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Effects of Processing On the Chemical Composition and Functional Properties of African Locust Bean (Parkia Biglobosa) Flour.

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Abstract: *The effects of boiling and fermentation on the chemical composition and functional properties of African locust bean flours were studied. The seeds were sorted, cleaned and processed into raw, boiled and fermented African locust bean flours. The flours produced were evaluated for proximate, vitamin and functional properties using standard analytical methods. The proximate composition of the samples showed that the flours had a range of moisture, 9.45-10.06%, crude protein, 21.24-22.62%, fat, 10.31-11.32%, ash, 3.00-4.19%, crude fibre, 3.25-3.84%, carbohydrate, 45.80-52.21% and energy, 378.59-388.83 KJ/100g, respectively. The vitamin composition of the flours showed that the vitamin A, ascorbic acid, vitamin E, thiamine, riboflavin and niacin contents of the samples varied between 3.26-4.91 mg/100g, 3.12-4.78 mg/100g, 2.78-3.83 mg/100g, 0.06-0.13 mg/100g, 0.03-0.08 mg/100g and0.11-0.22 mg /100g, respectively. Also, the functional properties of the flours revealed that the water absorption, oil absorption, foam, swelling and emulsion capacities and bulk density of the samples were significantly ($p<0.05$) higher in boiled flour compared to the samples fermented for 48 and 72 h, respectively. The proximate, vitamin and functional properties of the flours evaluated showed that the processed African locust bean flours have the potentials to be used as nutritional supplements and functional ingredients in the preparation of seasonings and other food products than the raw sample.*
Keywords: *African locust bean flour, boiling, fermentation, proximate composition, vitamin content, functional properties.*

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I. Introduction

The high cost of animal protein has directed interest towards the use of tropical legumes as potential sources of vegetable protein for human food and livestock feeds. Among the plant species, grain legumes are considered as the major sources of dietary proteins. They are consumed worldwide especially in developing and underdeveloped countries where the consumption of animal protein may be limited as a result of economic, social, cultural or religious factors (Ikenebomeh and Kok, 1984; Dike and Odunfa, 2003). Parkia biglobosa which is also known as the African locust bean or Ugba is a leguminous crop that is found in a wide range of environments in Africa. In a place where the tree is grown, the crushing and fermentation of the seeds constitute an important economic activity. The various parts of the African locust bean tree are used for medicinal purposes. As a standing tree, African locust bean may have a positive effect on the yield of other nearby crops. The chemical composition and nutritional significance of the African locust bean have been reported by Omafuvbe et al. (2000). The seeds of Parkia biglobosa are rich in fat, protein, sugar (soluble), carbohydrate and ascorbic acid. The cotyledon is very nutritious but it is low in fibre and ash contents when compared to the testa. Also, some simple reducing sugars including lactose are found in the cotyledons of African locust bean seeds. Alabi et al. (2005) reported that the oil derived from the cotyledons of the seeds have relatively high saponification value, low iodine and very low acid values, which make Parkia biglobosa seed oil to be very useful in soap making. In addition, the low iodine and acid values of the oil is an indication that it is suitable for human consumption.

According to Uwaegbute (1996), the powdery fruit pulp of African locust bean contains more carbohydrate than the seeds, which constitutes mainly of the reducing sugar, non-reducing sugar and other complex carbohydrates. The fruit pulp of the African locust bean is sweet to the taste which indicates the presence of natural sugar and thus, it serves as a potential energy source. The attractive yellow colour of the fruit pulp of African locust bean is an indication of the presence of phyto-nutrients particularly carotenoids which are important precursors of retinol (vitamin A). It has a sour taste which indicates the presence of ascorbic acid (vitamin C). It has been revealed that the fruit pulps of the locust bean seeds are used in rural African communities during emergencies especially when the grain stores are empty because they are edible and non-toxic (Owoyele et al., 1987; Akoma et al., 2001).

