Effect of Traditional Processing Methods on Cooking Time, Proximate and Amino Acid Composition of Pigeon Pea (*Cajanus Cajan*)

Ani, P.N.; Ibeanu, V.N.; Umerah, N.N. & Nwanga, T.J.
Department of Nutrition and Dietetics, University of Nigeria, Nsukka
Department of Food Science and Technology, Enugu State University of Science and Technology, P.M.B. 01660, Enugu, Nigeria

Abstract

Pigeon pea is underutilized mostly due to its long cooking time and limited knowledge of its benefits. Effect of traditional processing methods on cooking time, proximate and amino acid composition of pigeon pea were investigated. Pigeon pea was sorted and divided into five portions of 1.0 kg each. One portion was the control while remaining four portions were treated separately using boiling alone (PpB), soaking for 12 h and boiling (PpS), boiling with cooking salt (PpSs) and boiling with potash (PpBp). All the four samples were boiled until soft. The cooking time was recorded and the samples were analyzed for chemical composition from which metabolizable energy values were calculated. Soaking for 12 h before boiling and addition of potash reduced the cooking time by 50% and 24%, respectively. Proximate composition of the samples ranged from 15.58-18.65% (protein), 2.13-2.66% (fat), 2.48-3.38% (ash), 3.68- 5.18% (crude fiber) and 60.79 -63.88% (carbohydrate). Soaking for 12h prior to boiling ranked highest in protein content (16.69%) while boiling with potash reduced the fat (2.13%), ash (2.48%) and carbohydrate (60.79%) contents to great significant level. The boiled alone sample had the best amino acid profile. Although, addition of potash reduced the cooking time by 24%, it adversely affected the proximate and metabolizable energy values of pigeon pea. The findings could help enhance the nutritive quality of pigeon pea-based diets and improve its utilization.

Keywords: Amino acid; Cooking time; Processing; Methods; Pigeon pea; Proximate;

Introduction

Pigeon pea (*Cajanus cajan*) is a widely adapted, drought tolerant food legume crop that is believed to have originated from India (Kassa et al., 2012). It is widely grown in about 14 countries in over 14 million ha. Other major producers of pigeon pea in the world include Uganda, Tanzania, Kenya, Malawi, Ethiopia, and Mozambique in Africa; the Dominican Republic, Puerto Rico and West Indies in the

Caribbean region and Latin America; Burma and Thailand; Indonesia and the Philippines in Asia and Australia (Sinha, 1977). Pigeon pea is commonly consumed in India where it serves as an important source of protein in a mostly vegetarian diet. In Nigeria, it is more popular in the Northern and Western States. It is also consumed in Eastern States, especially among Nsukka people of Enugu State where the dry seeds are cooked until tender then mixed with cooked yam, maize, dried cocoyam grits or freshly cooked cocoyam, sweet potatoes in addition to vegetables, palm oil, salt, pepper and other spices (Enwere, 1998).

Pigeon pea is still underutilized in Nigeria due to various limiting factors such as presence of anti-nutritional factors and its hard-to-cook property. The anti-nutritional factors have been shown to be detrimental to human growth and other physiological processes especially when present at higher levels (Okomoda *et al.,* 2016). Also, long cooking time and the consequent fuel consumption affect the utilization of this legume in cuisines. Reduction of cooking time of hard-to-cook legumes is a priority to consumers especially in developing countries due to high cost of fuel. These have led to the use of different traditional processing methods irrespective of their effect on nutrient quality and health of the consumers. It was reported that due to its hard to cook phenomenon, pigeon pea is usually parboiled overnight and the parboiled pulses soaked in hot water and cooked the following morning to be served as breakfast (Babarinde et al., 2020).

The proximate composition of pigeon pea seed has been widely researched (Kunyanga et al., 2013; Adamu & Oyetunde, 2013). It has been reported to contain 17.95 -30.53% protein, 2.77 – 3.68% fat, 50.08 - 57.45% carbohydrate, 3.58 - 9.93% ash and 5.54 - 6.98% fibre. Pigeon pea is rich in amino acids especially aspartic acid, glutamic acid, lysine, phenylalanine and leucine (Akande et al., 2010; Kunyanga et al., 2013). Babarinde et al. (2020) produced breakfast food with blend of fonio and pigeon pea flours and found that substitution of fonio grain with pigeon pea increased the protein, ash, some amino and vitamins content of the breakfast food.

