PHYTOCHEMICAL COMPOSITION AND FUNCTIONAL PROPERTIES OF FLOUR PRODUCED FROM TWO VARIETIES OF TIGERNUT (*Cyperus esculentus*)

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Abstract: Two varieties of tigernut (black and brown) were purchased from a local market in Wukari, Taraba State, Nigeria. The nuts werecleaned, washed, drained, dried (50°C) and milled into flour. The samples were analysed for phytochemical composition and functional properties using standard methods. The brown variety had higher values of moisture (4.10%), fat (28.0%) and energy (575.6 kcal/100g) while the black variety is relatively richer in ash (3.0%), protein (4.58%) and carbohydrate (70.32%). The black variety had a relatively higher phytate (0.22 mg/g), tannin (0.91mg/g), saponin (0.17 mg/g), oxalate (0.001 mg/g) while the brown variety had higher values of polyphenols (1.25 mg/g), flavonoid (1.04 mg/g) and alkaloid (4.75%). The black variety had higher bulk density (0.462 g/ml), loose density (0.71 g/ml), water absorption capacity (0.82 ml/g) and, swelling capacity (2.86 g/g). Therefore, the two varieties of tigernut considered in this study have great potential for utilization in food processing and formulation.

Keywords: Tigernut, flour, variety, functional, phytochemical.

Introduction

The search for lesser known and underutilized crops,many of which are potentially valuable as human and animal foods has been intensified to maintain a balance between population growth and agricultural productivity, particularly in the tropical and sub-tropical areas of the world (Enujuigba and Akanbi, 2005). The worsening food crisis and the consequent wide spread prevalence of malnutrition in developing and underdeveloped countries have resulted in high mortality and morbidity rates, especially among infants and children in low income groups (Enujuigba and Akanbi, 2005).

Tigernut (*Cyperus esculentus*) is an underutilized sedge of the family *Cyperaceae* which produces rhizomesfrom the base and tubers that are somewhat spherical (Cortes *et al*., 2005). The plant is not really a nut but a tuber first discovered some 4000 years ago (Lowe and Whitewell, 2000). It has other names like yellow nutsedge, chufa, flatsedge, rush nut, water grass, earth almond, northern nut grass and nut grass (Lowe and Whitewell, 2000). Tigernut (*Cyperus esculentus*) is known in Nigeria as *aya* in Hausa, *ofio* in Yoruba and *akihausa* in Igbo. Tigernut (*Cyperus esculentus*) was reported as healthy and helps in preventing heart diseases, thrombosis and activates blood circulation. It helps in preventing cancer, due to high content of soluble glucose. It was also found to assist in reducing the risk of colon cancer (Adejuyitan *et al*., 2009). The nut is rich in energy content (starch, fat, sugars and protein), mineral (phosphorus, potassium) and vitamins E and C (Belewu & Belewu, 2007). Tigernut (*Cyperus esculentus*) is suitable for diabetic persons and also helps in losing weight (Borges *et al*., 2008). Tigernut flour has a unique sweet taste, which is ideal for different uses. It is a good alternative to many other flours like wheat flour, as it is gluten free and good for people who cannot take gluten in their diets. It is also used in the confectionery industry (Belewu & Abodunrin, 2006). It is considered good flour or additive for the bakery industry, as its natural sugar content is fairly high, avoiding the necessity of adding too much extra sugar (Anderson *et al*., 1994).

Tigernut *(Cyperus esculentus)* grows mainly in the middle belt and northern regions of Nigeria (Okafor *et al*., 2003), where three varieties (black, brown and yellow) are cultivated (Umerie *et al.*, 1997). Among these, only two varieties, yellow and brown are readily available in the market. The yellow variety is preferred to all other varieties because of its inherent properties such as bigger size, attractive colour and fleshier body (Belewu and Abodurin, 2006).

Food contains various compositions of nutrients and phytochemical and could have important or deleterious effects in the body when consumed. The composition of the nutrients and phytochemical, usually leads to side effects found in most plants which may lead to excessive weight gain, constipation, allergies, diarrhoea, (Anonymous, 2009). For a food to be considered safe for human and animal health, its effect on these parameters need to be investigated to understand the nutritional potentials and safety of such foods with a view to determining their acceptability. This work therefore aimed at determining the chemical composition, phytochemical and functional propertiesof two varieties of tigernut flour in order to be able to explore its potentials in food formulation.