African Locust bean seeds are used in the production of some important condiments such as dawadawa, iru and okpeye that are used as flavouring agents in the preparation of soups, stews, porridges and other foods. The seeds can also be processed into cakes and preserved for later use or used in the preparation of some indigenous drinks that are more than adequate to meet the FAO/WHO recommended daily allowance of protein of 0.5 g/kg body weight for an average healthy individual and 0.88 g/kg body weight for children aged 1-10 years (Akoma et al., 2001). The fermented African locust bean product is used as a flavouring agent. It is also used as a good source of body building protein. However, the use of African locust bean seeds and other legumes as cheap sources of plant protein is limited by the presence of anti-nutritional factors which are diverse range of naturally occurring compounds in many tropical plants. The African locust bean seeds contain some anti-nutritional and toxic factors such as oxalates, phytates, saponins, protease inhibitors, hydrocyanic acid and tannins, which hinder digestion in man, capable of precipitating other deleterious effects, have anti-vitamin activity and bind other active food components including nutrients. These anti-nutrients could be drastically reduced or eliminated by the use of simple processing techniques such as soaking, fermentation, boiling, blanching, roasting, autoclaving and germination (Balagonpalon et al., 1998; Esenwah and Ikenebomeh, 2008). African locust bean products in their various forms are known to exhibit certain functional properties that make them useful in food systems and these properties are well pronounced due to the nature of their protein and the presence of lecithin. The functional properties that are commonly pronounced in African locust bean products include water holding, oil binding, emulsification, foam, gelation and swelling capacities which are important in determining the quality of the final products. The objective of this study, was to evaluate the effects of processing on the proximate, vitamin and functional properties of African locust bean (Parkia biglobosa) flour.

II. Materials And Methods

Mature African locust bean (Parkia biglobosa) seeds used for the study were purchased from Ogige Market, Nsukka, Enugu State, Nigeria. The seeds were sorted, cleaned and divided into four equal portions of 500g each. Three portions were subjected to different processing treatments (boiling and fermentation for 48 and 72 h, respectively), while the fourth batch was processed raw.

Preparation of Raw African Locust Bean Flour

The raw African locust bean flour was prepared according to the method of Madubuike et al. (2003). During preparation, five hundred grammes (500 g) of African locust bean seeds which were free from dirt and extraneous materials were cleaned with 2litres of potable water and dehulled manually by cracking the seeds with stone to remove the hulls. The dehulled seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ºC for 6 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled in a hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an air tight plastic container, labeled and stored in a freezer until needed for further use.

3.2.2 Preparation of Boiled African Locust Bean Flour

The boiled African locust bean flour was prepared according to the method of Esenwah and Ikenebomeh (2008). During preparation, five hundred grammes (500 g) of African locust bean seeds which were free from dirt and extraneous materials were thoroughly cleaned with 2litres of potable water. The cleaned seeds were boiled with 3litres of potable water at 100 ºC on a hot plate for 8 h with occasional addition of water to avoid the drying up of water. After that, the boiled seeds were drained, rinsed and dehulled manually by pressing out of the seeds. The dehulled seeds were rinsed, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ºC for 10 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled in a hammer mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an air tight plastic container, labeled and stored in a freezer until needed for further use.

3.2.3 Preparation of Fermented African Locust Bean Flour

The fermented African locust bean flour was prepared according to the method of Esenwah and Ikenebomeh (2008). During preparation, five hundred grammes (500 g) of locust bean seeds which were free from dirt and extraneous materials were boiled with 3litres of potable water at 100 ºC on a hot plate for 8 h. The boiled seeds were drained, rinsed and dehulled manually by pressing out of the seeds. The dehulled seeds were drained, rinsed and wet milled in a hammer mill with 2litres of potable water into fine slurry. The slurry obtained was stirred manually with a wooden stirrer and sieved with a muslin cloth into a clean plastic bowl. The sieved slurry produced was divided into two equal parts and then transferred into separate clean bags and allowed to ferment individually in 1.5litres of water with the aid of naturally occurring microbial flora at room temperature (29±2^{0}C) for 48 and 72 h, respectively. After that, excess water was decanted and the fermented slurry was separately dewatered manually. The cake obtained in each case was spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ºC for 12 h with occasional stirring of the cake at intervals of 30 min to ensure uniform drying. The dried fermented cakes were milled separately in a hammer mill and sieved through a 500 micron mesh sieve. The flours produced were packaged individually in air tight plastic containers, labeled and stored in a freezer until needed for further use.