The transformation of raw food ingredients into edible form is referred to as food processing. The nutritional value of legumes significantly depends on the processing methods applied, anti-nutritional factors present or absent and interaction of nutrients with other food components (Ghadge et al., 2008). The effect of processing on nutrients (Sathya & Siddhuraju, 2015), anti-nutrients (Nwafor et al., 2017) and acceptability (Ngwu et al., 2014) of some underutilized legumes has been reported. Alaye et al. (2020) also reported significant increase in the crude protein content of an underutilized legume (*Mucuna pruriens*) processed using different processing techniques.

Processing method such as cooking is beneficial in reducing or eliminating the inherent anti-nutritional factors of legumes however, this also reduced some nutrients. Studies have shown that cooking legume seeds beyond 30 minutes reduced the nutrient content and anti-nutritional factors (Iorgyer et al., 2009; Nwafor *et al*., 2017). However, the hard-to-cook legumes such as pigeon pea take longer than 30 minutes at 100°C to be properly cooked for human consumption. This has made most people to pre-treat (soaking in water, addition of potash or salt before boiling) raw pigeon pea in order to reduce the cooking time but limited information abound on the effects of these pre-treatments on nutritive quality of the legume.

Objectives of the study

The objective of the study was to investigate the effect of different traditional processing methods on cooking duration, proximate and amino acid composition of pigeon pea (*Cajanus cajan*). Specifically the study determined:

1. effect of traditional processing methods on the cooking time of pigeon pea;
2. effect of traditional processing methods on the proximate composition of pigeon pea
3. extent to which the amino acid composition (profile) of pigeon pea is affected by the traditional processing methods.

Materials and Methods

***Design of Study*:** Experimental method was used for this research. Pigeon peas were purchased, sorted and divided into five portions. One portion was not processed while the remaining four portions were processed separately using different processing methods. The samples were further taken for chemical analysis.

***Materials*:** The materials used in this study were pigeon pea seeds, potash, and salt. Dried pigeon pea seeds, cooking salt and potash were purchased from *Ogige* market Nsukka in Enugu State, Nigeria.

***Preparation of Materials*:** The pigeon pea seeds were sorted to remove dirt and divided into five portions of 1.0 kg each. One portion was not processed (raw sample). The remaining four portions were washed in distilled water and drained.

***Preparation of sample*:** The drained samples were processed separately using different traditional methods. The second portion (PpB), (which acts as the control to the processed samples) was boiled at 100°C until soft. The third portion (PpS) was soaked in distil water (1:3 w/v) for 12 hours at ambient temperature, after which the water was discarded and the seeds were boiled at 100°C until soft. The fourth portion (PpSs) was boiled (100°C) with 20g of cooking salt until soft. The fifth portion (PpBP) was boiled (100°C) with 10g of potash until soft. The samples were dried in an air-oven at 50°C until well dried, and milled with Thomas-Wiley Mill, Model ED-5, England into fine flour to pass through a 70 mm mesh screen. The flours were separately packaged in air-tight containers, coded and taken for chemical analysis.

Softness was determined using the 1-5 scale established by Yeung et al. (2009), with 1 representing undercooked, 2: slightly undercooked, 3: average cooked, 4: slightly overcooked and 5 representing overcooked. A minimum of three seeds were pressed between the thumb and forefinger. The time required to achieve scale 3 (cooked) was recorded for the samples.

