EFFECT OF THERMAL PROCESSING TREATMENTS ON THE PROXIMATE,FUNCTIONAL AND PASTING PROPERTIESOF AFRICAN YAM BEAN (*Sphenostylisstenocarpa*) SEED FLOURS

ABSTRACT

The study was designed to evaluate the effect of thermal processing treatments on the proximate composition, functional and pasting properties of African yam bean seed flours. The African yam bean seeds were sorted, cleaned and divided into five equal lots of one kilogram each. Four lots were processed into boiled, blanched, roasted and autoclavedAfrican yam bean flours, while the last lot was processed raw and used as control. The flour samples obtained were analyzed for proximate composition, functional and pasting properties using standard methods. The proximate composition of the samples revealed that the flours had a range of 6.14-11.24% moisture, 8.18-14.37% crude protein, 3.06-4.61% fat, 2.04-3.32% ash, 3.18- 3.56% crude fibre, 62.90 -76.98% carbohydrate and 350.57 - 368.50kJ/100g energy, respectively. The functional properties of the flours equally revealed that thebulk density, water absorption, oil absorption, swelling, emulsification and foam capacities of the samples ranged from 0.43-0.68mg/mL, 0.48-0.76%, 0.45-1.57%, 2.32-2.72%, 1.27-2.69% and 1.43-1.86%, respectively. The pasting properties of the samples also showed that the trough, breakdown, setback and final viscosities as well as the peak time and pasting temperature of the flours were significantly ($p < 0.05$) higher in blanched and roasted African yam bean flours compared to the samples processed by boiling and autoclaving treatments. However, the study showed that the processed African yam bean flours could be used as nutrient dense and functional ingredients in the formulation of a variety of novel food products for children, adolescents, and adults especially in Nigeria and other developing countries where the problem of protein-energy malnutrition is prevalent than the raw sample.

Keywords: African yam bean seeds, boiling, blanching, roasting, autoclaving, proximate composition, functional properties, pasting properties.

INTRODUCTION

African yam bean (*Sphenostylisstenocarpa*) is an underutilized food legume usually cultivated mainly in Nigeria for its seeds and grown as tubers in Cote d'Ivoire, Ghana, Togo, Cameroun, Gabon, democratic republic of Congo, Ethiopia and parts of East Africa, notably Malawi and Zimbabwe (NRC, 2006). The pods are straight, very elongated, and slightly woody and range from 10-30cm in length. The fruit contains 20 – 30 seeds which are literally compressed and sub-cylindrical or ovoid in shape. It produces small tubers that look like elongated sweet potatoes but taste more like Irish potatoes (Ndidi *et al*., 2014). Africa yam bean is called *Uzaki* or *Ijiriji*, among the Igbos in south -eastern Nigeria. It is a bean-shaped leguminous crop that is usually black, brown, white, grey or speckled in appearance (Asoiro*et al*., 2011). The seeds are generally consumed in the entire south-eastern Nigeria and beyond. The seedsarehighly priced food and are also rich in protein, carbohydrate, minerals and vitamins (Liday, 2013). The level of crude protein in African yam bean is between 21 and 29% (dry matter basis) which is lower than that of soybean (38%), but the amino acid profile indicates that their lysine and methionine levels are equal to or better than that of soybean (Onyeike and Omubo – Dede, 2002; Anya and Ozungi, 2019). African yam bean is also one of the good sources of minerals like molybdenum, iron, copper, manganese, calcium and magnesium. African yam bean seeds are relatively rich in potassium which is an important electrolyte component of the cell and body fluids. It also helps to counter the pressing effects of sodium on heart and blood pressure. The seeds could be cooked like cowpea (even though it takes longer time to cook) and eaten as bean porridge or in combination with yam "jigbu" or "abacha" (tapioca)or toasted and eaten with palm kernel or coconut. The seeds are usually added to soups, made into sauces or milled into flour. They are usually prepared and eaten as food in the morning by farmers who bent on drinking water after eating it without getting famished for a very long time (Uche *et al.,* 2014).

Functional properties involve the physical and chemical characteristics which govern the behaviour of nutrients during processing and serve as the basis for product performance. Functional properties which affect food quality, storage and acceptability include bulk density, foam stability, oil absorption capacity, water absorption capacity, gelation and emulsification properties (Shevkani*et al.*, 2015). The utilization of plant proteins as ingredients in food preparations depend largely upon the beneficial qualities they impact to such foods which also depend to a great extent on their functional properties. Therefore, in order to successfully introduce a new supplement into a food item, it is important to find out if the supplement has suitable functional properties for food applications and consumer acceptability. This is because these properties play a critical role in enhancing both the shelf life and sensory properties of foods during production, processing and preparation (Akubor, 2017). African yam bean has a lot of nutritional and medicinal properties, yet, it remains a neglected and underexploited crop with no concerted efforts to enhance its utilization in food formulations for both human and animal consumption.Foods are generally classified according to their rheological states as solid, liquid, gel and emulsion with associated rheological behaviour. The rheology of food is the study of deformation and flow properties which can be measured (Mckenna and Lyng, 2003). These properties will affect the design of food processing plant as well as shelf life and other important factors including sensory properties that appeal to the consumers. Pasting properties are among the rheological qualities of starch that are commonly used to determine the behaviour of starch in a food system especially when an aqueous suspension of starch is heated above a critical temperature. (Usman *et al.*, 2016). Some of the important pasting properties that are usually determined during the processing of starchy, cereal and leguminous food products are peak, trough, setback, breakdown and final viscosities, in addition to other parameters which include peak time and pasting temperature. The objective of this study was to evaluate the effects of boiling, roasting, blanching and autoclaving on the proximate composition, functional and pasting properties of African yam bean seeds flours.

MATERIALS AND METHODS

Procurement of the Raw Materials

Mature dried African yam bean seeds used for the study were bought from Ogbete Main Market, Enugu, Enugu State, Nigeria.

Pre-preparation of the Seeds

The seeds were sorted manually to remove contaminants, cleaned and divided into five equal lots of 1kg each. The four lots were subjected to different heat processing treatments (boiling, blanching, roasting and autoclaving), while the and last lot was processed raw.