Chemical Analysis

The moisture, protein, fat, crude fibre and ash contents of the samples were determined in triplicate according to standard analytical methods (AOAC, 2006). The carbohydrate content of the samples was calculated by subtracting the percentage differences of moisture, crude protein, fat and ash from 100 percent (Onwuka, 2005). Energy was calculated by multiplying the values of protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively (Tarek, 2002). The vitamin A, thiamine and riboflavin contents of the samples were determined according to the methods of Onwuka (2005). Ascorbic acid and niacin contents were determined using standard analytical methods (AOAC, 2006) while vitamin E content was determined according to the method of Pearson (1976).

Functional Properties

The water absorption, fat absorption and foam capacities of the samples were determined in triplicate according to the methods of Onwuka (2005). Bulk density was determined by the method of Giami and Bekebain (1992). Emulsion capacity was determined according to the method of Akinyede and Amoo (2009) while swelling capacity was determined by the method of Takashi and Sieb (1988).

Statistical Analysis

The results were expressed as mean ± standard deviation and the test for statistical significance was carried out using one-way analysis of variance (ANOVA). The Statistical Package for Social Sciences (SPSS, Version 20) software was used to determine the significant differences. Significant means were separated using Turkey's Least Significance Difference (LSD) test and differences were considered significant at $p<0.05$.

III. Results And Discussion

Proximate Composition

The proximate composition of raw and processed African locust bean flours are presented in Table 1. The moisture content of the samples was significantly ($p<0.05$) higher in boiled flour than in the fermented samples. The increase could be due to the imbibition of large quantity of water by the seeds during processing as a result of boiling. Omafuvbe et al. (2004) reported that the high moisture content of legume and other flours affect their storage stability due to increased microbial action. The observation, however, is in agreement with the report of Madubuike et al. (2003) for boiled Afzelia africana flour. The crude protein content of the flours was significantly ($p<0.05$) higher in the flour fermented for 72 h compared to the sample fermented for 48 h and that processed by boiling. The increase in crude protein content could be attributed to decrease in the concentration of carbohydrate which serves as an energy source for the fermentative microorganisms (Ogbadu and Okagbue, 2004). The fat content of the samples which ranged from 10.31 to 11.32% was significantly ($p<0.05$) increased by fermentation than the boiling treatment. The increase could be due to decrease in carbohydrate content. However, the result is in agreement with the report of Omafuvbe et al. (2000) for fermented soybean flour. Fat is important in the diets because it promotes the absorption of fat soluble vitamins and is in itself a high energy yielding nutrient (Okaka et al., 2006). The ash content of the flours varied from 3.00 to 4.19%. The values obtained in this study were lower than the ash content (4.16-4.48%) of boiled and fermented soybean flours. The low ash content of African locust bean flours is an indication that they are not good sources of minerals (Enwere, 1998). The crude fibre content of flours ranged from 3.25 to 3.84% with the flour fermented for 72 h having the least value followed by the sample fermented for 48 h and that processed by boiling. The reduction in the crude fibre contents of the fermented samples could be attributed to the degradation of fibre components by microbes during fermentation by converting them to volatile fatty acids for their nutrition (Akpet et al., 2012). Fibre has been credited for the promotion of increased excretion of bile salts, sterols and fat which have been implicated in the etiology of certain ailments in humans (Okaka et al., 2006). The carbohydrate content of the samples was significantly ($p<0.05$) higher in boiled flour than in the samples fermented for 48 and 72 h, respectively. The reduction in carbohydrate content could be due to the utilization of some of the sugars by fermenting organisms for growth and metabolic activities during fermentation (Omafuvbe et al., 2004). The energy content of the flours ranged from 378.61 to 388.83 kg/100g. The energy content was significantly ($p<0.05$) increased by fermentation than the boiling treatment. The differences in energy values of the samples could be attributed to variation in their protein, fat and carbohydrate contents (Esenwah and

Ikenebomeh, 2008). In effect, fermentation greatly increased the nutrient contents of African locust bean flours than the boiling treatment.