Chemical/Proximate Analysis
The moisture, protein, fat, ash and crude fibre content of the samples (raw and processed) were determined according to the Association of Official Analytical Chemist (AOAC, 2010) methods. Moisture content was determined by air oven method. The protein content was determined using the micro-Kjeldahl method and nitrogen content converted to protein using 6.25 as the conversion factor. Soxhlet extraction method was used to determine the fat content of the samples. Ash was obtained by weighing 5 g of individual charred samples into a tarred porcelain crucible then incinerated at 600^{o}C for 6 h in ash muffle furnace until ash was obtained. Crude fibre was determined by exhaustive extraction of soluble substances in a sample using $H_2SO_4$and NaOH solution, after the residue was ashed and the loss in weight recorded as crude fibre. The carbohydrate contents were determined by difference. The percentage values of the moisture, protein, fat, ash and crude fibre were added and the total subtracted from 100%. Metabolizable energy was calculated by applying the energy conversion factors (one gram of protein, fat, carbohydrate and fibre yields 4, 9, 4 and 2 kcal of energy, respectively) as described in the West African Food Composition Table (Stadlmayr *et al.,* 2012).

$$\text{Calculated metabolizable energy (kcal)} = (\text{Protein} \times 4 + \text{Fat} \times 9 + \text{Fibre} \times 2 + \text{Carbohydrate} \times 4).$$

Amino acid composition was determined using the method described by Spackman et al., 1958. The samples were dried to a constant weight and defatted in a Soxhlet extractor. The defatted sample was hydrolyzed with7ml of 6N HCl in a sealed Pyrex tube at 105^{o}C ± 5^{o} C for 22 h. The hydrolysate was evaporated in a rotary evaporator and loaded into the Technicon Sequential Multi sample Amino acid Analyser (TSM). The steam carrying the amino acid reagent mixture passed through a heating bath where development of the coloured reaction product occurred. The absorbance was proportional to the concentration of each amino acid and was measured by colorimeter. All determinations were performed in triplicates.

Statistical Analysis: Data generated from laboratory analysis were analyzed using Statistical Package for Social Sciences (SPSS), version 20. Data were presented as mean ± standard deviation. Cooking time was presented in chart. Analysis of variance (ANOVA) was used to compare means. Duncan's new multiple range tests were used to separate group means. Significance was considered at $p < 0.05$.

Findings

Effect of traditional processing methods on cooking time of pigeon pea

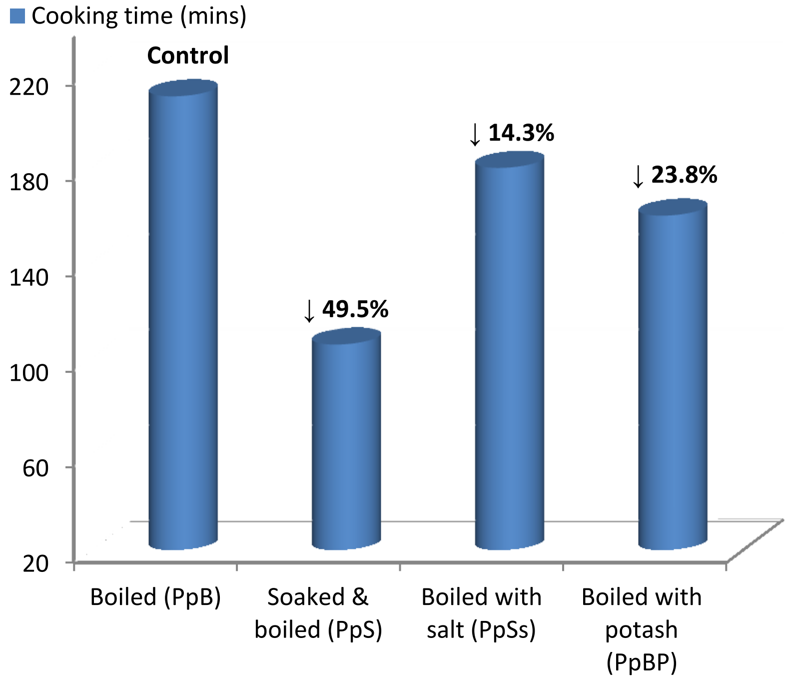

Figure 1: Cooking time (min) of processed pigeon peas

Figure 1 shows the cooking time of the samples. Soaking before boiling (PpS) reduced the cooking time by 49.5. The cooking time reduced by 23.8% when boiled with potash (PpBP). Boiling with salt (PpSs) reduced the cooking time by only 14.3%. This finding shows that soaking pigeon pea before boiling had the highest effect in reducing cooking time followed by boiling with potash.