Materials and Methods

Sample preparation

The two varieties of tiger nut used (black and brown) were obtained from a local market in Wukari, Taraba State, Nigeria. The nuts were cleaned, washed, drained, dried in an oven and ground into flour. The flour samples were sieved (45 µm mesh size). The black and brown tigernut flour were packaged in medium density polyethylene (ZipLock) bags, labeled black (BRF) and brown (BKF) and stored at 14°C until required for use.

Sample analyses

Proximate composition and energy

AOAC (2005) methods were used to determine moisture, protein, fat, crude fibre and ash contents while carbohydrate wascalculated by difference. Total energy value (in cal/g) of each sample was calculated by multiplying the carbohydrate, fat and protein contents with their physiological fuel values (4, 9, 4 kcal, respectively).

Functional properties

Water and oil absorption capacities

Water and oil absorption capacities of the flour samples weredetermined by Beuchat (1977) methods. One gram of the flour wasmixed with 10 ml of water or oil in a centrifuge tube and allowed tostand at room temperature (37 ± 2°C) for 1 h. It was then centrifugedat 200 x g for 30 min. The volume of water or oil on the sedimentwater measured. Water and oil absorption capacities werecalculated as ml of water or oil absorbed per gram of flour.

Foam capacity and foam stability

The method described by Narayana and Narasinga (1982) wasused for the determination of foaming capacity (FC) and foam stability (FS). Two grams of flour sample was added to 50 ml distilled waterat 30 ± 2°C in a 100 ml measuring cylinder. The suspension wasmixed and properly shaken to foam and the volume of the foamafter 30 s was recorded. The forming capacity was expressed as a percentageincrease in volume. The foam volume was recorded 1 h after whippingto determine the foam stability as a percentage of the initial foam volume.

Bulk density

A 50 g flour sample was put into a 100 ml measuring cylinder. Thecylinder was tapped continuously until a constant volume was obtained.The bulk density (g cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3) (Okaka and Potter, 1979).

Swelling capacity

This was determined with the method described by Narayana and Narasinga (1982) with modification for small samples. One gram of the floursample was mixed with 10 ml distilled water in a centrifuge tube andheated to 80°C and held for 30 min. This was continually shaken during theheating period. After heating, the suspension was centrifuged at1000 x g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as: swellingpower = weight of the paste/weight of dry flour.

Determination of phytochemical composition

Determination of alkaloid

Determination of alkaloid was made by the method described by Harborne (1973). The alkaloid content was determined gravimetrically. Five grams of the sample was weighed and dispersed in 10% acetic acid solution in ethanol to form a ratio of 1:10 (10%). The mixture was allowed to stand for 4 h at 28°C. It was later filtered using Whatman No. 42 grade of filter paper. The filtrate was concentrated to one quarter of its original volume by evaporation and treated with drop wise addition of concentrated aqueous NH_4OH until the alkaloid was precipitated. The alkaloid precipitated in a weighed filter paper was washed with 1% ammonia solution, and dried in the oven at 80°C. Alkaloid content was calculated and expressed as a percentage of the weight of sample analyzed.

Determination of saponin

The spectrophotometric method was used for saponin analysis as described by Brunner (1984). One gram of the flour sample was weighed into a 250-mL beaker and 100 mL iso-butyl alcohol was added. The mixture was shaken on a shaker (UDY Corporation, Fort Collins, CO) for 5 h to ensure uniform mixing. The mixture was filtered through a Whatman No. 1 filter paper into a 100-mL beaker and 20 mL of 40% saturated solution of magnesium carbonate was added. The mixture obtained was further filtered through a Whatman No. 1 filter paper to obtain a clear colourless solution. One milliliter of the colorless solution was homogenized into a 50-mL volumetric flask and 2 mL of 5% $FeCl_3$ solution was added and made up to mark with distilled water and allowed to stand for 30 min for blood red color to develop. Standard saponin solutions (0–10 ppm) were prepared from saponin stock solution and treated with 2 mL of 5% FeCl solution as done for experimental samples. The absorbance of the sample as well as standard saponin solutions were read after color development on a Spectronic 2lD spectrophotometer (Milton Roy, Houston, TX) at a wavelength of 380 nm. The percentage saponin was also calculated.