Vitamin Composition

The vitamin composition of raw and processed African locust bean flours are presented in Table 2. The vitamin A content of the samples which ranged from 3.26 to 4.24 mg/100g was significantly ($p<0.05$) lower in the boiled sample compared to the flours fermented for 48 and 72 h, respectively. The decrease could be due to the oxidation of vitamin A during processing as a result of boiling (Alabi et al. 2005). Vitamin A improves the normal vision of the eye. The ascorbic acid content of the flours was significantly ($p<0.05$) lower in boiled flour than in the samples fermented for 48 and 72 h, respectively. The decrease could be due to the leaching of the vitamin into the processing water during boiling. The observation is in agreement with the report of Oladunmoye (2007) for fermented African locust bean flour. Ascorbic acid plays an important role in the prevention of scurvy. It promotes the healing of the wound and maintenance of healthy immune system in humans (Lee and Kadar, 2000). The vitamin E content of the samples which ranged from 2.78 to 3.83 mg/100g was significantly ($p<0.05$) lower in boiled sample compared to the fermented samples. Vitamin E is a strong antioxidant which functions properly in human metabolism (Fellows, 2009). The thiamine content of the samples was significantly ($p<0.05$) reduced in the boiled sample compared to the samples fermented for 48 and 72 h, respectively. The decrease could be due to the leaching of the vitamin into the processing water during boiling. Thiamine functions as a co-enzyme in energy metabolism. It also helps in the treatment of beriberi and in the proper functioning of peripheral nerves (Okaka et al., 2006). The riboflavin content of the flours ranged from 0.03 to 0.08 mg/100g with the boiled sample having the least value. Riboflavin (vitamin B_2) functions as part of a group of enzymes called flavoproteins. The presence of this vitamin in human diet helps to improve growth and reproduction. It also helps to prevent anaemia and abnormal gait (Alabi et al., 2005). The niacin content of the samples was significantly ($p<0.05$) reduced by boiling treatment compared to the samples processed by fermentation. The reduction in niacin content could be as a result of leaching (Fellows, 2009). Generally, fermentation had greater effect in enhancing the vitamin contents of African locust bean flours than the boiling treatment.

Functional Properties

The functional properties of raw and processed African locust bean flours are presented in Table 3. The water absorption capacity of the samples was significantly ($p<0.05$) higher in boiled flour than in the fermented samples. The increase could be due the presence of high amount of starch in the boiled flour. The observation is in agreement with the report of Obatolu et al. (1998) for boiled and fermented soybean and African locust bean flours. The high water absorption capacity of a food product is an indication that the product will associate with water in a situation where water is limiting (Giami, 1993). The bulk density of the samples which ranged from 0.43 to 0.72% was significantly ($p<0.05$) reduced by fermentation than the boiling treatment. The bulk density generally depends on the particle size of the sample and it is a measure of heaviness of a sample. Bulk density is important in determining the packaging requirement and material handling during processing and preparation of food products (Malomo et al., 2012). The oil absorption capacity of the flours was significantly ($p<0.05$) higher in the flours fermented for 48 and 72 h, respectively compared to the sample processed by boiling. The oil absorption capacity of a food product could be used as an important index for monitoring the spoilage of the product. It also increases the ability of protein to bind fats. Fat acts as a flavour retainer and, hence it increases the mouth feel of the food products (Kinsella, 1996). The emulsion capacity of the samples which ranged from 22.72 to 24.83% was reduced significantly ($p<0.05$) by fermentation than the boiling treatment. The emulsion capacity reflects the capacity of the product to aid in the formation of an emulsion. It is also related to the ability of a food product to adhere to the interfacial area of oil and water in an emulsion (Richard et al., 1992). The swelling index of the flours was significantly ($p<0.05$) reduced by boiling than the 48 and 72 h fermentation treatment. This may be as a result of the factors that influence the swelling index of powdered products which include temperature, availability of water, species of starch and extent of starch damage due to thermal and mechanical processes etc (Milan-Carrillo et al., 2000). Flours with good swelling capacity will be useful in the preparation of soups, sauces and gravies. The foam capacity of the samples which ranged from 19.72 to 23.57% was significantly ($p<0.05$) higher in the samples fermented for 48 and 72 h, respectively compared to the boiled flour. Flours with good foam capacity are desirable for use in the preparation of whipped cream and salad dressings. Graham et al. (2003) reported that the presence of flexible protein molecules in a food product can readily reduce the surface tension to give good foam stability. Generally, the functional properties of African locust bean flours were drastically reduced by boiling than the fermentation treatment with the exception of oil absorption, swelling and foam capacities.