Preparation of Raw African Yam Bean Flour

The raw African yam bean flour was prepared according to the method described by Anya and Ozung (2019). One kilogram (1kg) of African yam bean seeds was cleaned with 3litres of potable water to remove the dirt and other extraneous materials. After that, the cleaned seeds were drained, rinsed, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{o}C for 10 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were dehulled by cracking them in the attrition mill followed by winnowing to remove the hulls. The dehulled seeds were milled into flour using the attrition mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Preparation of Boiled African Yam Bean Flour

The boiled African yam bean flour was prepared according to the method described by Anya and Ozung (2019). One kilogram (1kg) of the cleaned seeds was soaked in 3 litres of potable water at room temperature (30±2^{o}C) for 8 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing them in-between palms to remove the hulls. The dehulled seeds were boiled with 2.5 litres of potable water at 100^{o}C for 30 min on a hot plate. The boiled seeds were drained, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{o}C for 14 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the attrition mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Preparation of Blanched African Yam Bean Flour

The blanched African yam bean flour was prepared according to the method described by Anya and Ozung (2019). One kilogram (1kg) of the cleaned seeds was soaked in 3 litres of potable water at room temperature (30±2^{o}C) for 8 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing them in-between palms to remove the hulls. The dehulled seeds were hot water blanched at 75^{o}C for 15 min on a hot plate. The blanched seeds were drained, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{o}C for 12 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the attrition mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Preparation of Roasted African Yam Bean Flour

The roasted African yam bean flour was prepared according to the method described by Anya and Ozung (2019). One kilogram (1kg) of the cleaned seeds was soaked in 3 litres of portable water at room temperature (30±2^{o}C) for 8 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing them in-between palms to remove the hulls. The dehulled seeds were rinsed, spread on the trays and roasted in a hot air oven (Model DHG 9101 ISA) at 240^{o}C for 90 min with occasional stirring of the seeds at intervals of 10 min to ensure uniform roasting. The roasted seeds were milled into flour using the attrition mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Preparation of Autoclaved African Yam Bean Flour

The autoclaved African yam bean flour was prepared according to the method described by Anya and Ozung (2019). One kilogram (1k g) of the cleaned seeds was soaked in 3 litres of potable water at room temperature (30±2^{o}C) for 8 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing them in-between palms to remove the hulls. The dehulled seeds were placed in a beaker and autoclaved in an autoclave (Model 75 x G, UK, England) at the temperature of 121^{o}C and pressure of 6 atmospheres for 1 h. The autoclaved seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{o}C for 8 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the attrition mill and sieved through a 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labelled and kept in a refrigerator until needed for analysis.

Proximate Analysis

The moisture, crude protein, fat, ash and crude fibre contents of the samples were determined on dry weight basis according to the methods of AOAC (2010). Carbohydrate was determined by difference (AOAC, 2010). The energy content of each sample of the flours was calculated from the proximate composition using the Atwater factorsof 4×protein, 9×fat and 4×carbohydrate (AOAC, 2010).All determinations were carried out in triplicate samples.

Evaluation of Functional Properties

The bulk density, swelling, foam, emulsification, water and oil absorption capacities of the flour sampleswere determined on dry weight basisaccording to the methods described by Onwuka (2005).All determinations were carried out in triplicate samples.

Evaluation of Pasting Properties

The pasting properties of each sample of the flours was determined on dry weight basis using Rapid Visco Analyzer (RVA) (Model Newport Scientific Pty. Ltd., Warne-Wood NSW 2012, Australia) according to the methods of AACC (2000). The pasting properties of the samples were read from the pasting profile with the aid of thermocyline for windows software that was connected to a computer.All determinations were carried out in triplicate samples.

Statistical Analysis

The data generated were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 23) software. Significant means were separated using Turkey's least significant difference (LSD)test at $p < 0.05$.

RESULTS AND DISCUSSION

Proximate Composition of Raw and Processed African Yam Bean Flour Samples

The proximate composition of raw and processed Africa yam bean flour samples are presented in Table 1

The moisture content of the raw sample was 11.24% and that of the processed samples ranged between 6.14 to 11.24% with the roasted sample having the least value (6.14%),while the boiled sample had the highest (6.56%) value. There were significant differences ($p< 0.05$) in the moisture content of the flour samples. The increase in the moisture content of the boiled flour sample could be attributed to the absorption of the large quantity of water by the seeds as a result of boiling during processing.The observation is in agreement with the report of Nsa and Ukachukwu (2009).The moisture contents of the raw and processed samples were comparable to the values (11.85% and 6.12 – 6.89%) reported by Arawande and Borokin (2010) and Onuoha *et al*. (2017) for raw and boiled pigeon pea and African yam bean flours, respectively. The moisture contents of both the raw and processed samples were within the maximum range of moisture (0-13%)that is compatible with the proper packaging and storage of legume flours (Azeke*et* *al*.,2005). The low levels of moisture in raw, boiled, blanched, roasted and autoclaved samples of African yam bean flour suggest that they could keep for a long period of time without deterioration and spoilage that could be caused by the presence of microorganisms and chemical reactions. The moisture content of the food is used as a measure of its stability and susceptibility to microbial and chemical/enzymatic deterioration and spoilage during storage.

The crude protein content of the raw sample was 14.37% and that of the processed samples ranged between 8.18 and12.32% with the boiled and roasted samples having the least (8.18%) and the highest values (12.32%), respectively. The crude protein values (14.37% and 8.18 – 12.32%) obtained in this study for both the raw and processed flours were lower than the protein contents (12.18% and 6.12 -10.280%) reported by Jacob *et al*. (2015) for raw,cooked and roasted melon seed flours. There were significant differences ($p<0.05$) in the crude protein contents of the flour samples. The crude protein content of the flour samples was significantly higher ($p<0.05$) in roasted and autoclaved samples compared to the samples processed by boiling and blanching treatments. The reduction in the protein contents of the boiled and blanched samples could be attributed to leaching of some soluble proteins into boiling and blanching water during processing (Obasi and Wogu,2008; Akubor, 2017). It has been earlier reported that when food is subjected to roasting and autoclaving, the activities of the proteolytic enzymes are increased (Mbah *et al*., 2012). The higher protein values obtained for the roasted and autoclaved samples could be due to the increase in the activities of proteolytic enzymes which hydrolysed the inherent proteins to their constituent amino acids and peptides. Dietary proteins are needed for the synthesis of new cells, enzymes and hormones required for the development of the body (Okaka*et al*.,2006).