Determination of total phenolic compounds

The samples (100 g) were extracted, by stirring with methanol 250 mL for 3 h. The extracted samples were then filtered through Whatman No. 1 filter paper, the residue was washed with 100 mL methanol, and the extracts were cooled. The extracts were evaporated to dryness under vacuum, using a rotary evaporator. The residues were dissolved with 10 mL of methanol and used for determination of total phenolic compounds. This determination was performed as gallic acid equivalents (mg/100g), by using Folin- Ciocalteau phenol reagent. The diluted methanol extracts (0.2 mL) were added, with 0.8 mL of Folin- Ciocalteau phenol reagent and 2.0 mL of sodium carbonate (7.5%), in the given order. The mixtures were vigorously vortex-mixed and diluted to 7 mL of deionized water. The reaction was allowed to complete for 2 h in the dark, at room temperature, prior to being centrifuged for 5 min at 125 g. The supernatant was measured at 756 nm on a spectrophotometer. Methanol was applied as a control, by replacing the sample. Gallic acid was used as a standard and the results were calculated as gallic acid equivalents (mg/100 g) of the sample. The reaction was conducted in triplicate and the results were averaged (Brunner, 1984).

Determination of total flavonoid

This was also determined according to the method outlined by Harborne (1973). Five grams of the sample was boiled in 50 mL of 2 mol/L HCl solution for 30 min under reflux. The contents were allowed to cool and then filtered through a Whatman No. 42 filter paper. A measured volume of the extract was treated with equal volume of ethyl acetate starting with a drop. The flavonoid precipitated was recovered by filtration using weighed filter paper. The resulting weight difference gave the weight of flavonoid in the sample.

Determination of tannin content

Tannin content of the flour samples was determined using the methods described by Harborne (1973). The sample (0.2 g) was measured in a 50-mL beaker; 20 mL of 50% methanol was added, covered with homogenizer, placed in a water bath at 77–80°C for 1 h, and the contents stirred with a glass rod to prevent lumping. The mixture was filtered using a double-layered Whatman No. 1 filter paper into a 100-mL volumetric flask using 50% methanol to rinse. This was made up to mark with distilled water and thoroughly mixed. One milliliter of the sample extract was homogenized into a 50-mL volumetric flask, and 20 mL

distilled water, 2.5 mL Folin-Denis reagent, and 10 mL of 17% Na_2CO_3 were added and mixed. The mixture was made up to mark with distilled water, thoroughly mixed, and allowed to stand for 20 min when a bluish-green coloration developed. Standard tannic acid solutions in the range of 0–10 ppm were treated similarly as the 1 mL sample above. The absorbances of the tannic acid standard solutions as well as samples were read after color development on a Spectronic 21D spectrophotometer at a wave length of 760 nm. Percentage tannin was calculated.

Determination of phytic acid

An indirect colorimetric method of Harborne (1973) was used for phytate determination. This method depends on an iron to phosphorus ratio of 4:6. A quantity of 5 g of the test sample was extracted with 3% trichloro acetic acid. The phytate was precipitated as ferric phytate and converted to ferric hydroxide and soluble sodium phytate by adding sodium hydroxide. The precipitate was dissolved in hot 3.2 N HNO and the color read immediately at 480 nm. The standard solution was prepared from Fe $(NO_3)_3$ and the iron content was extrapolated from a $Fe(NO)_3$ standard curve. The phytate concentration was calculated from the iron results assuming a 4:6 iron:phosphorus molecular ratio.

Determination of oxalate content

Oxalate was determined by AOAC (2005) method. One gram of the sample was weighed in a 100-mL conical flask. Seventy-five milliliters of 3 mol/L H_2SO_4 was added and the solution was stirred intermittently with a magnetic stirrer for about 1 h and then filtered using Whatman No. 1 filter paper. The sample filtrate (extract) (25 mL) was collected and titrated against hot (80–90°C) 0.1 N $KMnO_4$ solution to the point when a faint pink color appeared that persisted for at least 30 s. The concentration of oxalate in each sample was obtained from the calculation: 1 mL 0.1 permanganate = 0.006303 g oxalate.

Sensory analysis

Sensory evaluation was performed on the products by twenty-member untrained sensory panelists randomly selected. A 9-point hedonic scale was used in scoring the products (Ijarotimi and Keshinro, 2012) so as to help determine the degree of acceptability in terms of mouth feel/texture, appearance, flavour, over all acceptability.