IV. Conclusion

From the study, it was observed that the boiling and fermentation treatments used affected the proximate, vitamin and functional properties of African locust bean flours. The study showed that fermentation generally improved the protein, fat, vitamin A, ascorbic acid, thiamine and riboflavin contents of the products than the boiling treatment while their carbohydrate, ash and crude fibre contents decreased. Also, the bulk density, water absorption and emulsion capacities of the samples were increased by boiling treatment while the oil absorption, swelling and foam capacities were drastically enhanced by fermentation. It is therefore suggested that any of these treatments can be used for processing African locust bean seeds since they are very common and relatively cheap. Generally, fermentation resulted in the production of flours of higher nutrient density and better functional properties than the boiling treatment.

Table 1: Proximate composition (%) of African locust bean flours.

Parameter	Raw	Boiled	Fermented for 48 h	Fermented for 72 h
Moisture	$9.45^{d} \pm 0.04$	$10.06^{a} \pm 0.03$	$9.66^{c} \pm 0.00$	$9.74^{b} \pm 0.06$
Crude protein	$21.26^{c} \pm 0.06$	$21.24^{c} \pm 0.06$	$21.45^{b} \pm 0.04$	$22.62^{a} \pm 0.01$
Fat	$10.31^{d} \pm 0.01$	$10.71^{c} \pm 0.01$	$11.19^{b} \pm 0.00$	$11.32^{a} \pm 0.01$
Ash	$4.19^{a} \pm 0.01$	$3.93^{b} \pm 0.00$	$3.37^{c} \pm 0.03$	$3.00^{d} \pm 0.14$
Crude fibre	$3.84^{a} \pm 0.04$	$3.66^{b} \pm 0.00$	$3.54^{c} \pm 0.05$	$3.25^{d} \pm 0.04$
Carbohydrate	$45.80^{d} \pm 3.54$	$54.21^{a} \pm 0.01$	$49.99^{b} \pm 0.08$	$49.66^{c} \pm 0.11$
Energy (kJ/100g)	$382.61^{c} \pm 13.$	$378.59^{d} \pm 0.07$	$387.66^{b} \pm 0.20$	$388.83^{a} \pm 0.33$

Values are mean ± standard deviation of triplicate determinations. Values followed by different superscripts in the same row are significantly different ($p<0.05$).

Table 2: Vitamin composition(mg/100g) of African locust bean flours.

Parameter	Raw	Boiled	Fermented for 48 h	Fermented for 72 h
Vitamin A	$4.91^{a} \pm 0.01$	$3.26^{d} \pm 0.00$	$4.24^{b} \pm 0.01$	$4.17^{c} \pm 0.01$
Ascorbic acid	$4.78^{a} \pm 0.03$	$3.12^{d} \pm 0.03$	$3.28^{b} \pm 0.01$	$3.20^{c} \pm 0.00$
Vitamin E	$3.83^{a} \pm 0.01$	$2.78^{d} \pm 0.04$	$3.55^{b} \pm 0.08$	$3.25^{c} \pm 0.00$
Thiamine	$0.13^{a} \pm 0.00$	$0.06^{d} \pm 0.00$	$0.07^{c} \pm 0.00$	$0.08^{b} \pm 0.00$
Riboflavin	$0.08^{a} \pm 0.00$	$0.03^{c} \pm 0.00$	$0.03^{c} \pm 0.00$	$0.04^{b} \pm 0.00$
Niacin	$0.22^{a} \pm 0.03$	$0.11^{d} \pm 0.01$	$0.16^{c} \pm 0.01$	$0.17^{b} \pm 0.00$

Values are mean ± standard deviation of triplicate determinations. Values followed by different superscripts in the same row are significantly different ($p<0.05$).

Table 3: Functional properties of African locust bean flours.

