital, not only for the palatability, reduction of the levels of anti-nutrients and toxins, but also to enhance the bioavailability of nutrients [8].

Pigeon pea is said to be a rich source of antioxidant constituents for the improvement of human health. According to Uchegbu and Ishiwu [10], germinated and non-germinated pigeon pea seeds contain high concentration of phenolic antioxidant (95.01 and 85.20 mg/GAE/100 g dry weight) and strong DPPH scavenging activity (73.02% and 52.1%), respectively. Furthermore, the variations in quantitative phenolic contents and antioxidant activities of 82 pigeon pea accessions was reported to contain 24.48 mg GAE g⁻¹ DE and 6.57 mg AAE g⁻¹ DE, respectively [11]. Antioxidants are indispensable group of food additives for their unique properties of shelf-life extension of food products without any adverse effect on their sensory or nutritional qualities [12]. Phenolic and flavonoids antioxidants scavenge free radical actions and inhibit their oxidative mechanisms that lead to degenerative diseases [13]. There is presently a scarceness of information on the antioxidant activity and other bioactive components of pigeon pea in literature. The main objective of this study was to evaluate the variations in antioxidant activity, physical, chemical and selected antinutritional factors of two pigeon pea (*Cajanus cajan* (L)) varieties as affected by processing methods.

2. Materials and methods

2.1 Sources of raw materials

Brown and white varieties of pigeon pea seeds were procured from Eke Eha-Amufu market in Enugu State. Reagents used for analyses were obtained from Optimum Laboratories, Umuahia, Abia State.

2.2 Sample preparation

Unprocessed, boiled, roasted and sprouted pigeon pea seed flour were obtained using the method described by Emenonye [14] and Akubor and Obiegbuna [15] with slight modifications as shown in Figures 1 & 2. Brown and white varieties of pigeon pea seeds were separately sorted, washed in potable water and divided into four parts of 200 g each. The first portion was dried in oven at 60 °C for 8 h, milled (using attrition mill) and sieved (250 µm mesh size) to obtain raw pigeon pea seed flour. The second portion was boiled (in 250 ml potable water for 10 min and dried (oven at 60 °C for 8 h), milled (using attrition mill) and sieved (250 µm mesh size) to obtain boiled pigeon pea flour. The third portion was steeped in water (250 ml) for 6 h and left in the dark for 24 h to germinate. This was followed by rinsing in tap water, drying (in oven at 60 °C for 8 h), milling (using attrition mill) and sieving (250 µm mesh size) to obtain sprouted pigeon pea seed flour. Thereafter, the fourth portion of the pigeon pea seed was roasted in a free-standing oven with a temperature probe at 120 °C for 10 min, dried at 60 °C for 8 h, milled using attrition mill and sieved using 250 µm mesh size to obtain roasted pigeon pea seed flour.