The fat contents of the raw, boiled, blanched, roasted and autoclaved samples of African yam bean flours were 4.61, 3.06, 3.10, 3.23 and 3.16%, respectively. The result showed that boiling and blanching treatments significantly ($p<0.05$) reduced the fat content than the roasting and autoclaving (3.32 and 3.16%) techniques compared to the raw sample which had the highest fat content (4.16%). The observed decrease in fat contents of boiled and blanched African yam bean flours could be due to oxidative breakdown of fat components into fatty acids and glycerol as a result of heat during processing. The fat content of the flour samples was generally higher compared to other alternative protein sources such as pigeon pea (2.33%), velvet bean (1.61%)

and sword bean (2.94%) (Ahamefule, 2005; Akinmutimi, 2007; Elais *et al.,* 2010) but fell within the range reported for *Canavalliaplagiosperma* seeds (5.94%) (Ahamefule and Odoemelam, 2008). In addition, the studies carried out by other researchers (Asoiro and Ani, 2011; Chikwendu *et al*., 2014) revealed that the fat content of African yam bean has a composition that is comparable to that of groundnut and cotton seed oil by being high in palmitic and oleic acids. However, the high fat content (3.5%) of African yam bean seeds can cause rancidity in foods prepared from the seed flours, and this could be overcome through the extraction of the oil before being used in the formulation of food products or by the addition of antioxidants. Fat is important in human diets because it is a high energy-yielding nutrient (Oraka and Okoye, 2017).

The ash content of the raw sample was 3.32% and that of the processed samples ranged from 2.04 to2.96%. The boiled sample had the least value (2.04%), while the roasted sample had the highest value (2.96%) which was slightly lower than the ash content of the raw sample (3.32%). The result showed that the African yam bean flours were generally low in ash content and had the values that could not compare favourably with other alternative vegetable protein sources like pigeon pea, lima bean, lablab bean, *Mucuna* bean and castor oil seed flours with ash contents of 2.85, 3.22, 3.56, 4.31 and 5.61%, respectively (Carew *et al*., 2003; Ahamefule, 2005;Akinmutimi, 2007; Nsa, 2008). The ash content showed significant ($p<0.05$) difference between the raw and thermally processed African yam bean flour samples. The raw sample however recorded higher ash content (3.32%) compared to the boiled (2.04%) and blanched (2.12%) samples which had the least ash contents. The decrease in ash contents of the boiled and blanched flours could be attributed to leaching of some mineral elements into boiling and blanching media during processing. The observations are in close agreement with the reports of Ukachukwu and Obioha (2000) and Nsa (2008) for boiled and blanched *Mucuna Cochinchinosis* and castor oil seed flours, respectively. In this present study, autoclaving and roasting treatments recorded the highest values of 2.87% and 2.96%, respectively compared to the sample processed by boiling treatment (2.04%). This trend is also in line with the reports of Ahamefule and Odoemelam (2006) and Oraka and Okoye (2017) who stated that roasted and autoclaved flour samples had higher ash contents than the samples processed by boiling and blanching treatments. The increase in ash contents of autoclaved and roasted flour samples may be as a result of loss of moisture due to the application of dry heat, which tend to increase the concentration of inorganic contents of the flours.

The crude fibre content of the raw sample was 3.56% and that of the processed samples which ranged between 3.18 and 3.46% was significantly ($p<0.05$) lower in boiled and blanched flours compared to the samples processed by autoclaving (3.23%) and roasting (3.46%) treatments. The result showed that the crude fibre content of the processed flours was generally lower than that of the raw sample which recorded the highest (3.56%) value. The decrease in the crude fibre contents of boiled and blanched samples is in agreement with the findings of Onuoha *et al.*(2017) who reported that boiling and blanching generally reduced the crude fibrecontents of legumes. The observed trend in this study could be due to the softening and subsequent loss of hardcoat of some of the seeds during the boiling and blanching processes. Fibre has been credited for the promotion of increasedexcretionof bile acids, sterols and fats which have been implicated in the etiology of certain ailments in humans (Okaka*et al.*,2006). Some of the crude fibres are hydrophilic and so, they help to maintain the moist and soft condition of faecal mass which facilitates easy passage of it through the large bowel or large intestine.

The carbohydrate content of the samples varied from 62.90% for the raw sample to 71.89% (roasted), 73.19% (autoclaved), 75.00% blanched and 76.98% (boiled), respectively. Thermal processing resulted in carbohydrate values that were significantly ($p<0.05$) different. Boiling and blanching of African yam bean seeds during processing significantly ($p<0.05$) increased the carbohydrate content compared to the roasting and autoclaving treatments which drastically decreased the carbohydrate contents of the roasted and autoclaved flour samples. The relatively low carbohydrate values recorded by the roasted and autoclaved African yam bean flours could be attributed to reduction in solubilization and breakdown of some carbohydrate components into carbonic acid and carbon dioxide by roasting and autoclaving treatments during processing (Obasi and Wogu, 2008).

The energy content of the samples varied from 350.57kj/100g for the raw sample to 368.18, 368.50, 365.91 and 366.52kJ/100g for the samples processed by boiling, blanching, roasting and autoclaving treatments, respectively. There were significant ($p < 0.05$) differences in the energy contents of raw and processed flour samples. Boiling and blanching of African yam bean seeds during processing caused significant ($p< 0.05$) increase in the energy values of the samples than the raw, roasted and autoclaved flour samples which had the energy values of 350.57, 365.91 and 366.52kj/100g, respectively. The lower energy values of roasted and autoclaved African yam bean flours compared to the boiled and blanched flour samples may be due reduction in their carbohydrate contents and volatility of energy related nutrients like fat during processing as a result of roasting and autoclaving treatments. The observation is in agreement with the report of Ahamefule and Odoemelam (2006) for roasted and autoclaved *CanavalisPlagiosperma* seed flours. Generally, boiling, blanching, roasting and autoclaving treatments greatly reduced the crude protein, fat, ash and crude fibre contents of the flours with slight increase in their carbohydrate and energy contents compared to the raw sample.

Functional Properties of Raw and Processed African yam bean flour Samples

The functional properties of raw and processed African yam bean flour samples are presented in Table 2.

The bulk density of the samples ranged from 0.43g/ml in autoclaved African yam bean flour to 0.68g/ml in the raw flour sample. There were significant ($p<0.05$) differences in the bulk densities of the African yam bean flour samples. The raw sample had the highest bulk density (0.68g/ml), while the least bulk density (0.43g/ml) was recorded for the sample processed by autoclaving. The result showed that boiling and autoclaving could be used to prepare low bulk density African yam bean flours than roasting and blanching treatments. Bulk density is dependent on the factors such as method of measurement, particle size of the sample, structure of the starch polymers, solid density and surface properties of the molecules and could be improved when the particles are small, compactible, properly tapped or vibrated and when suitable packaging material is used (Plaami,1997; Akubor, 2017). The low bulk density also helps to reduce transportation and storage costs. The reduction in bulk densities of processed African yam bean flours observed in this study would be an advantage in the use of the flours for the preparation of supplementary foods. It is also a good indication that the flours could be used for food formulations with less fear of retrogradation.