Parameter	Raw	Boiled	Fermented for 48 h	Fermented for 72 h
Water absorption Capacity (ml/g)	$1.82^{a} \pm 0.00$	$1.65^{b} \pm 0.00$	$1.51^{c} \pm 0.01$	$1.47^{d} \pm 0.02$
Bulk Density (g/ml)	$0.72^{a} \pm 0.01$	$0.60^{b} \pm 0.00$	$0.43^{c} \pm 0.00$	$0.46^{c} \pm 0.00$
Oil Absorption Capacity (ml/g)	$2.00^{c} \pm 0.00$	$1.54^{d} \pm 0.00$	$2.08^{b} \pm 0.02$	$2.51^{a} \pm 0.01$
Emulsion Capacity (%)	$24.83^{a} \pm 0.10$	$23.82^{b} \pm 0.01$	$22.75^{c} \pm 0.03$	$22.72^{c} \pm 0.03$
Swelling Capacity (%)	$1.83^{a} \pm 0.04$	$1.19^{d} \pm 0.01$	$1.43^{b} \pm 0.04$	$1.35^{c} \pm 0.03$
Foam Capacity (%)	$22.72^{b} \pm 0.03$	$19.72^{c} \pm 0.06$	$23.57^{a} \pm 0.04$	$23.55^{a} \pm 0.10$

Values are mean ± standard deviation of triplicate determinations. Values followed by different superscripts in the same row are significantly different ($p<0.05$).

References

[1]. Akoma, O., Onuoha, S.O. and Ozigis, A.A. (2001). Physico-chemical attributes of wine produced from the yellow plulp of Parkia biglobosa. Nigerian Food Journal ;19: 76 – 86.
[2]. Akpet, S.O, Ukorebi, E. A, Ayuk, B.A, Esseien, A. and Anoh, K.U. (2012). Effect of fermented locust bean seeds (Parkia clapatoniana) as a replacement for full-fat soybean meal on the performance and haemathological parameters of weaning rabbits. Journal of Biology, Agriculture and Health; 2(7): 4-7.
[3]. Alabi, K.B., Oboh, .G. and Akindahunsi, A.A. (2005). Fermentation changes the nutritive value, polyphenol distribution and antioxidant properties of Parkia biglobosa seeds (African locust bean). Nigerian Journal of Biochemistry; 22: 363 – 376.
[4]. AOAC (2006)**.**Official Methods of Analysis. Association of Official Analytical Chemists.18thedn.Washington D. C. USA. Pp. 214-226.
[5]. Akinyede, A.I and Amoo, A.I. (2009). Chemical and functional properties of full-fat and defatted cassia fistula seed flours. Pakistan Journal of Nutrition; 8:765-769.
[6]. Balagonpalon, C; Padonosa, G; Nanda, S.K and Moorthy, S.N (1998). Cassava in Food, Feeds and Industry. C.R.C press. Boca Raton, Florida. Pp: 126-132.
[7]. Dike, E.N and Odunfa, S.A. (2003). Microbiological and biochemical evaluation of a fermented soyabean product- soya dawadawa. Nigerian Food Journal; 21-103-110