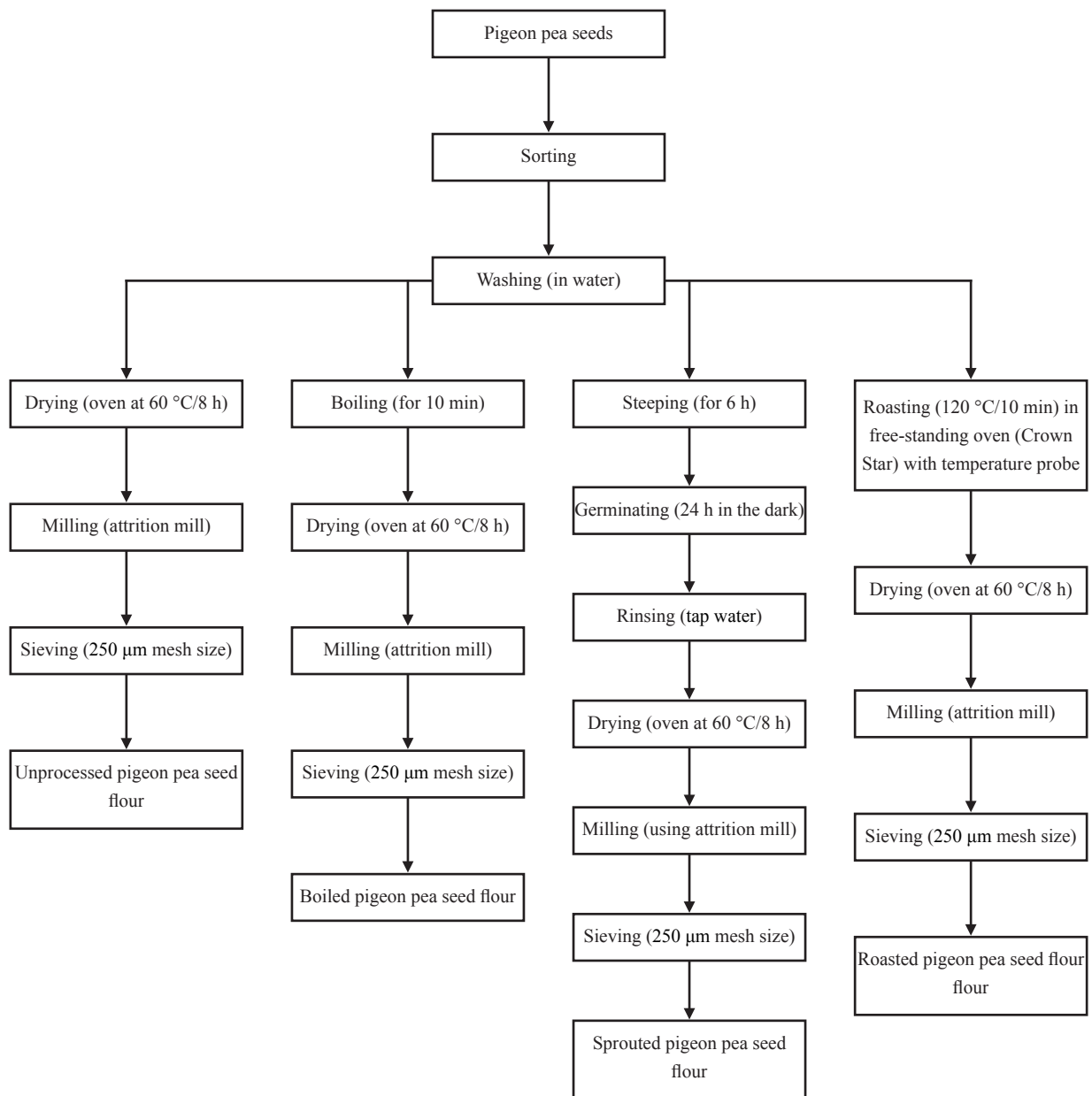


Figure 1. Process flow chart for pigeon pea seeds flour production [15]



Raw white pigeon pea



Raw brown pigeon pea



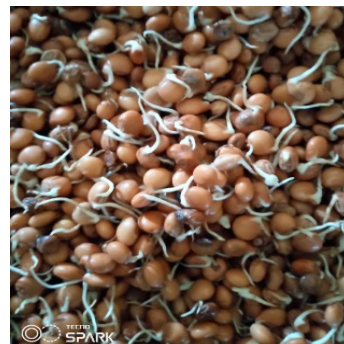
Boiled white pigeon pea



Boiled brown pigeon pea



Sprouted white pigeon pea



Sprouted brown pigeon pea



Roasted white pigeon pea



Roasted brown pigeon pea

Figure 2. Processed white and brown pigeon pea varieties

2.3 Determination of functional properties of pigeon pea seed flour

The functional properties of the pigeon pea seed flour: bulk density, wettability, water absorption capacity (WAC), oil absorption capacity (OAC), gelatinization temperature, and swelling index (SI) were determined according to the method described by Onwuka [16] as follows:

2.4 Bulk density

Ten grams (10 g) of flour sample was poured into a 100 ml measuring cylinder. The cylinder was tapped fifty (50) times on a laboratory bench to constant volume. The volume of sample was recorded. Bulk density (g/ml) = weight of sample/volume of sample after tapping.

2.5 Wettability

One gram (1 g) of flour sample was added into 250 ml graduated cylinder of 1 cm diameter. A finger was placed over the opened end, inverted and clamped at a height of 10 cm on the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was then removed to allow the test sample become dumped. Wettability was recorded as the time taken by the sample to become completely wet.

2.6 Water and oil absorption capacities

One gram (1 g) of flour sample was mixed with 10 ml distilled water or oil and allowed to stand at ambient temperature for 30 min. It was then centrifuged for 30 min at 3000 rpm. Water or oil absorption capacity was expressed as percent water or oil bound per gram flour. Water/oil absorption (g/g) = weight after centrifuge-weight of tube/weight of sample.