The raw African yam bean flour had relatively high-water absorption capacity (0.76%) and that of the processed flour samples ranged from 0.48 to 0.68%. The study showed that there were significant ($p<0.05$) differences in the water absorption capacities of the flour samples. The boiled sample had the lowest water absorption capacity (0.48%), while the sample processed by roasting had the highest water absorption capacity (0.68%) followed by autoclaved African yam bean flour which had the water absorption capacity value of 0.66%. The chemical components that enhance water absorption capacity of the flours are proteins and carbohydrates because they contain hydrophilic parts such as polar or charged side chains (Lawal and Adebowale, 2004). The dissociation of African yam bean flour protein into subunits by roasting and autoclaving may have occurred during processing. This may have unmasked the polar residues from the interior of the protein molecules, which lead to increase in water absorption capacities of the roasted and autoclaved African yam bean flours. The boiled sample had the least water absorption capacity due to the fact that the seeds had absorbed much water during boiling. The roasted African yam bean flour had the highest water absorption capacity due to the loss of water during the roasting process. The increase in water absorption capacity due to roasting could also be attributed to the heat dissociation of proteins, gelatinization of starch in the flour and the swelling of crude fibre (Adegunwa*et al.*, 2014). The ability to absorb water is a very important property of all the flours used in food preparations. Water absorption capacity is a measure of the strength of starch inter granular bond. Low water absorption capacity could be attributed to light association, while high water absorption capacity is an indication of a loose association of native starch polymers or low lipid content (Adebowale *et al*., 2008). Water absorption capacity describes the water association ability of the flour under limited water supply. Flours with good water absorption capacities would be useful in the preparation of bakery products in which hydration is needed to improve handling features (Oppong *et al*., 2015; Eze *et al.*, 2024).

The oil absorption capacity of the flour samples was lowest (0.45%) in boiled African yam bean flour and highest in the raw flour sample (1.57%). The result revealed that all the treatments decreased the oil absorption capacity compared to the raw sample with boiling exerting greater effect. According to Chinma*et al.*(2009), more hydrophobic proteins have superior binding capacity to lipids and this indicates that non-polar amino acid chains bind more readily to paraffin chain of fats. Based on this suggestion, it could be said that the raw African yam bean flour which recorded higher oil absorption capacity had more available non-polar side chains in its protein molecules than the other processed flour samples. Oil absorption capacity is a measure of the ability of the flour to absorb fat. The flours and other ingredients with high oil absorption capacity play important role in stabilizing food systems with high fat content and can also act as emulsifiers (Akubor, 2017). The ability to absorb oil is a very important property of all the flours used in the preparation of foods. The ability of foods to absorb oil may also help to enhance the sensory properties such as flavour retention and mouth feel of such food products.

The swelling capacity of the raw sample was (2.72%) and that of the processed flour samples ranged from 2.32 to 2.67%. The study showed that all the treatments significantly ($p<0.05$) reduced the swelling capacity with the boiling exerting greater effect. The reduction in the swelling capacities of the processed flours could be due to processing effects caused by dextrinisation of starch molecules which were degraded and in turn reduced their ability to absorb water (Akubor, 2017). The extent of swelling depends primarily on the temperature, availability of water, species of starch and other carbohydrates and proteins. Swelling capacity is the ability of the flour to absorb water and hold it in the swollen flour granules (Arukwe*et al*., 2017). The flours that have good swelling capacities would be suitable for use in thickening of the soups, stews and sauces.

The emulsification capacity of the processed flour samples ranged from 1.27 to 1.54% and that of the raw sample was 2.69%. The result showed that all the treatments caused a significant ($p<0.05$) decrease in the emulsification capacity with the boiling having greater effect followed by blanching, autoclaving and roasting treatments. Emulsification capacity is a measure of the maximum amount of oil emulsified by protein in a given amount of flour. The efficiency of emulsification varies with the type of protein, its concentration, pH, ionic strength, viscosity of the system, temperature and method of preparation, the rate of oil addition, sugars and moisture content (Adegunwa*et al*., 2012; Nwodo and Okoye, 2023). Proteins with high emulsifying ability are desirable for use in the preparation of salad dressings and sausages. The emulsification properties of protein containing products like legumes may result from both soluble and insoluble proteins, as well as other components such as polysaccharides. Protein can emulsify and stabilize the emulsion by decreasing the surface tension of the oil droplet and providing electrostatic repulsion on the surface of the oil droplet (Sikorski, 2002; Adegunwa*et al*., 2014). In addition, some types of polysaccharides can also help to stabilize the emulsion by increasing the viscosity of the system. The low emulsification capacity of the African yam bean flours suggests that they are not suitable for use in the preparation of sausages and in stabilizing colloidal food systems.

The foam capacity of the raw flour sample was 1.86% and that of the processedsamples ranged between 1.43 and 1.72% for boiled and autoclaved African yam bean flours, respectively. Foams can be produced by whipping air into liquid as fast as possible (Sikorski, 2002). The reason why flours are capable of producing foams is that proteins in the flours are surface active. Soluble proteins can reduce surface tension at the interface between the air bubbles and surrounded liquid. Thus, the coalescence of the bubbles is obtained. In addition, protein molecules can unfold and interact with one another to form multilayer protein film with an increased flexibility at the air liquid interface. As a result, it is more difficult for air bubbles to break, and the foams are more stabilized (Adebowale *et al.*, 2012). Foamability is related to the rate of decrease of the surface tension of the water interface caused by the absorption of protein molecules. It is also a function of the type of protein, pH and processing methods (Akubor, 2017). The processing methods employed in this study may have increased the surface tension of the protein molecules which in turn reduced the foamability of the flours. Foams are used to improve texture, consistency and appearance of foods. The low foaming properties of both raw and processed African yam bean flours suggest that they may not be suitable for use in the preparation of akara balls in Nigeria. However, the raw and autoclaved African yam bean flours may find application in bakery and confectionery products. Generally, roasting and autoclaving improved the functional properties of African yam bean flour than boiling and blanching treatments.

Pasting Properties of Raw and Processed African yam bean Flour Samples.

The pasting properties of raw and processed African yam bean flour samples are presented in Table 3.