The proximate composition, metabolizable energy and amino acid composition of raw pigeon pea

Table 1: Proximate Composition, Metabolizable Energy and Amino Acid Composition of Raw Pigeon Pea

Variables		Raw pigeon pea
Proximate composition (%)	Protein	18.65±0.01
	Fat	2.66±0.03
	Ash	3.38±0.01
	Crude fibre	5.18±0.04
	Moisture	6.25±0.01
	Carbohydrate	63.88±0.04
[a]Metabolizable energy value (Kcal/100g)	Energy	364.42±0.05
Amino acid composition (mg/100g)	Isoleucine	650.26±0.01
	Leucine	1263.24±0.02
	Lysine	1222.25±0.01
	Methionine	147.20±0.06
	Cysteine	115.26±0.01
	Phenylalanine	750.16±0.01
	Tyrosine	385.86±0.01
	Threonine	585.85±0.01
	Tryptophan	215.26±0.01
	Histidine	395.58±0.01
	Glutamic acid	2333.23±0.02
	Arginine	1266.64±0.01

[a]Calculated metabolizable energy (kcal) = (Protein × 4 + Fat × 9 + Fibre × 2 + Carbohydrate × 4)

Table 1 shows that raw pigeon pea had an energy value of 364.42 kcal/100g with 63.88% carbohydrate and 18.65% protein. Among the proximate values fat (2.66%) was the least followed closely by ash (3.38%) and crude fibre (5.18%). The abundant amino acids were glutamic acid (2333.23 mg) arginine (1266.64mg) and leucine (1263.24mg) while cysteine (115.26 mg), methionine (147.20) and tryptophan (215.26mg) were the least amino acids.

The proximate and metabolizable energy values of the processed samples

Table 2: Proximate Composition (%) and Metabolizable Energy Value (kcal) of the Processed Samples

Variables	Boiled (PpB)	Soaked & boiled (PpS)	Boiled with salt (PpSs)	Boiled with potash (PpBP)
Protein	15.58±0.01[a]	16.69±0.03[d]	16.34±0.01[b]	16.49±0.01[c]
Fat	2.26±0.01[c]	2.17±0.02[b]	2.23±0.01[c]	2.13±0.03[a]
Ash	2.54±0.01[b]	2.78±0.01[c]	3.25±0.01[d]	2.48±0.01[a]
Crude fibre	4.43±0.01[d]	3.68±0.01[a]	3.97±0.05[c]	3.85±0.03[b]
Moisture	12.46±0.03[a]	13.75±0.01[c]	12.64±0.01[b]	14.26±0.01[d]
Carbohydrate	62.01±0.02[d]	60.93±0.21[b]	61.57±0.02[c]	60.79±0.03[a]
Energy[a]	342.44±0.02[c]	337.37±0.02[a]	339.65±0.04[b]	335.99±0.22[a]

Mean values in the same row with different superscripts are significantly different at $p < 0.05$
[a]Calculated metabolizable energy (kcal) = (Protein × 4 + Fat × 9 + Fibre × 2 + Carbohydrate × 4)

Table 2 shows that processed pigeon pea seed contained 15.58 - 16.69% protein, 60.79 - 62.01% carbohydrate, 2.13 - 2.26% fat, and 2.48 - 3.25% ash. Boiling alone (PpB) resulted to sample with the highest significant ($p < 0.05$) amount of carbohydrate, crude fibre and fat while addition of potash (PpBP) significantly ($p < 0.05$) reduced the fat, carbohydrate, crude fibre and ash content of the sample. Ash content was significantly increased (3.25%) by boiling the sample with salt. Moisture content was highest in PpBP (14.26%) followed by PpS (13.75%) and PpSs (12.64%). The metabolizable energy value of the samples ranged from 335.99–342.44 kcal/100g with the PpBP and PpB having the lowest and highest energy value, respectively.