2.7 Gelatinization temperature

A solution of 10% of flour sample was prepared in a test tube. The aqueous suspension was heated in water bath with continuous stirring. The gelatinization temperature was recorded 30 sec after gelatinization was visually noticed.

2.8 Swelling index

Two grams (2 g) of flour sample in test tube was suspended in 10 ml of distilled water and incubated in an agitated water bath at 50 °C for 30 min. The paste was allowed to cool to room temperature. The cool paste was centrifuged at $3000 \times g$ for 30 min. The supernatant was discarded and the weight of the gel was determined. Swelling index (g/g) = weight of gel/weight of dry sample.

2.9 Determination of proximate composition of pigeon pea seed flour

The moisture, crude fat, crude protein, crude fiber, and ash of the pigeon pea varieties seed flour were determined by the method described by AOAC [17]. Carbohydrate content was determined by difference using the formula: % carbohydrate = 100 - % (protein + fat + fibre + ash + moisture content.)

2.10 Determination of mineral composition of pigeon pea seed flour

The minerals content was determined using the procedure according to the method described by Onwuka [16]. Fe was determined at the 510 nm wavelength, magnesium (Mg) and calcium were determined by compleximetric titration method.

2.11 Determination of antioxidant activity of pigeon pea seed flour

2.11.1 Preparation of pigeon pea extract

A quantity of 0.5 g of the ground powdered samples was mixed with 5 ml of the extracting solvent acetone/deionized water (50:50 v/v) in a 50 ml BD Falcon tubes using Ultra Turax for 10 sec and then capped and re-mixed in a Vortex mixer for 1 min. They were then placed on a multi-purpose rotator for 30 min at 600 rpm. Subsequently, the samples were centrifuged at 4 °C for 5 min and at 6,000 rpm. Two (2) ml of sample extract were collected and stored in the dark at 4 °C for the determination of antioxidant activities with the protocols of ABTS, DPPH, and ORAC assays.

2.11.2 Determination of antioxidant activity

Antioxidant activity determined by DPPH (2,2-Diphenyl-1-picrylhydrazyl) was according to the method reported by Blois [18]. Antioxidant activity determined by Ferric Reducing Antioxidant Power (FRAP) assay was based on the reduction of the Fe (III)-TPTZ complex to the ferrous form at low pH. This reduction was monitored by measuring the absorption change at 593 nm [19]. ABTS⁺ radical cation was determined by the method described by Ukom et al. [20]. Total flavonoids (TF) content was determined by Aluminum chloride method of Yong et al. [21]. Total polyphenols content was determined using Folin Ciocalteu reagent as described by Georgé et al. [22].

2.11.3 Determination of antinutrient factors of pigeon pea seed flour

The spectrophotometer method was used for the determination of phytate according to the method of AOAC [17]. Tannin content was determined by the method described by Nwosu [23], while the trypsin inhibitor was determined using the spectrophotometric method described by Nwosu [23].

2.12 Statistical analysis

All experiments in this study are reported as the mean of duplicate analyses. One-way analysis of variance was carried out using the Statistical Product for Service Solution Version 22.0 to compare between the mean values while treatment mean was separated using Duncan Multiple Range Test at 95% confidence level ($p < 0.05$).

3. Results and discussion

3.1 Proximate composition of two pigeon varieties as affected by processing methods

Variations in the proximate composition of two varieties of pigeon pea as influenced by different processing methods are represented in Table 1. The results showed significant ($p < 0.05$) differences in the processed pigeon pea varieties. Higher ($p < 0.05$) moisture content was observed in the boiled (C_1) 11.60% and (C_2) 10.90%, sprouted (D_2) 11.06% and (D_1) 10.40% samples, while the lowest moisture value was observed in roasted pigeon pea varieties (B_1) 9.20% and (B_2) 7.97%. The brown pigeon pea variety and roasted treatment revealed lower moisture values than the white variety and other treatment methods. Furthermore, the results presented that brown pigeon pea variety was significantly ($p < 0.05$) higher in crude ash (5.04%), crude fiber (5.31%) and crude protein (24.36%) content, while the white pigeon pea variety showed higher fat content (5.19%) irrespective of the processing treatments. The results also revealed that processing methods showed significantly ($p < 0.05$) different nutrient values. For example, roasting gave the highest crude ash (5.04%) content while the least ash content (1.69%) was seen in white boiled pigeon pea variety. Similarly, fat content (5.19%) was highest in boiled white pigeon pea variety, while the least value was seen in roasted brown (0.93%) variety. The high temperature of roasting caused lipid damage due to oxidation reactions as evidenced in the roasted fat values [24]. Crude fibre was revealed to be higher in brown treated variety especially the roasted brown variety (5.31%). Processing methods showed that protein was highest in the roasted brown variety (24.36%), while the least was observed in boiled white variety (20.83%), respectively. Carbohydrate content was shown to be highest in sprouted white variety (60.09%), while the least was from roasted white variety (55.88%). Compared with literature reports, pigeon pea (*Cajanus cajan*) was said to contain 20-22% protein, 1.2% fat, 3.8% ash and 65% carbohydrate [25].