Results and Discussion

Proximate composition

Percentage moisture, fat and proteinvalues of black and brown varieties of tigernut are presented in Fig. 1. The proximate composition of food is a major index of nutritious potentials of food crops. The brown variety had higher values of moisture (4.10%), fat (28.0%) while the black variety is relatively richer in ash (3.0) and protein (4.58%). Moisture content, ash and protein obtained for both samples were close to valuesobtained for soybean and tigernut flour blends reported by Emmanuel-Ikpeme *et al*. (2012). The low moisture of both samples would have a positive effect on shelf stability. Result obtained for fat content of the brown variety corroborated earlier value of 24.3% reported by Ekeayanwu and Ononogbu (2010). Fat is important in diet because it promotes absorption of fat and soluble vitamins (Bogert *et al*., 1994).

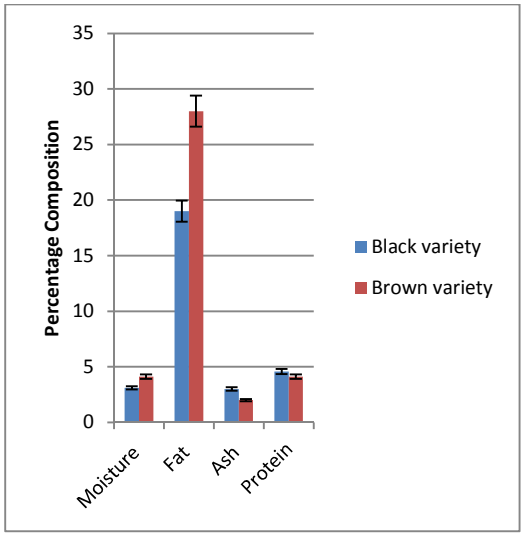

Fig. 1: Proximate composition of black and brown varieties of tigernut

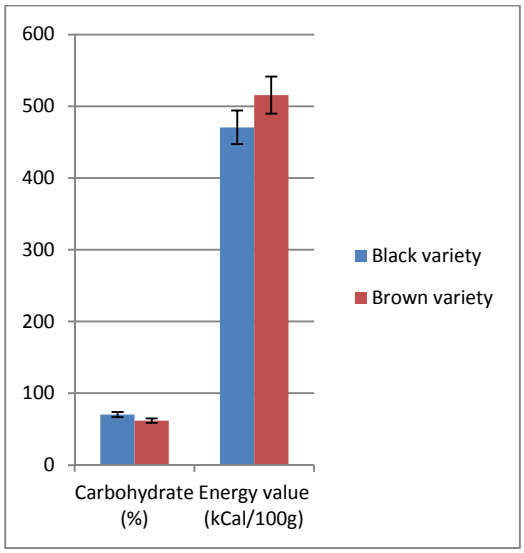

Fig. 2: Carbohydrate content and energy values of black and brown variety of tigernut

Fig 2 shows the percentage composition of carbohydrate (61.78-70.32%) and energy values (470.6 -515.6 kcal) of black and brown varieties of tigernut. The black variety had a higher carbohydrate composition of 70.32% whilethe brown variety had a higher energy content of 515.6 kcal/100g. The calorific value of the two varieties-black and brown tigernut (470.6 and 515.6 kcal, respectively) showed that it could be a reliable source of energy and can thus provide a large portion of the daily requirement of 2,500 – 3,000 kilocalories (Ekeanyanwu and Ononogbu 2010) for adults if large quantities are consumed as it usually the case in the northern Nigeria. Carbohydrate composition and energy values obtained for both samples differ from those reported for yellow variety of tigernut by Oladele and Aina (2007) which could be due to relatively low moisture level (3.10-4.10%) of the samples under study. The ash content of the two varieties(3.0 and 2.0%) were within the range of 1. 5-2.5 recommended by Pomeranz and Clifton (1981) and

Ekeanyanwu and Ononogbu (2010). The black and brown tiger nut gave a relatively high level of fiber (12.3 and 13.5%, respectively). The existence of a casual relationship between the absence of fiber in diet and the incidence of wide range of diseases in man; notably diabetes, mellitus, obesity and coronary. Heat disease has long been reported (Eastwood 1974; Mendelhoff 1978; Ekeanyanwu and Ononogbu, 2010).