The peak viscosity of the processed samples ranged from 47.33 to 68.22 RVU and that of the raw sample was 73.99 RVU.The peak viscosity which is the maximum viscosity developed during the pasting profile was highest (73.99 RVU) in raw African yam bean flour and lowest(47.33RVU) in boiled flour sample. There were significant ($p<0.05$) differences in the peak viscosities of the flour samples. The control sample (raw flour sample) which had a peak viscosity value of 73.99 RVU showed significant ($p<0.05$) difference from those of the boiled (47.33 RVU), autoclaved (53.24 RVU), roasted (64.83 RVU) and blanched (68.22 RVU) African yam bean flours, respectively.Peak viscosity indicates the water holding capacity of the starch and is often correlated with the final product quality. As the temperature increased during processing, the starch granules of the flours swell and increase the viscosity of the paste until the peak value is reached. The peak viscosity of the samples increased with the level of the starch in the flour samples(Owuamanam*et al.*, 2014;Adegunwa*et al*., 2014). The result showed that all the treatments employed during processing significantly($p<0.05$) reduced the peak viscosity of the processed African yam bean flours compared to the raw sample which had the highest peak viscosity value of 73.99 RVU.The result is in agreement with the report of Arukwe*et al*. (2017)who stated that the low peak viscosities observed in the boiled,autoclaved, roasted and blanched African yam bean flours are beneficial nutritionally in the formulation of infant foods.

The trough viscosity of the raw sample was 62.32RVU and that the processed samples ranged between 24.94 and 55.73RVU. The least trough viscosity (24.94RVU) was recorded in the boiled sample, while the highest value (62.32RVU) was recorded in the raw sample. The trough viscosity values varied significantly ($p<0.05$) among all the flour samples. During the holding period of a typical pasting test, the sample is subjected to a period of constant temperature of 95℃ and mechanical shear for a certain period of time. This further disrupts the starch granules and the amylose molecules generally leach out into the solution and align in the direction of the shear (Chinma *et al.*, 2009). The period is sometimes called shear thinning, hot paste viscosity, holding strength, paste stability or trough due to the breakdown in viscosity which accompanied it. Trough viscosity is the minimum viscosity value in the constant temperature phase of the RVA profile. It measures the ability of paste to withstand breakdown during cooling (Oluwamukomi and Jolayemi, 2012). Boiling drastically reduced the trough viscosity than the autoclaving, roasting and blanching treatments. Generally, all the treatments employed reduced the trough viscosity of African yam bean flours. Hence, the boiled (24.94RVU), autoclaved (32.22RVU), roasted (44.27RVU) and blanched (55.73RVU) flour samples which had low trough viscosity values compared to the trough viscosity value of the raw sample (62.32 RVU) could be said to have better hot paste stability than the raw sample. However, the low trough viscosity values of the processed African yam bean flours would make them useful in processes that require stable paste with low retrogradation tendency, such as filler in meat industry.

The breakdown viscosity of the processed African yam bean flour ranged from 31.25 to 51.83RVU and that of the raw sample was 67.95 RVU.There were significant ($p<0.05$) differences in the breakdown viscosities of the African yam bean flour samples. The highest breakdown viscosity (67.95RVU) was recorded in the raw flour sample, while the sample processed by boiling had the least (31.25RVU) breakdown viscosity. Boiling and autoclaving drastically reduced the breakdown viscosity of the samples than the roasting and blanching treatments. At the breakdown, the swollen starch granules disrupt further and the amylose molecules leach out into the solution (Ragaee and Abdel-Aal, 2006; Shimelis *et al.,* 2006). Higher values of breakdown viscosities are associated with high peak viscosities which in turn are related to the degree of swelling of the starch granules.

The setback viscosity of the raw flour sample was 53.22RVU and that of the processed flour samples ranged from 21.55 to 49.48RVU with the boiled sample having the lowest value(21.55RVU)followed by the autoclaved(27.55RVU), roasted(41.44RVU)and blanched(47.48RVU) samples, respectively. There were significant ($p<0.05$) differences in the setback viscosities among all the African yam bean flour samples. Setback viscosity is an index of the retrogradation of linear starch molecules during cooling. The setback viscosity is usually the difference between the final viscosity and trough viscosity of the RVA profile. The higher the setback viscosity, the lower the retrogradation of the viscous paste during cooling and the lower the staling rate of the product made from the flour (Sanni and Eniola, 2004; Adegunwa*et al*.,2014).Setback viscosity has been correlated with the textural characteristics of the food products (Mckenna and Lyng, 2003).

The final viscosity of the raw African yam bean flour was 70.61 RVU and that of the processed flour samples ranged 34.45 and 68.06RVU.The result showed that all the treatments reduced the final viscosity of the samples. There were significant ($p<0.05$) differences in the final viscosities among all the African yam bean flour samples. The lowest final viscosity(34.45RVU)was recorded in the boiled flour sample which also differ significantly($p< 0.05$) from the values recorded in samples processed by autoclaving(43.35 RVU),roasting(57.95 RVU)and blanching (68.06 RVU) methods, respectively compared to the raw sample which had the final viscosity value of 70.61 RVU. This implied that the blanched and raw African yam bean flours which had the highest final viscosity values(68.06RVU) and (70.61RVU) would be less stable after cooling, while the boiled, autoclaved and roasted samples with the lowest final viscosity values would be more stable after cooling. The final viscosity is the viscosity obtained at the end of the pasting test.It is commonly used to define the quality of a particular starch-based flour since it indicates the ability of the flour to form a viscous paste or gel after cooking and cooling. It also gives a measure of the resistance of paste to shear force during stirring (Shimels*et al*., 2006; Adebowale *et al*.,2008). Pasting characteristic is highly dependent on the amylose and amylopectin ratio of the starch component. Information on the pasting profile of the flours has been used to correlate the functionality of starchy ingredients in processes such as baking and extrusion cooking (Alozie *et al*., 2009; Alozie and Chinma, 2015).

The peak time of the processed African yam bean flours ranged from 4.18 to 5.69 min and that of the raw sample was 6.05 min. It was observed from the result that the peak time of the flour samples was significantly ($p<0.05$) reduced by all the treatments employed during processing. The raw African yam bean flour had the highest peak time value (6.05 min), while the boiled sample had the lowest (4.18min) peak time value followed by the autoclaved (4.75min), roasted (5.25min) and blanched (5.69min) African yam bean flours, respectively. The result showed that the raw, roasted and blanched flour samples which had higher peak time values than the boiled and autoclaved samples would take longer time to form paste on cooking. Peak time is a measure of cooking time of the flour sample (Oluwamukomi and Jolayemi, 2012). Arukwe*et al. (*2017) stated that the flours with higher peak time values would not cook faster and require much heating to form paste than those with lower peak time values. The observation is in agreement with the report of Adegunwa*et al.* (2014) for boiled, autoclaved and roasted bambara groundnut flours. Peak time indicates the total time taken by a flour sample to attain its peak viscosity and the lower the peak time, the faster the cooking time (Usman *et al*., 2016). Generally, the boiled and autoclaved African yam bean flours which had relatively lower peak time values than the roasted and blanched samples would cook faster and require less heating to form paste during cooking.