Furthermore, Jeevarathinam and Chelladurai [26] reported similar range of values as 3.50-4.05% ash, 19.39-22.30% protein, 1.70-3.24% fat, 1.50-5.56% fiber and 57.16-57.60% carbohydrate. Other legumes in literature, chickpea and cowpea compared with the ash, protein and carbohydrate results obtained in this study [27-29]. From these results, pigeon pea is a good source of proteins and carbohydrates and differences in nutrient values are due to variety and processing treatments. Pigeon pea flour has been used in composite mixes for bread, cookies and extruded cassava products due to its high level of protein and iron contents [30].

Table 1. Proximate composition of two pigeon pea varieties as affected by processing method (%dw)

Processing methods	Moisture content	Crude ash	Crude Fat	Crude fibre	Crude protein	Carbohydrate
A ₁	10.84 ^b ± 0.02	2.06 ^d ± 0.02	4.98 ^b ± 0.04	1.47 ^d ± 0.01	22.91 ^d ± 0.01	57.75 ^b ± 0.11
A ₂	9.70 ^c ± 0.01	4.21 ^b ± 0.02	1.37 ^d ± 0.02	4.49 ^b ± 0.01	23.49 ^c ± 0.01	56.31 ^c ± 0.08
B ₁	9.20 ^c ± 0.01	3.80 ^{bc} ± 0.03	2.51 ^{cd} ± 0.02	4.70 ^a ± 0.02	23.86 ^a ± 0.01	55.88 ^d ± 0.01
B ₂	7.97 ^d ± 0.01	5.04 ^a ± 0.01	0.93 ^d ± 0.01	5.31 ^a ± 0.01	24.36 ^a ± 0.02	56.39 ^c ± 0.04
C ₁	11.60 ^a ± 0.03	1.69 ^d ± 0.02	5.19 ^a ± 0.01	1.30 ^c ± 0.01	20.83 ^c ± 0.01	59.37 ^a ± 0.04
C ₂	10.90 ^b ± 0.02	2.29 ^c ± 0.01	1.31 ^d ± 0.01	2.31 ^c ± 0.01	23.84 ^b ± 0.02	59.37 ^a ± 0.06
D ₁	10.40 ^c ± 0.03	1.83 ^d ± 0.01	4.41 ^c ± 0.01	1.86 ^d ± 0.01	21.63 ^c ± 0.01	60.09 ^a ± 0.04
D ₂	11.06 ^a ± 0.02	2.33 ^c ± 0.01	1.31 ^d ± 0.01	2.31 ^c ± 0.01	23.84 ^b ± 0.02	59.28 ^a ± 0.06

Values and mean ± SD analyzed in duplicate. Mean value in the same row following different superscript are significantly different (P < 0.05). **Key:** A₁: Raw white pigeon pea, A₂: Raw brown pigeon pea, B₁: Roasted white pigeon pea, B₂: Roasted brown pigeon pea, C₁: Boiled white pigeon pea, C₂: Boiled brown pigeon pea, D₁: Sprouted white pigeon pea, D₂: Sprouted brown pigeon pea.

3.2 Functional properties of two pigeon varieties as affected by processing methods

Variations in the functional properties of pigeon pea varieties as affected by processing methods are highlighted in Table 2. Different processing methods (roasting, boiling and sprouting) affected (p < 0.05) the bulk density, oil and water absorption capacities, swelling index, wettability and gelatinization temperature. Brown pigeon pea variety showed higher proportions of bulk density no matter the processing method. Bulk density depends on the method of measurement, relative volume, geometry, size, solid density and surface properties of the flour and could be improved when the particles are small, compactable, properly tapped/vibrated and the type of packaging material used [31]. The bulk density ranged from B₁ (0.48) to A₂ (0.71) g/g. White pigeon pea variety showed significantly lower (P < 0.05) values (0.48 to 0.56 g/g) irrespective of the processing method. Low bulk density as observed in white pigeon pea variety is advantageous in the formulation of complimentary foods [32].