Phytochemical composition

Phytochemical composition of black and brown varieties of tigernut is presented in Fig. 3. Phytate, tannin, polyphenols, flavonoid, saponin, oxalate and alkaloid content of the black and brown variety of tiger nut are 0.22 and 0.16 mg/g, 0.91 and 0.53 mg/g, 1.07 and 1.25 mg/g, 0.88 and 1.04 mg/g, 0.17 and 0.006 mg/g, 0.003 and 0.0023 mg/g, 3.7 and 4.75%, respectively.The black variety is relatively richer in phytate (0.22 mg/g), tannin (0.91 mg/g), saponin (0.17 mg/g) and oxalate (0.003 mg/g), while the brown variety had higher values of phenol (1.25 mg/g), flavonoid (1.04 mg/g) and alkaloid (4.75%) contents. Values obtained for tannins, phytates and oxalate for both samples were lower than 2.37 mg/100g, 21.42 mg/100g and 13.12 mg/100g, respectively reported by Oladele *et al.* (2009). However, values obtained for polyphenols and alkaloids were higher than values reported by the same authors. Saponin contents of both samples were lower than the value reported by Ekeanyanwu and Ononogbu (2010). Alkaloids, saponins and tannins are known to have antimicrobial activity, as well as other physiological activities (Sofowara 1993, Evans 2005), Some have been used either as an analgesic, antispasmodic, bactericidal agents (Frantisek, 1991).

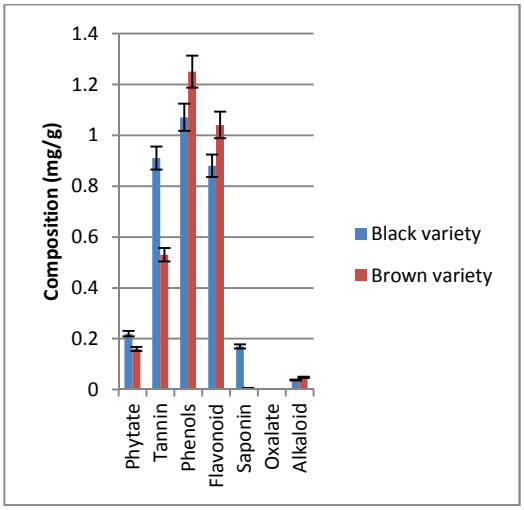

Fig. 3: Phytochemical composition of black and brown varieties of tigernut

Saponins have been reported to be useful in reducing inflammation of upper respiratory passage and also chiefly as foaming and emulsifying agents and detergent (Frantisek, 1991). Tanin compounds have antimicrobial activities and are responsible for preventing and treating urinary tracts infections and other bacterial infections (Ekeanyanwu *et al.*, 2010).The result of the determination of phytochemical test indicated that the tuber possess some biologically active compounds which could serve as potential source of vegetable drugs in herbal medicine (Ekeanyanwu *et al.*, 2010). Due to inherent high polyphenolic and alkaloids contents, both black and brown varieties of tigernut should be subjected to processing. Oladele *et al.* (2009) reported reduction in phytates, tannin, polyphenols, oxalate and alkaloid contents of processed tigernut.

Functional Properties

Bulk density (packed), loose density, oil absorption capacity, water absorption capacity, swelling capacity, swelling index and least concentration for gelation of black and brown varieties of tiger nut as presented in Fig. 4 are 0.463 and 0.439 g/ml; 0.71 and 0.614 g/ml; 0.46 and 0.62 ml/g; 0.82 and 0.73 ml/g; 2.86 and 2.14 g/g; 0.36 and 0.36; and 0.2 and 0.22. The black variety is relatively higher in bulk density, loose density, water absorption capacity and swelling power than the brown variety.Values obtained for loose and packed densities were lower than 0.62 and 0.55 g/ml respectively reported for yellow variety by Oladele and Aina (2007).

Water absorption capacities of the samples were also lower than 1.26 ml/g reported for yellow variety by Oladele and Aina (2007). Water absorption capacity describes flour-water association ability under limited water supply. This result suggests that tigernut flour may find application in baked products e.g. biscuits. The relatively low oil absorption capacity shows that tigernut may be a lower flavour retainer than African yam bean (1.42 ml/g) flour (Eke and Akobundu (1993). The low oil absorption capacity of tigernut might be due to low hydrophobic proteins which show superior binding of lipids (Kinsella, 1976).