The amino acid composition (profile) of processed pigeon pea samples

Table 3: Amino Acid Composition (Profile) (mg/100g) of Processed Pigeon Pea Samples

Variables	Boiled (PpB)	Soaked & boiled (PpS)	Boiled with salt (PpSs)	Boiled with potash (PpBP)
Isoleucine	635.34±0.01[d]	440.24±0.01[c]	435.30±0.08[b]	426.36±0.01[a]
Leucine	1156.22±0.01[d]	1065.59±0.01[b]	1055.57±0.02[a]	1112.23±0.01[c]
Lysine	1188.54±0.01[d]	1005.23±0.01[b]	1001.24±0.01[a]	1006.35±0.01[c]
Methionine	163.54±0.01[d]	115.26±0.01[b]	110.24±0.01[a]	117.56±0.01[c]
Cysteine	166.55±0.01[c]	110.03±0.01[b]	105.56±0.01[a]	110.24±0.01[b]
Phenylalanine	696.66±0.01[d]	652.24±0.01[c]	645.56±0.01[b]	635.34±0.01[a]
Tyrosine	375.54±0.01[d]	355.36±0.01[c]	350.23±0.01[b]	345.26±0.01[a]
Threonine	555.26±0.01[d]	550.34±0.01[c]	542.26±0.01[b]	535.37±0.01[a]
Tryptophan	188.85±0.01[a]	205.26±0.01[d]	200.25±0.01[c]	196.36±0.01[b]
Histidine	360.44±0.01[b]	362.25±0.01[c]	352.25±0.01[a]	625.25±0.01[d]
Glutamic acid	2055.32±0.01[a]	2166.24±0.01[c]	2144.24±0.01[b]	2304.11±0.02[d]
Arginine	1288.26±0.01[d]	1266.97±0.01[b]	1255.23±0.01[a]	1268.56±0.01[c]

Mean values in the same row with different superscripts are significantly different at $p < 0.05$

Table 3 shows that the sample that was processed by boiling alone (PpB) had the highest amino acid content except for tryptophan, histidine and glutamic acid while addition of potash (PpBP) increased the glutamic acid, histidine and arginine contents. Boiling with salt significantly ($p < 0.05$) reduced leucine, lysine, methionine, cystine, histidine and arginine compared to the other processing methods. Among the processed samples, boiling (PpB) had the highest effect in enhancing the amino acid content of pigeon pea seed whereas boiling with salt and potash significantly ($p < 0.05$) reduced the amino acid composition of the legume.

Discussion of Findings

It was observed that the cooking time of pigeon pea reduced by approximately 50% when soaked in water before boiling. The effect of soaking on cooking time of common beans was evaluated by Correa *et al*. (2010, which showed that cooking time was reduced after soaking. This Siddiq and Uebersax (2012) attributes to water dispersion into the starch granules and protein fractions, protein denaturation and starch gelatinization resulting in tender beans. High loss of nutrient into the soaking water remains the implication of soaking legumes prior to cooking. However, Ramı´rez-Ca´rdenas et al. (2008) revealed that loss of nutrient could be minimized by cooking the legume with the soaking water instead of discarding it. Other beneficial effects of soaking such as elimination of antinutrients have been reported (Yasir & Asif, 2018). Addition of potash in legumes during cooking has been an age long practice especially in rural areas where it is believed to reduce the cooking time of hard-to-cook legumes. In this study, addition of cooking salt and potash reduced the cooking time by 14.3 and 23.4%, respectively compared to the reference sample (PpB). The reduced cooking time of the sample treated with potash as reported supports the findings of Momoh et al. (2019). According to the authors potash acts as a tenderizer for pigeon pea and that the higher the concentration of potash, the higher the level of tenderness. Earlier studies by Onwuka & Okala (2003) and Avila et al. (2015) on the impact of potash and sodium chloride (salt) on the cooking time of African yam beans and cowpeas showed decrease in cooking time of the legumes soaked in water containing these salts.