The pasting temperature of the raw African yam bean was 84.34^{0}C and that of the processed samples ranged from 70.75 to 80.94 ^{0}C. The least pasting temperature (70.75 ^{0}C)was obtained for the boiled flour sample followed by the samples processed by autoclaving (72.85^{0}C), roasting (77.45^{0}C) and blanching (80.94^{0}C) methods, respectively compared to the raw sample which had the highest pasting temperature value of 84.34^{0}C. The result showed that all the treatments employed reduced the pasting temperature of the samples. There were significant ($p<0.05$) differences in the pasting temperatures of all the samples. The pasting temperature values (70.75

– 80.94^{0}C) obtained in this study for the processed African yam bean flours were lower than the values (89.45 – 98.38^{0}C) reported by Owuamanam*et al*. (2014) for soaked and sprouted tropical legume flours. The pasting temperature provides an indication of the maximum temperature required to cook a given flour sample. The low pasting temperature values obtained for the boiled (70.75^{0}C) and autoclaved (72.85^{0}C) flour samples compared to the values of the roasted (77.45^{0}C) and blanched (80.94^{0}C) flours clearly showed that they would cook faster and save more fuel than the roasted and blanched flour samples.

CONCLUSION

The study showed that thermal processing greatly affected the proximate, functional and pasting properties of the processed African yam bean flour compared to the raw flour sample. The result showed that boiling and blanching treatments had greater effects in reducing the protein, fat, ash and crude fibre contents of the processed African yam bean flours with slight increase in their carbohydrate and energy contents than roasting and autoclaving processes when compared with the raw sample.The functional properties of the samples revealed that boiling and blanching treatments drastically reduced the bulk density, water absorption, oil absorption, swelling, emulsification and foam capacities of the processed flour samples than roasting and autoclaving techniques. However, the raw African yam bean flour had higher functional properties than the processed African yam bean flours. The pasting properties of the samples also showed that the peak, trough, breakdown, setback and final viscosities as well as the pasting time and pasting temperature of the samples processed by blanching and roasting treatments were higher than the values recorded by the boiled and autoclaved African yam bean flours compared to the raw flour sample which had the highest values in all the pasting properties evaluated in this study. Therefore, any of these heat treatment methods could be used to process African yam bean seeds into flour. However, since autoclaves might not be easily accessible to local or homemade processors of African yam bean flour, the widely used methods of boiling and roasting can be used without much difficulty.

Table 1: **Proximate composition (%) of raw and processed African yam bean flour samples.**

Parameters	Raw	Boiled	Blanched	Roasted	Autoclaved
Moisture	$11.24^{a} \pm 0.01$	$6.56^{b} \pm 0.01$	$6.43^{c} \pm 0.16$	$6.14^{e} \pm 0.01$	$6.22^{d} \pm 0.03$
Crude Protein	$14.37^{a} \pm 0.01$	$8.18^{e} \pm 0.01$	$10.15^{d} \pm 0.01$	$12.32^{b} \pm 0.04$	$11.33^{c} \pm 0.02$
Fat	$4.61^{a} \pm 0.01$	$3.06^{e} \pm 0.01$	$3.10^{d} \pm 0.04$	$3.23^{b} \pm 0.07$	$3.16^{c} \pm 0.01$
Ash	$3.32^{a} \pm 0.01$	$2.04^{e} \pm 0.01$	$2.12^{d} \pm 0.01$	$2.96^{b} \pm 0.05$	2.87^{c} ± 0-02
Crude Fibre	$3.56^{a} \pm 0.01$	$3.18^{e} \pm 0.01$	$3.20^{d} \pm 0.01$	$3.46^{b} \pm 0.01$	$3.23^{c} \pm 0.03$
Carbohydrate	$62.90^{e} \pm 0.01$	$76.98^{a} \pm 0.06$	$75.00^{b} \pm 0.02$	$71.89^{d} \pm 0.03$	$73.19^{c} \pm 0.26$

Energy (KJ/100g)	350.57^{e}± 0.08	368.18^{b} ± 0.02	368.50^{a} ± 0.47	365.91^{d} ± 1.79	366.52^{c} ± 0.23

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

Table 2: Functional properties of raw and processed African yam bean flour samples.

Parameters	Raw	Boiled	Blanched	Roasted	Autoclaved
Bulk Density (mg/ml)	0.68^{a}± 0.00	0.47^{c} ±0.01	0.56^{b}± 0.41	0.51^{b}± 0.01	0.43^{d} ± 0.00
Water Absorption Capacity (%)	0.76^{c}±0.01	0.48^{d} ±0.01	0.54^{c} ±0.02	0.68^{b} ± 0.00	0.66^{b} ± 0.02
Oil Absorption Capacity (%)	1.57^{a} ±0.07	0.45^{e} ±0.01	0.64 ^{d} ±0.01	1.28^{c} ±0.01	1.33^{b} ±0.01
Swelling Capacity (%)	2.72^{a} ±0.02	2.32^{e} ±0.01	2.67^{b} ±0.01	2.62^{c} ±0.02	2.57^{d} ±0.01
Emulsification Capacity	2.69^{a} ±0.021	1.27^{e} ±0.01	1.44^{d} ± 0.03	1.54^{b} ± 0.00	1.48^{c} ±0.01
Foam Capacity (%)	1.86^{a} ±0.00	1.43^{e} ±0.07	1.45^{d} ± 0.00	1.67^{c} ±0.01	1.72^{b} ±0.01

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

Table 3: Pasting properties of raw and processed African yam bean flour samples

Parameters	Raw	Boiled	Autoclaved	Roasted	Blanched
Peak Viscosity (RVU)	73.99^{a}±0.47	47.33^{e}±0.01	53.24^{d}±0.02	64.83^{c}±0.55	68.22^{b}±0.94
Trough Viscosity (RVU)	62.32^{a} ±0.01	24.94^{e} ±0.39	32.22^{d} ±0.01	44.27^{c} ±1.49	55.73^{b} ±0.68
Breakdown Viscosity (RVU)	67.95^{a} ±0.31	31.25^{e} ±0.01	35.10^{d} ±0.31	46.00^{c} ±1.08	51.83^{b} ±0.86
Setback Viscosity (RVU)	53.22^{a} ±0.56	21.55^{e} ±0.02	27.55^{d} ±0.02	41.44^{c} ±0.71	49.48^{b} ±0.54
Final Viscosity (RVU)	70.61^{a} ±0.00	34.45^{e} ±0.01	43.35^{d} ±0.02	57.95^{c} ±0.00	68.06^{b} ±0.01
Peak Time (Min)	6.05^{a} ±0.00	4.18^{e} ±0.01	4.75^{d} ±0.02	5.25^{c} ±0.00	5.69^{b} ±0.01
Pasting Temp. (^{o}C)	84.34^{a} ±0.01	70.75^{e} ±0.55	72.85^{d} ±0.52	77.45^{c} ±1.11	80.94^{b} ±0.55

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

REFERENCES

AACC (2000). *Approved Methods of Analysis*. *American Association of Cereal Chemists*. 10^{th}edn St. Paul Publishers New York. *Pp 214-218*.