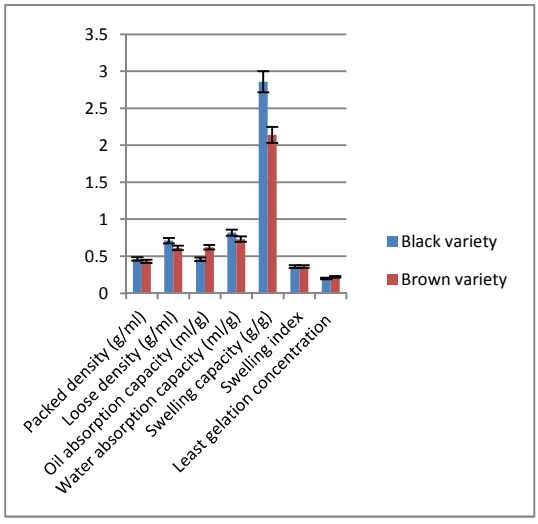

Fig. 4: Functional properties of black and brown varieties of tigernut

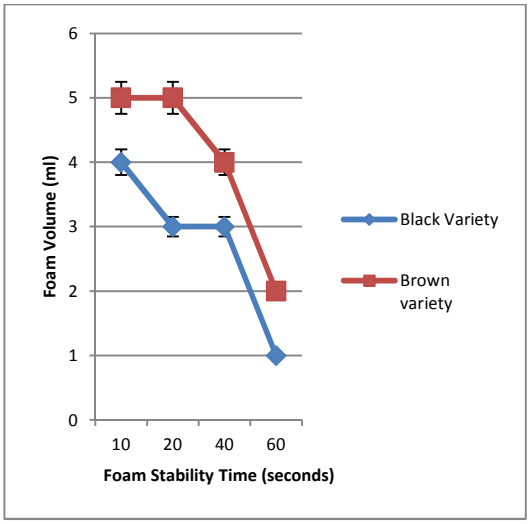

Fig. 5: Foam stability of black and brown varieties of tigernut

Fig. 5 shows the foam stability of black and brown varieties of tigernut at different time intervals (10, 20, 40 and 60 s). For both varieties, foam stability decreased with time. The brown variety had better foam stability at various times considered.Food materials with good foaming capacity and stability are useful in theformulation of aerated foods. Foam formation and stability are dependent onprotein type, pH, surface tension, viscosity and processing method (Eltayeb *et al*., 2011).

Conlusion

It is evident that the two varieties (brown and black) of tigernut considered in this study have great potential for utilization in food systems. It is a rich source of fat with moderate amount of protein. The low bulk density also suggests its application in infant food formulation.The phytochemical composition of tiger nut could be a potential in the production of antibodies and improvement of biological body systems of the consumer.

References

Adejuyitan JA, Otunola ET, Akande EA, Bolarinwa IF & Oladokun FM 2009. Some physicochemicalproperties of flour obtained from fermented tigernut (*Cyperus esculentus*) sourced from amarket in Ogbomoso, Nigeria. *Afr. J. Food Sci*., 3: 51-55.

Anderson JW, Smith BM & NJ Gustafson1994. Health benefits and practical aspects of high fibre diets. *Am. J. Clinical Nutr*. 59:1242S-1247S.

Anonymous 2009. Twenty nine (29) food side effects you may not know. http://www.Healthassist.net/food/sideeffects/side-effects.shtml. Retrieved August 16,
2009.

Association of Official Analytical Chemists (AOAC) 2005. *Official Methods of Analysis*. Association of Official Chemists, 15th Edn., Washington DC. Associationof Official Analytical Chemists, pp. 10-30.

Belewu, MA, OA. Abodunrin, 2006.Preparation ofkuunu from unexploited rich food source, Tigernut (*Cyperus esculentus*). *World J. Dairy & Food Sci.*, 1: 19-21.

Belewu MA, Belewu KY2007.Preparation of Kunnu from unexploited rich food source: Tiger nut (Cyperus esculentus). *Pak. J. Nutr*. 7: 109-111.

Beuchat LR 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. *J. Agric. Food Chem.*, 25: 258 – 261.

Bogert JL, Briggs GM & Galloway DH 1994. Nutrition and physical fitness, *Int. J. Food Sci. Nutri.*, 45: 223-230.

Cortes C, Esteve M, Frigola A & Torregrosa F 2005. Quality characteristics of horchata (a Spanish vegetable beverage) treated with pulsed electric fields during shelf life. *Food Chem.*, 9(12): 319-325.