The recorded reduction in nutrient content of processed samples compared to the raw pigeon pea was expected. This is because heat treatment brings about various physical, chemical and enzymatic changes which directly or indirectly affect the nutrient composition. For instance, boiling legumes separates the bean cells resulting in the release of some cell contents (nutrients) into the processing water consequently leading to reduction in the nutrient content. The significant increase in the moisture content of soaked sample in the present study is in close agreement with the findings of Deshmukh and Pawar (2020). With the addition of potash (PpBP), we observed that the fat, carbohydrate, crude fibre and ash content of pigeon pea reduced significantly ($p < 0.05$). This finding disagrees with the report that potash added to *Ekuru*, produced from two cultivars of beans significantly increased the crude fat, ash and carbohydrate content of the products (Yewande & Thomas, 2015). The difference could be attributed to the method of preparation and interaction with other food ingredients added to the beans samples (*Ekuru*). Onwuka and Okala (2003) also reported that heat treatment and salt influenced the protein content of legumes when cooked.

Soaking before boiling (PpS) significantly ($p < 0.05$) reduced the crude fibre content while boiling (PpB) produced sample with the highest fibre content among the treated samples. Increased total and insoluble dietary fibre was also reported in chickpea, pigeon pea and lentil during cooking (Vidal-Valverde & Frias, 1991), which was partly attributed to the production of Maillard reaction due to high temperature. Dietary fibre has been linked to health beneficial effects including lowering of blood cholesterol, control of colon cancer and reduction of glycaemic levels.

Glutamic acid was the most abundant amino acid (2055.32 - 2333.23 mg/100g) in pigeon pea irrespective of the processing method applied. This was followed by arginine, lysine and leucine. This result corroborates the reports of other researchers who reported that glutamic acid was the most abundant amino acid in pigeon pea (Oshodi & Olaofe, 1993, Akande et al., 2010), and various other Nigerian underutilized legumes (Ogungbenle & Ebadan, 2014, Aremu et al., 2006). Furthermore, the result showed that pigeon pea seed contained limited amount of sulphur-containing amino acids, cysteine and methionine. This finding is in line with a previous study that showed that pigeon pea has low concentration of cysteine and methionine (Akande et al., 2010). Our finding is also in line with the amino acid analysis of goat pea reported by EL-Suhaibani *et al*. (2020) which showed that sulphur-containing amino acids are limited in the legume. Among the heat-treated samples, boiling alone (PpB) had the highest effect in enhancing the amino acid content of pigeon pea seed whereas boiling with salt and potash significantly ($p < 0.05$) reduced the amino acid composition of the legume. The decrease in amino acid concentration was highest in the sample boiled with salt. Denaturation of protein seems to be the reason for this finding. According to Sinha and Khare (2014) salts strip off the essential layer of water molecules from the protein surface eventually denaturing the protein.

Conclusion

This study has shown that processing methods have significant effect on cooking time and nutrient composition of pigeon pea. Boiling provided the best quality amino acid profile among the heat treated samples while addition of cooking salt led to poor amino acid profile. Although, addition of potash and salt reduced the cooking time, they negatively affected the proximate and metabolizable energy value of pigeon pea. The results of this study could help enhance the nutritive quality of pigeon pea-based diets and improve its utilization.

Recommendations

Based on the results of this study, we recommend that:

1. the use of traditional processing methods with the aim of reducing

the cooking time of pigeon pea should be done with caution as the nutritive value of the legume could be adversely affected.

2. pigeon pea should be consumed with other food crops such as cereals in order to improve the amino acid quality of the diet.

References

Adamu, A. S. & Oyetunde, J. G. (2013). Comparison of dietary proximate and mineral values of twovarieties of bean. *Asian Journal of Natural and Applied Sciences*; 2, 103-106.

Akande, K.E., Abubakar, M.M., Adegbola, T.A., Bogoro, S.E. & Doma, U. D. (2010). Chemical Evaluation of the Nutritive Quality of Pigeon Pea [Cajanus cajan (L.) Millsp.]. *International Journal of Poultry Science*; 9 (1): 63-65.

Alaye, S. A., Layade, K. T., Omole, E. B., Onihunwa, J. O., Joshua, D. A. & Akande, O. A. (2020). Eects of Different processing methods on proximate composition of *Mucuna pruriens*. *International Journal of Progressive Science and Technologies*; 20(2), 229-233.