Oil absorption capacity (OAC) and water absorption capacity (WAC) revealed that white pigeon pea variety had significantly higher (P < 0.05) values than the brown variety, the processing method notwithstanding. OAC indicates the rate at which flour protein bind to fat during food processing operations [33]. The result of the OAC ranged from A₂ (1.07%) to B₁ and C₁ (2.97%). The OAC in this study is slightly within the range of 1.0-1.81% reported by Awuchi, [34] on soybean-wheat flour blends. Being a legume with high protein and oil contents, high OAC can be important in food formulations where oil binding capacity is needed in foods like sausage and baked products [35]. The OAC also enhances the flavor and mouth feel retention of food [34]. The WAC ranged from C₂ (1.05 g/ml) to A₁ (2.51 g/ml). A₁ being the highest value, and followed by B₁ (2.25 g/ml) that was insignificantly different (p > 0.05). Boiled and sprouted flour exhibited the least oil and water absorption capacities. Previous reports opined that lower WAC may be required

for constituting thinner gruels or porridges where more flour is needed per unit volume of gruel or porridge [36]. WAC has been reported to measure the water-holding capacity of flour due to starch swelling in excess of water, and an index of the degree of starch gelatinization. It equally represents the ability of food products to associate with water when it is limited in such situations as in dough and paste production [37]. The increase in the WAC of A₁ and B₁ could be attributed to the heat dissociation of proteins, gelatinization of carbohydrate and swelling of crude fiber in the flour [34].

Swelling index (SI) and water absorption capacity goes together in food systems. Increase in one directly affects the increase of the other. It means that the swelling ability (as in WAC) depends on the availability of water, temperature, type of starch and other carbohydrates [38]. The swelling index ranged from A₁ (0.81%) to B₁ (3.51%). Lowest value was shown in unprocessed pigeon pea varieties, while the highest value was obtained in roasted process irrespective of the variety. It showed that the roasted flour with less moisture picked more water in the swelling process. Appreciable results were revealed in both boiled and sprouted processed varieties which were insignificant ($p > 0.05$). The high swelling index of boiled pigeon pea varieties indicates that they are more suitable in food systems where swelling is required.

The result of the wettability showed significant differences ($p < 0.05$) with the boiled pigeon pea varieties having the highest values (58.35-59.70%), followed by the unprocessed pigeon pea varieties (49.70-50.40%), while the roasted results were lowest (29.90-31.65%), respectively. Overall, the brown pigeon pea variety exhibited higher values irrespective of processing methods.

Gelatinization (GT) shows the thickening and gelling ability of starchy food materials. GT showed wide variations ($p < 0.05$) according to processing methods. The GT of unprocessed samples was highest (83.5-84.00 °C), followed by the sprouted samples (65.55-66.20 °C), while the least GT was observed in the boiled samples (49.95-52.60 °C), irrespective of the variety. It was suggested by Kaur and Singh [39] that lower pasting temperatures favour lower energy costs and will improve the stability of food components. However, the brown variety was slightly higher in GT values. The results show that the raw pigeon peas would be more beneficial in making pudding where thickening and gelling are needed.

Table 2. Functional properties of two pigeon pea varieties as affected by processing methods