Adebowale, A. A., Sanni, S.A. and Oladapo, F. O. (2008). Chemical, functional and sensory properties of yam – bread fruit flour. *Nigerian Food Journal; 26: 2 – 12.*

Adebowale, A.A., Fetuga G.O., Apata C.B. and Sanni, L.O. (2012). Effect of variety and initial moisture content on physical properties of improved millet grain. *Nigerian Food Journal*; *30:5-10*. 1-101. 27-28.

Adebowale, K. O. and Lawal, O. S. (2003). Foaming, gelation and electrophoretic characteristics of *Mucuna bean* (*Mucuna pruriens*) protein concentrate. *FoodChemistry*; 83: 237-247.

Adegunwa, M.O., Adebowale, A. A., Bakare, H. A. and Kalejaiye, K.K. (2014). Effects of treatments on the anti-nutritional factors and functional properties of bambara groundnut

(*Vigna subterranean*) flour. *Journal of Food Processing and Preservation; 38: 1875 – 1881.*

Adegunwa, M.O., Adebowale, A.A. and Solana, E.O. (2012). Effect of thermal processing on the biochemical composition, anti-nutritional factors and functional properties of beniseed (*Sesamum indicum*) flour. *American Journal of Biochemistry and Molecular Biology; 2: 175 – 182.*

Adeyemi, I.A and Beckley, O. (1986). Effect of period of maize fermentation and sourcing on chemical properties and amylograph pasting viscosity of ogi. *Journal of Cereal Science; 4:353-360.*

Ahamefule, F. O. (2005). Evaluation of pigeon pea – cassava based diets for goat production in southeastern Nigeria. A Ph.D. Thesis, Department of Animal Science, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria. *Pp. 78 – 86.*

Ahamefule, F. O. and Odoemelam, V. U. (2006). Effect of de-hulling on proximate composition, antinutritional properties and mineral content of *Canavalisplagiosperma* seeds. *Tropical Journal of Animal Science*; *9(2): 35 – 43*.

Ahamefule, F. O. and Odoemelam, V. U. (2008). Effect of soaking duration on the proximate composition, gross energy, mineral content and some antinutritional properties of *Anaralisplagosperma* seeds. *Proceedings of the 13th Annual Conference of the Animal Science Association of Nigeria, ABU Zaria, Nigeria.Pp. 491 – 494.*

Akinmutimi, A. H. (2007). Effect of cooking period on the nutrient composition of velvet beans (*Mucunapruriens*). *Proceedings of the 32nd Annual Conference of the Nigerian Society of Animal Production. University of Calabar, Nigeria.Pp. 223 – 226.*

Akubor, P. I. (2017). Effect of processing methods on the chemical composition and functional properties of pigeon pea seed. *Innovare Journal of Food Science; 5(4): 16 – 19.*

Alozie, Y. E. and Chinma, C.E. (2015). Proximate composition, physical and sensory properties of cake prepared from wheat and cocoyam flour blends. *Journal of Food Research; 4(5): 181 – 188.*

Alozie, Y.E., Udofia, S., Lawal. O. and Ani, I. F. (2009). Nutrient composition and sensory properties of cakes made from wheat and African yam bean flour blends. *Journal of Food Technology; 7: 115 – 118.*

Anya, M. I. and Ozung, P.O. (2019). Proximate, mineral and anti-nutritional compositions of raw and processed African yam bean (*Sphenostylisstenocarpa*) seeds in Cross River State, Nigeria. *Global Journal of Agricultural Sciences, 18: 19-29.*

AOAC. (2010). *Official Methods of Analysis.Association of Analytical Chemists*. 18th edn Washington D.C. U.S.A Pp 200-523.

Arawande, J.C and Borokini, F.B. (2010). Comparative study on chemical composition and functional properties of three Nigerian legumes (jack beans, pigeon pea and cowpea). *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS); 1 (1): 89-95.*

Arukwe, D. C., Nwanekezi, E.C. and Agomuo, J.K. (2017). Effect of combined processing methods on the functional and pasting properties of pigeon pea (*Cajanuscajan*) flour. *International Journal of Science and Qualitative Analysis; 3(3): 23-30.*

Asoiro, F. U. and Ani, A. O. (2011). Determination of some physical properties of African yam bean. *Pacific Journal of Science and Technology;* 12 (1): 374 – 380.

Azeke, M.A., Fretzdoff, B., Beuning, C., Pfaue, W., Holfzapfel, W. and Betsche. T. (2005). Nutritional value of African yam bean (Sphenostylisstenocarpa): improvement by lactic acid fermentation. *Journal of the Science of Food and Agriculture; 85(6): 963-970.*

Carew, I. B., Hardy, D. Weis, J., Aletor, F., Mischler, S. A., Gernant, A. and Zakrzewska, E. I. (2003). Heating raw velvet bean (*Mucunapruriens*) reverses some anti-nutritional factors: effect on organ growth, blood chemistry and organ histology on growing chicken. *Tropical and Sub-Tropical Agroecoystems, 1:267-295*.

Chinma, C.E., Adewuyi, O. and Abu, O. J. (2009). Effect of germination on the chemical, functional and pasting properties of flours from brown and yellow varieties of tiger nut (*Cyperusesculentus*). *Food Research international; 42: 1104-1109.*

Chinwendu, J. N. Obiakor, O., Philomena, N. and Maduforo, A. N. (2014). Effect of fermentation on the nutrient and antinutrient composition of African yam bean (*Sphenostylisstenocarpa*) seeds and pearl millet (*Pennisetum glaucum*) grains. *International Journal of Science and Technology; 2(12): 169-178.*

Elais, L. G., Fernandez, D. and Bressani, R. (2010). Possible effect of seed coat polyphenolics on the nutritional quality of bean protein. *Journal of Food Science*, 49 (1): 43 – 52.

Eze, S. I., Okoye, J. I. and Onwuama, N. N. (2024). Effect of germination time on the properties of flours from red and brown varieties of pigeon pea (*Cajanus cajan*) seeds. *International Journal of Biochemistry Research and Review*; 33(3): *49-62*.

Jacob, A. G., Etong, D. I. and Tijjani, A. (2015). Proximate, mineral and anti-nutritional compositions of melon (*Citrullus lanatus*) seeds. *British Journal of Research; 2(5): 142-151*.