Eke OS & Akobundu ENT 1993. Functional properties of African yam bean seed flour as affected by processing. *Food Chem.*, 48: 337-340.

Ekeanyawu RC & Ononogbu CI 2010. Nutritive value of Nigerian tigernut. *Agric. J.*, 5(5): 297-302.

Ekeanyanwu RC, Njoku O & Ononogbu IC 2010. The phytochemical composistion and some bichemical effects of Nigerian tiger nut tuber. *Pak. J. Nutri.*, 9(7): 709-715.

Eltayeb ARSM, Ali OA, Abou-Arab AA & Abu-Salem FM 2011. Chemical composition andfunctional properties of flour and protein isolate extracted from bambara groundnut (*Vigna subterranean*). *African J. Food Sci.*, 5(2);, 82-90.

Emmanuel-Ikpeme CA, Ekpeyoung IO & Igile GO 2012. Chemical and protein quality of soybean (*Glycine max*) and tigernut (*Cyperus esculentus*). *World J. Dairy & Food Sci.*, 1(1): 19-21.

Enujuigha VN & Akanbi CT 2005. Composition changes in African oil bean (*Pentaclethra macrophylla* Benth) seeds during thermal processing. *Pak. J. Nutr.*, 4: 27-31.

Eastwood MA 1974. Dietry fiber in human nutrition. *J. Sci. Food Agric.*, 29: 1523-1527.

Evans NS 2005. *Trease and Evans Pharmocognosy*. 15th Edn., Elsevier, India, pp. 1-24.

Harborne JB 1973. Phenolic compounds. In: *Phytochemical Methods*. A guide to modern techniques on plant analysis. Chapman and Hall Ltd, London, pp. 33-88.

Frantiset SS 1991.The natural guide to medicinal herbs and plants. Tiger Bark Cast. Twinkemhan, United Kingdom, pp. 1-5.

Ijarotimi OS Keshinro OO 2012. Formulation and nutritional quality of infant formula produced from germinated popcorn, bambara groundnut and african locust bean
flour. *J. Microbio., Biotech. & Food Sci.*, 1(6): 1358-1388.

Lowe DB & Whitewell T 2000. Yellow nutsedge (*Cyperus esculentus*) management and tuber reduction in Bermuda grass turf with selected herbicide programmes. *Weed Tech.*, 14: 72-76.

Kinsella JE 1976. Functional properties of protein foods. Crit., Rev. Sci., Nutri., 1: 219-229

Mendelhoff AL 1978. Dietry fibre and gastrointestinal disease: some facts and fancies. *Med. Clin. North Ame.*, 62:165-171.

Pomeranz A & Clifton D 1981. *Food Analysis Theory and Practices*. AVI Publishing Co. Westport LT, p. 17.

Narayana K & Narasinga MS 1982. Functional properties of raw and heat processed winged bean flour. *J. Food Sci.*, 47: 1534-1538.

Ocheme BO, Adedeji OE, Lawal G & Zakari UM 2015. Effect of germination on functional properties and

degree of starch gelatinization of sorghum flour. *J. Food Res.*, 4(2): 159-165.

Okafor JNC, Mordi JI, Ozumba AU, Solomon HM & Olatunji O 2003. Preliminary studies on the characterization of contaminants in tigernut. In: *Proceedings of 27th Annual Conference of Nigerian Institute of Food Science and Technology*, 13th – 17thOctober, 2003, pp. 210-211.

Okaka JC & Potter NN1979. Physicochemical and functional propertiesof cowpea powders processed to reduce beany flavour. *J. Food Sci*., 44: 1235-1240.

Oladele AK & Aina JO 2007. Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). *African J. Biotech.*, 6(21): 2473-2476.

Oladele KA, Osundahunsi FO & Adebowale AY 2009. Influence of processing techniques on the nutrients and antinutrients of tigernut. *World J. Dairy & Food Sci.*, 4(2): 88-93.

Sofowora EA 1993. Medicinal plants and traditional medicine in Africa. Ibadan, Oweri –Kaduna-Lagos, Specrum Books Ltd, pp. 159-238.

Umerie SC, Okafor EP & Uka AS 199. Evaluation of the tubers and oil of *Cyperus esculentus. Bioresource Tech.*, 61: 171-173.