[8]. Enwere, N.J. (1998). Foods of Plant Origin. Afro-Obis publications, Nsukka, Nigeria. Pp. 70 – 75.
[9]. Esenwah, C.N. and Ikenebomeh, M.J. (2008). Processing effects on the nutritional and anti-nutritional contents of African locust bean (Parkia-biglobosa (Benth) Seed. Pakistan Journal of Nutrition. **7** (2): 214 – 217.
[10]. Fellows, P.J. (2009). Food Processing Technology: Principles and Practice. 2nd edn.CRC Press, United Kingdom. Pp. 90-150.
[11]. Giami, S.Y. (1993).Effect of processing on the proximate composition and functional properties of cowpea (Vigna unguiculata) flour. Food Chemistry; 47: 153-160.
[12]. Giami, S.Y. and Bekebain, D.A. (1992). Proximate composition and functional properties of raw and processed full-fat fluted pumpkin (Telfairia occidentalis) seed flour. Journal of Science of Food and Agriculture; 59: 321-325.
[13]. Graham, R. D. and Welch, R. M. (1996).Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany; 55(3): 353-364.
[14]. Ikenebomeh, M.J and Kok, R. (1984). Mass balance of the processing and fermentation of the African locust bean (Parkia biglobosa Welve). Journal of Food science and Technology; 17:48-50.
[15]. Kinsella, J. E. (1996). Functional properties of food proteins: a review. Critical Reviews in Food Science and Nutrition, 7: 219-280.
[16]. Lee, S. K. and Kader, A. A. (2000). Pre-harvest and post-harvest factors influencing vitamin C content of horticultural crop. Biological Technology, 20: 207-220.
[17]. Madubuike, F. N., Agiang, E. A., Ekenyem, B. U. and Ahaotu, E. O. (2003). Replacement value of rubber seed cake on performance of starter broiler. Journal of Agriculture and Food Science; 1: 21-27
[18]. Malomo, O., Ogunmoyelu, O. A. B., Adekoyeni, O. O., Jimo, O., Ogunsina, B. S. I. O., Olaoye, A. O., and Babawale, B. D. (2012). Nutritional and physical properties of kariya seeds. International Agrophysiology; 25: 97-100.
[19]. Milan-Carrillo, J., Reves-Moreno, C., Armienta-Redelo, E., Carattbez-Trejo, A. and Mora-Escobedo, R. (2000).Physicochemical and nutritional characteristics of extruded flours from fresh and hardened Chickpeas (Cicer arietinum). Lebensmittel-Wissenschaft and Technologies; 33: 117 – 123.
[20]. Obatolu, V.A., Osho, S.M. and Uwagbu, A.C.I. (1998). Comparative Physiochemical Properties of Fermented Soybean and Locust Bean. In: Post-Harvest Technology and Commodity Marketing. IITA. Ed. R.S,.B. Ferris. Ibadan; Pp. 163 – 168.
[21]. Ogbadu, L.J. and Okagbue, R.U. (2004). Fermentation of African locust bean (P. biglobosa) seeds with the use of different species of bacillus. M.Sc. Dissertation. Department of Microbiology, University of Nigeria, Nsukka, Nigeria. Pp. 80-84.
[22]. Okaka, J.C., Akobundu, E.N.T. and Okaka, A.N.C. (2006). Food and Human Nutrition: An Integrated Approach. 3rdedn. Cjanco Academic Publishers, Enugu, Nigeria. Pp. 99-128.
[23]. Oladunmoye, M.K. (2007). Effect of fermentation on nutrient enrichment of African locust bean (Parkia biglobosa). Research Journal of Microbiology; 2: 185-189.
[24]. Omafuvbe, B.O., Falade, O.S., Oshuntogun, B.A. and Adewusi, S.R.A. (2004).Chemical and biochemical changes in African locust bean (Parkia biglobosa) and melon (Citrullus vulgaris) seeds during fermentation of condiments. Pakistan Journal of Nutrition; 3: 140 – 145.
[25]. Omafuvbe, B.O., Shonukan, O.O. and Abiose, S.H. (2000).Microbiological and biochemical changes in the traditional fermentation of soybean for soy-daddawa (a Nigerian food condiment).Journal of Food Microbiology; 17: 469-474.
[26]. Onwuka, G.I (2005). Food Analysis and Instrumentation: Theory and Practice. Naphthali Publishers Ltd, Lagos, Nigeria. Pp. 133-142.
[27]. Owoyele, J.A; Shok, M and Olagbemiro C. A., (1987). Some chemical constituents of the fruit pulps of Parkia clappertoniana as a potential industrial raw material. Savanna, 9(2): 24-27.
[28]. Pearson, D. (1976). The Chemical Analysis of Foods. Churchill Livingstone Publishers, Edinburge. Pp. 70-75.
[29]. Rickard, J.E., Blanshard, J.M.V. and Asaoka, M. (1992). Effects of cultivar and growth season on the gelatinization properties of cassava (Manihot esculenta) starch. Journal of Food Science and Agriculture; 59: 53 – 58.
[30]. Takashi, S. and Sieb, P. A. (1988).Paste and gel properties of prime corn and wheat starches with and without native lipids. Cereal Chemistry; 65: 474-483.
[31]. Tarek, A.E. (2002). Nutritional composition and anti-nutritional factors of chickpeas (Cicer arietinum) undergoing different cooking methods and germination. Plant Foods for Human Nutrition; 54:83-97.
[32]. Uwaegbute, A.C. (1996). African Locust Bean In: Foods from Legumes and Oil Seeds. (E. Nwokezia, and J.A. Smart, eds). Chapman and Hall Publishers, London. Pp. 124 – 129.

Ezugwu, E.N "Effects of Processing On the Chemical Composition and Functional Properties of African Locust Bean (Parkia Biglobosa) Flour. "IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 12.7 (2018): 09-14.