AOAC. (2010). Official method of analysis (20th ed.). Washington, DC: Association of Official Analytical Chemists.

Aremu, M. O., Olaofe, O., & Akintayo, T. E. (2006). A comparative study on the chemical and amino acid composition of some Nigerian under-utilized Legume flours. *Pakistan Journal of Nutrition*; 5(1), 34-38.

Ávila, B. P., Santos dos Santos, M., Nicoletti, A. M., Alves, G. D., Elias, M. C., Monks, J., & Gularte, M. A. (2015). Impact of Different Salts in Soaking Water on the Cooking Time, Texture and Physical Parameters of Cowpeas. *Plant foods for Human Nutrition (Dordrecht, Netherlands)*; *70*(4), 463–469. https://doi.org/10.1007/s11130-015-0504-7

Babarinde, G. O., Adeyanju, J. A., Ogunleye, K. Y., Adegbola, G. M., Ebun, A. A., Wadele, D. (2020). Nutritional composition of gluten-free flour from blend of fonio (*Digitaria iburua*) and pigeon pea (*Cajanus cajan*) and its suitability for breakfast food. *Journal of Food Science and Technology*; 57(10), 3611-3620.

Correa, M. M., de Carvalho, L. M., Nutti, M. R., de Carvalho, J. L., Neto, A. R., & Ribeiro, E. M. (2010). Water absorption, hard shell and cooking time of common beans (*Phaseolus vulgaris L.*). *African Journal of Food Science and Technology;* 1(1), 013-020.

Deshmukh, B. A., & Pawar, V. S. (2020). Effects of different pretreatments on physicochemical and anti nutritional quality of moth bean. *Journal of Pharmacognosy and Phytochemistry*; 9(1), 1965-1968.

EL-Suhaibani, M., Ahmed, M. A., & Osman, M. A. (2020). Study of germination, soaking and cooking effects on the nutritional quality of goat pea (*Securigera securidaca L.*). *Journal of King Saud University-Science;* 32(3), 2029-2033.

Enwere, N. (1998). Food of plant origin. Nsukka, Afro-Orbis Publication.

Ghadge, P.N., Vairagar, P. R., & Prasad, K. (2008). Some physical properties of chick pea split (*Cicer arietinum* L.). *Agricultural Engineering International: the CIGR Ejournal*. 10(FP 07 039).

Iorgyer, M.I., Adeka, I.A., Ikondo, N.D., & Okoh, J.J. (2009). The impact of boiling periods on the proximate composition and level of some anti-Nutritional factors in Pigeon Pea (*Cajanus Cajan)* Seeds. *Production Agriculture and Technology;* 5 (1), 92-102.

Kassa, M. T., Penmetsa, R. V., Carrasquilla-Garcia, N., Sarma, B. K., Datta, S. et al. (2012). Genetic patterns of domestication in pigeon pea (*Cajanus Cajan* (L) Millsp.) and wild *Cajanus Cajan* relatives. *PLos One*; 7(6): e39563. https://doi.org/10.1371/journal.pone.0039563

Kunyanga, C., Imungi, J., & Vellingiri, V. (2013).Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. *Journal of Applied Biosciences*; 67, 5277-5288.

Momoh, T. B., Yaro, C. A., Usuman, S. O. & Iyeh, V. A. (2019). Effect of potash on the tenderness and phytochemical constituents of *Cajanus Cajan. Trends Applied Sciences Research*; 14, 278-282.

Ngwu, E. K., Aburime, L. C. & Ani, P. N. (2014). Effect of processing methods on proximate composition of African yambean (*Sphenostylis stenocarpa*) flour and sensory characteristics of their gruel. *International Journal of Basic and Applied Sciences*; 3 (3), 285-290.