Lawal, O. S. and Adebowale, K. O. (2004). Effect of acetylation and succinylation on solubility profile, water absorption capacity, oil absorption capacity and emulsifying properties of *Mucuna bean* (*Mucuna pruriens)* protein concentrate. *Nahrung Food,48: 129 – 136.*

Liday, C. A. (2013). Protin from land plants as potential resources for human nutrient and food security. *Trend in Food Science and Technology;32: 25 – 42.*

Mbah, B. O. Eme, P. E. and Ogbusu, O. F. (2012). Effect of cooking methods (boiling and roasting) on the nutrient and antinutrient contents of *Moringa oleifera seeds. Pakistan Journal of Nutrition; 11(3): 211 – 215.*

McKenna, B. M. and Lyng, J. C. (2003). *Texture in Food. In: Introduction to Food Rheology and its Measurement*. Booksgoogle.com. pp. 2-3. Retrieved 10 Aug 2014.

Ndidi,U. S., Ndidi, C. U., Olagunju, A., Muhammad,A., Graham Billy, F and Okpe, O (2014). Proximate, antinutrients and mineral composition of raw and processed (boiled and roasted) (*Sphenostylisstenocarpa*) seeds from southern Kaduna, northwest Nigeria. *Journal of Food Science and Nutrition;* 12 (3): 9-14.

NRC. (2006). Lost crops of Africa. Volume II: Vegetables. The National Academic Press, Washington, DC, USA. Pp. 44-45.

Nsa, E. E. (2008). Chemical and biological assay of castor oil meal (*Ricnus communis*) as an alternative nutrient source in pullet bird's diets. A Ph.D. Thesis, Department of Animal

Nutrition and Forage, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. *Pp. 73 – 79.*

Nsa, E. E. and Ukachukwu, S. N. (2009). Effect of thermal processing methods on the proximate composition, gross energy, minerals and ricin content of undecorticated castor oil seed (*Ricinus communis*). *Global Journal of Agricultural Sciences; 8(2): 223 -227.*

Nwodo, J. I. and Okoye, J. I. (2023). Effect of soybean flour addition on the proximate composition, functional pasting properties of soy-poundo yam flour. Research Journal of Food Science and Quality Control; 9 (3): 63 – 77.

Obasi, N. E. and Wogu, C. O. (2008). Effect of soaking time on proximate and mineral compositions and anti-nutritional factors of yellow maize (*Zea mays*). *Nigerian food Journal;*26(2):47738-47739.

Okaka, J. C., Akobundu, E. N. T. and Okaka, A. N. T. (2006). *Food and Human Nutrition. An Integrated Approach,*Ocjano Academic Publishers, Enugu, Nigeria. *Pp. 373-386.*

Oluwamukomi, M.O. and Jolayemi, O. S. (2012). Physicothermal and pasting properties of soy – melon enriched 'garri' semolina from cassava. *International Journal of Agriculture and Engineering (CIGR); 14(3): 105-110.*

Onuoha, C.H., Harry B.J. and Eze S.O, (2017). Evaluation of nutrient and anti- nutritional factors of different species of African yam bean (*Sphenostylisstenocarpa*). *European Journal of Basic and Applied Sciences. 4(1): 2059-3058.*

Onwuka, G.I (2005). *Food Analysis and Instrumentation; Theory and Practice*. Naphthali publishers Ltd, Lagos, Nigeria. Pp. 95-96.

Onyeike, E.N. and Omubo-Dede, T.T. (2002). Effect of heat treatment on proximate composition, energy values, and level of some toxicants in African yam bean (*Stenostylisstenocarpa*) seeds varieties. *Plant Foods for Human Nutrition*; *57: 223-231*.

Oppong, D., Arthur, E., Kwadwo, S. O., Badu, E. and Sakyi, P. (2015). Proximate composition and some functional properties of soft wheat flour. *International Journal of Innovative Research, Science and Engineering Technology; 4: 753–758.*

Oraka, C. O. and Okoye, J. I. (2017).Effect of heat processing treatments on the nutrient and anti-nutrient contents and functional properties of lima bean (*Phaseolus lunatus*) flour. *International Journal of Food Science and Nutrition; 2(3): 13-17.*

Owuamanam, C. I., Ogueke, C. and Edom, T. (2014). Use of seed sprouting in modification of food nutrients and pasting profile of tropical legume flours. *Nigerian Food Journal; 32(1): 117-`25.*

Plaami, S.P. (1997). Content of dietary fibre in foods and its physiological effects. *Food Research International;13: 29-76.*

Ragaee, S. and Abdel-Aal, E.M. (2006). Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chemistry; 95:9-18.*

Sanni, S.A. and Eniola, S.A. (2004). Sensory characteristics of plantain-wheat biscuits. In: G.O. Adegoke, L.O., Sanni, K.O., Falade, J. and Uzo-Peters, P.I. (eds). *Proceedings of the 28th Annual Conference of theNigerian Institute of Food Science and Technology, University of Ibadan, Ibadan, Nigeria. Pp. 152-153.*

Sherkani, K., Singh, N., Kaur, A. and Rana, J. C. (2015). Structural and functional characterization of kidney bean and field pea protein isolates: a comparative study, *Food Hydrocolloids; 43: 679 – 689.*

Shimelis, A. E., Meaza, M. and Rakshif, S. (2006). Physicochemical properties, pasting behaviour and characteristics of flour and starch from improved bean (*Phaesolus vulgaris*) varieties grown in east Africa; IGRE; *8: 1 -18.*

Sikorshi, Z. E. (2002). *Proteins.* In: Chemical and Functional Properties of Food Components (Z. E. Sikorski eds). CRC Press Inc. Boca Raton, Florida. *Pp. 138 – 178.*

SPSS (2008). Statistical package for Social Sciences (SPSS) version SPSS 16.0, SPSS Inc., Chicago, IL., USA.

Uche, S. N., Charity, U. N., Abbas, O., Aliyu, M., Francis, G. and Oche, O. (2014). Proximate, vitamin and mineral compositions of raw and processed (boiled and roasted *Sphenostylisstenocarpa*) seeds from southern Kaduna northwest, Nigeria. *International Scholarly Research Notices; 20(4): 280 – 287.*

Ukachukwu, S. N. and Obioha, F. C. (2000). Effect of time duration of thermal treatments on the nutritive value of *Mucuna cochinchinensis. Global Journal of Pure and Applied Sciences;* 6(1): 11-15.

Usman, M. A., Bolade, M. K. and James, S. (2016). Functional properties of weaning food blends from selected sorghum (*Sorghum bicolor(L*) *Moench*) varieties and soybean (*Glycine max*). *African Journal of Food Science*; *10 (8): 112 – 121*.