Processing Parameters	Bulk density (g/g)	Oil absorption capacity (%)	Water absorption capacity (g/ml)	Swelling index (%)	Wettability (%)	Gelatinization temperature (°C)
A ₁	0.55 ^c ± 0.05	1.28 ^{ab} ± 0.01	2.51 ^a ± 0.01	1.81 ^d ± 0.01	49.70 ^b ± 1.41	84.00 ^a ± 0.28
A ₂	0.71 ^a ± 0.01	1.07 ^c ± 0.01	1.19 ^c ± 0.01	1.93 ^c ± 0.01	50.40 ^b ± 0.28	83.50 ^a ± 0.14
B ₁	0.48 ^d ± 0.01	2.97 ^a ± 0.01	2.25 ^a ± 0.03	3.51 ^a ± 0.01	29.90 ^d ± 0.141	60.35 ^d ± 0.07
B ₂	0.63 ^c ± 0.01	1.17 ^b ± 0.01	1.37 ^{ab} ± 0.01	3.38 ^a ± 0.03	31.65 ^d ± 0.07	63.50 ^c ± 0.14
C ₁	0.56 ^a ± 0.01	2.97 ^a ± 0.01	1.28 ^b ± 0.01	2.68 ^b ± 0.01	58.35 ^a ± 1.41	52.60 ^e ± 0.14
C ₂	0.68 ^{ab} ± 0.01	1.14 ^c ± 0.01	1.05 ^d ± 0.01	2.04 ^c ± 0.03	59.70 ^a ± 0.85	49.95 ^e ± 0.07
D ₁	0.55 ^c ± 0.05	1.15 ^c ± 0.01	1.25 ^c ± 0.04	2.01 ^c ± 0.01	42.65 ^c ± 0.07	65.55 ^b ± 0.07
D ₂	0.66 ^b ± 0.01	1.18 ^b ± 0.01	1.30 ^b ± 0.01	2.61 ^b ± 0.01	45.45 ^c ± 0.07	66.20 ^b ± 0.14

Values and mean ± SD analyzed in duplicate. Mean value in the same row following different superscript are significantly different ($P < 0.05$). **Key:** A₁: Raw white pigeon pea, A₂: Raw brown pigeon pea, B₁: Roasted white pigeon pea, B₂: Roasted brown pigeon pea, C₁: Boiled white pigeon pea, C₂: Boiled brown pigeon pea, D₁: Sprouted white pigeon pea, D₂: Sprouted brown pigeon pea.

3.3 Selected antinutritional and mineral composition of two pigeon varieties as affected by processing methods

Pigeon pea and other legumes have their nutritive values bound by some antinutritional factors, like trypsin inhibitors, haemagglutinin and saponin [2, 7]. These inhibitors have deleterious effects and are said to interfere with food utilization, bioavailability and health of consumers. They affect the activity of digestive enzymes and cause the loss of pigeon pea rich nutrients chiefly protein, calcium and iron. These anti-nutritional substances can be inactivated by domestic processing methods before they can be safely consumed. Some of these processing methods are soaking, blanching, sprouting, roasting and cooking/boiling [40].

The results of some selected antinutritional factors showed wide significant variations ($p < 0.05$) (Table 3). The phytate, tannin and trypsin inhibitor results ranged from 0.13-2.55%, 0.42-0.94 mg/100 g and 4.93-9.04 Tiu/mg. The highest values were obtained in the unprocessed white and brown samples for all the antinutritional factors and irrespective of the processing method. On the contrary, sprouting process retained the lowest antinutritional factors at between 45 to 55% when compared to the unprocessed pigeon pea sample. A value of 9.9 mg⁻¹ trypsin inhibitor was recorded for matured pigeon pea by Faris et al. [41] The results revealed that processing methods, sprouting < roasting < boiling inactivated these heat sensitive antinutritional factors and reduced their concentrations to safe levels. All the treatments reduced the level of tannins in the seed but sprouted pigeon pea exerted greater effect. Tannins are water soluble compounds and may be destroyed by heat and reduced by lixiviation process.

Table 3. Some antinutritional and mineral compositions of two pigeon pea varieties affected by processing methods

Samples	Phytate (%)	Tannin (mg/100 g)	Trypsin Inhibitor (Tiu/mg)	Ca mg/100 g	Mg mg/100 g	Fe mg/100 g
A ₁	2.25 ^a ± 0.01	0.91 ^a ± 0.03	9.04 ^a ± 0.01	105.00 ^c ± 1.41	59.00 ^b ± 0.28	9.96 ^b ± 0.01
A ₂	2.55 ^a ± 0.01	0.94 ^a ± 0.01	8.98 ^a ± 0.01	102.50 ^c ± 0.71	56.25 ^c ± 0.64	10.30 ^b ± 0.14
B ₁	0.30 ^b ± 0.03	0.46 ^{bc} ± 0.28	5.36 ^d ± 0.01	97.60 ^d ± 0.99	46.80 ^d ± 0.00	9.95 ^b ± 0.01
B ₂	0.28 ^b ± 0.01	0.46 ^{bc} ± 0.01	4.93 ^d ± 0.01	94.35 ^d ± 0.21	47.10 ^d ± 0.14	9.97 ^b ± 0.01
C ₁	0.27 ^b ± 0.01	0.51 ^b ± 0.02	5.98 ^b ± 0.01	113.50 ^b ± 2.12	80.56 ^a ± 0.14	11.24 ^a ± 0.01
C ₂	0.25 ^b ± 0.01	0.51 ^b ± 0.01	5.83 ^b ± 0.01	121.50 ^b ± 0.71	80.00 ^a ± 0.07	11.29 ^a ± 0.01
D ₁	0.13 ^c ± 0.03	0.44 ^c ± 0.01	5.77 ^c ± 0.01	124.00 ^a ± 2.12	59.35 ^b ± 0.02	11.38 ^a ± 0.26
D ₂	0.14 ^c ± 0.01	0.42 ^c ± 0.02	5.68 ^c ± 0.01	123.50 ^a ± 1.41	59.15 ^b ± 0.21	11.24 ^a ± 0.01