Nwafor, F. I., Egonu, S. N., Nweze, N. O., & Ohabuenyi, N. (2017). Effect of processing methods on the nutritional values and antinutritive factors of Adenanthera pavonina L. (Fabaceae) seeds. *African Journal of Biotechnology*; 16, 106–112. https://doi.org/10.5897/AJB2016.15782

Ogungbenle, H. N., & Ebadan, P. (2014). Nutritional Qualities and Amino Acid Profile of Velvet Tamarind (*Dalium guineense*) Pulp. *British Biomedical Bulletin*; 2 (1), 006-016.

Okomoda, V.T., Tiamiyu, L.O., & Uma, S.G. (2016**).** Effects of hydrothermal processing on nutritional value of *Canavalia ensiformis* and its utilization by ***Clariasgariepinus*** (Burchell, 1822) fingerl**ings.** *Aquaculture Reports*; 3 (1), 214-219, 10.1016/j.aqrep.2016.04.003

Onwuka, U. N., & Okala, O. (2003). Effects of selected salts on the cooking time, protein content and sensory properties of African yam beans and cowpeas. *Food Service Technology*; 3(1), 3-7. DOI:10.1046/j.1471-5740.2003.00060.x

Oshodi,A.A., Olaofe, O. & Hall, G.M. (1993).Amino acid, fatty acids and mineral composition of pigeon pea. *International Journal of Food Science and Nutrition*; 43,187-191.

Ramı´rez-Ca´rdenas, L., Leonel, A.J., & Costa, N.M.B. (2008). Effect of domestic processing on nutrient and antinutritional factor content in different cultivars of common beans. *Cieˆncia e Tecnologia de Alimentos*; 28, 200–213.

Sathya, A., & Siddhuraju, P. (2015). Effect of processing methods on compositional evaluation of underutilized legume, *Parkiaroxburghii* G. Don (yongchak) seeds. *Journal of Food Science and Technology*; 52(10), 6157–6169. doi: 10.1007/s13197-015-1732-4

Siddiq, M., & Uebersax, M.A. (2012). Dry beans and pulses: Production, processing and nutrition (1st ed.), Wiley-Blackwell.

Sinha, S. K., (1977). Food legumes: Distribution adaptability and biology of yield, In: Plant production and protection paper 3. FAO, Rome, pp: 102.

Sinha, R., & Khare, S. K. (2014). Protective role of salt in catalysis and maintaining structure of halophilic proteins against denaturation. *Frontiers in Microbiology*; 5, 165. https://doi.org/10.3389/fmicb.2014.00165

Spackman, D. H., Stein, W. H., & Moore, S. (1958). Automatic recording apparatus for use in the chromatography of amino acids. *Analytical Chemistry*; 30, 1990-1991.

Stadlmayr, B., Charrondière, U. R., Enujiugha, V. N., Bayili, R. G., Fagbohoun, E. G., Samb, B., et al. (2012). West African Food Composition Table/Table De Composition Des Aliments D'afrique De L'ouest. Rome: FAO.

Takahashi, T., Toda, E., Singh, R. B., De Meester, F., Wilczynska, A., Wilson, D., & Juneja, L. R. (2011). Essential and Non-Essential Amino Acids in Relation to Glutamate. *The Open Nutraceuticals Journal*; 4, 205-212.

Vidal-Valverde, C., & Frias, J. (1991). Legume processing effects on dietary fibre components. *Journal of Food Science*; 56,1350–1352. doi: 10.1111/j.1365-2621.1991.tb04770.x.

Wu, G. (2009). Amino acids metabolism functions and nutrition. *Amino Acids*; 37, 1-17.

Yasir, A. & Asif, A.(2018). Impact of Processing on nutritional and antinutritional factors. *Annals of Food Science and Technology*; 19, 199 – 215.

Yeung, H., Ehler, J. D., Waniska, R. D., Alviola, J. N., & Rooney, L. W. (2009). Rapid screening methods to evaluate cowpea cooking characteristics. *Field Crops Research*; 112, 245-252.

Yewande, B. A., & Thomas, A. O. (2015). Effects of processing methods on nutritive values of *Ekuru* from two cultivars of beans *(Vigna unguiculata* and *Vigna angustifoliata)*. *African Journal of Biotechnology*; 14(2), 1790-1759.