Values and mean ± SD analyzed in duplicate. Mean value in the same row following different superscript are significantly different ($P < 0.05$). **Key:** A₁: Raw white pigeon pea, A₂: Raw brown pigeon pea, B₁: Roasted white pigeon pea, B₂: Roasted brown pigeon pea, C₁: Boiled white pigeon pea, C₂: Boiled brown pigeon pea, D₁: Sprouted white pigeon pea, D₂: Sprouted brown pigeon pea.

The results of selected pigeon pea varieties exhibited variations ($p < 0.05$) in the mineral concentrations according to different processing treatments as shown in Table 3. Roasting method retained lower mineral values. It showed that sprouting retained more calcium in both the white and brown pigeon pea varieties (124.0 and 123.50 mg/100 g), followed by boiled brown and white varieties (121.50 and 113.50 mg/100 g), while the least was obtained in roasted white and brown varieties (94.35 and 97.60 mg/100 g), respectively. Sprouting and boiling methods were believed to cause the softening and release of bound calcium, whereas, the unprocessed and roasting method did not. Boiling method significantly ($p < 0.05$) affected the magnesium composition of pigeon pea varieties when compared to other

methods. The magnesium values for both boiled white (80.56 mg/100 g) and boiled brown (80.0 mg/100 g) varieties were insignificant ($p > 0.05$), but were far above the roasted results. The result of iron content showed that boiled and sprouted samples irrespective of variety contained insignificantly ($P > 0.05$) higher values than other processing treatment. It was observed that boiling and sprouting had enough moisture to necessitate the solubilization of mineral elements bound to the cotyledons for easy extractability during the analysis. On variety (white or brown pigeon pea), there was no major difference in minerals nutrient. The report of Faris et al. [41] for Ca (120.8 mg/100 g) and Mg (122 mg/100 g) content of pigeon pea was slightly above but far lower than the Fe (4.6 mg/100 g) content reported in this study. The differences may be due to seasons, geographical and agronomical practices.

3.4 Antioxidant activity of two pigeon pea varieties as affected by processing methods

Table 4. Antioxidant activity of two pigeon pea varieties as affected by processing methods

Processing methods	Total flavonoid MgQE/100 g	FRAP mmol/100 g	Total phenol mgGAE/100 g	ABTS $\mu\text{mTrolox/g}$	DPPH (%)
A ₁	1.01 ^a ± 0.01	7.71 ^a ± 0.21	137.05 ^a ± 0.35	20.91 ^d ± 0.73	8.68 ^d ± 0.02
A ₂	1.02 ^a ± 0.00	7.86 ^a ± 0.01	135.30 ^a ± 0.14	22.98 ^d ± 0.25	8.75 ^d ± 0.03
B ₁	0.81 ^b ± 0.01	4.64 ^b ± 0.03	103.58 ^b ± 0.88	140.06 ^a ± 0.01	103.25 ^a ± 0.21
B ₂	0.78 ^b ± 0.01	4.71 ^b ± 0.01	103.95 ^b ± 0.50	141.10 ^a ± 0.07	101.55 ^a ± 0.49
C ₁	0.57 ^c ± 0.01	1.72 ^d ± 0.02	49.10 ^c ± 0.71	23.61 ^c ± 0.01	63.60 ^e ± 0.14
C ₂	0.40 ^d ± 0.01	1.84 ^d ± 0.02	49.65 ^d ± 0.71	24.62 ^c ± 0.02	62.40 ^e ± 0.02
D ₁	0.44 ^d ± 0.01	2.51 ^c ± 0.01	93.58 ^c ± 0.02	47.64 ^b ± 0.08	90.72 ^b ± 0.00
D ₂	0.55 ^c ± 0.01	2.26 ^c ± 0.01	97.15 ^c ± 0.21	46.51 ^b ± 0.02	92.24 ^b ± 0.57

Values and mean ± SD analyzed in duplicate. Mean value in the same row following different superscript are significantly different ($P < 0.05$). **Key:** A₁: Raw white pigeon pea, A₂: Raw brown pigeon pea, B₁: Roasted white pigeon pea, B₂: Roasted brown pigeon pea, C₁: Boiled white pigeon pea, C₂: Boiled brown pigeon pea, D₁: Sprouted white pigeon pea, D₂: Sprouted brown pigeon pea.

Variations in the results of antioxidant activity of pigeon pea varieties is shown in Table 4. The results showed that the pigeon peas demonstrated varied ($p < 0.05$) antioxidant activity. This was expected because the phenolic antioxidant constituents were major contributors to antioxidant activity. The scavenging activity of %DPPH of pigeon pea extracts ranged from 8.68 (A₁) to 103.25% (B₁). In agreement with this study, the range of %DPPH values (52.1 to 73.02%) were reported in non-germinated and germinated pigeon pea [10]. Similarly, the FRAP activity ranged from 1.72 (C₁) to 7.86 mmol/100 g (A₂). ABTS activity was between 20.91 (A₁) and 141.10 $\mu\text{m trolox/g}$ (B₂). The results showed that roasted pigeon pea of both varieties demonstrated the highest antioxidant activity than the other methods. It has been demonstrated by other researchers that the roasting process introduces the formation of Maillard reaction products possessing phenolic and antioxidant activity potentials to validate the higher phenolic and antioxidant activity values [42-43]. Boiled pigeon pea variety posited the lowest antioxidant and antioxidant scavenging power when compared to other processing methods. Boiled treatment applied to the pigeon pea varieties did change their antioxidant scavenging activity, affecting the significant loss of %DPPH, ABTS and greater loss of FRAP value. These changes posit that thermal instability and lixiviation affected the hydrophilic-soluble antioxidant compounds from the pigeon peas during the boiling process [44]. Phenolic compounds are natural plant metabolites used to protect plants from biotic stresses, diseases, insects and environmental predators [45]. This study revealed that the total polyphenol (TP) ranged from (C₁) 49.10 to (A₁) 137.05 mgGAE/100 g, but was highest in the unprocessed samples (135.30-137.05 mgGAE/100

g), followed by the roasted samples (103.58-103.95 mgGAE/100 g), and was least affected in boiled processed method (49.10-49.65 mgGAE/100 g). A high content of TP was obtained in the sprouted samples (93.58-97.15 mgGAE/100 g) probably due to enzymatic and microbial metabolism of the macromolecules in the process. Compared with the phenolic content of pigeon pea in literature, Uchegbu and Ishiwu [10] reported a range of values (85.20 to 95.01 mg/GAE/100 g dry weight) which was similar to our study, while Choi et al. [11] declared lower total polyphenol values (24.48 mg GAE g⁻¹ DE). In the total flavonoids (TF) content, the unprocessed samples maintained greater concentration, followed by the roasted samples. It ranged from 0.40 to 1.01 mg QE/100 g with the sprouted and boiled pigeon peas having the least values. It was generally observed that the brown variety of pigeon pea showed slightly greater contents of antioxidant and antioxidant activity than the white pigeon pea in most of the processed methods. This is in line with the observation of Parmar et al. [46] who reported that total phenol content varied with the color of kidney bean.

4. Conclusion

The variations in the results of the physical, chemical, antinutritional properties and antioxidant scavenging activity of two varieties of pigeon pea (*Cajanus cajan* (L)) was studied. The results revealed that the pigeon pea varieties were good sources of protein, iron, carbohydrate and polyphenols. It further showed that the pigeon pea varieties produced strong scavenging power in DPPH and ABTS assays *in vitro*. The results of the functional properties exhibited that pigeon pea flour can be utilized for bakery purposes and in value addition to foods. Processing methods affected the antinutritional factors, reducing them to safe levels. Roasted method obtained the best crude ash, crude fiber, crude protein and antioxidant activity values especially in the brown variety, while the highest iron content was obtained in boiled and sprouted processing methods. The nutritional quality of protein, iron and carbohydrate in pigeon pea varieties qualifies it as important foodstuff for the vulnerable poor population who cannot afford animal foods.

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Conflict of interest

The authors declare no competing financial interest.

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