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Chemical composition and functional properties of Sorghum-African yam bean flour blends

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The proximate composition, mineral content and functional properties of sorghum and African yam bean flour blends were investigated. The sorghum flour (SF) was blended with African yam bean flour (AYBF) in the ratios of 90:10, 80:20, 70:30, 60:40 and 50:50 (SF: AYBF), respectively. The flour blends obtained were analyzed for proximate composition, mineral content and physical qualities using standard methods. The proximate composition of the blends showed that the protein content of the samples increased steadily with increased substitution with African yam bean flour from 8.46% in 90:10 (SF: AYBF) to 14.76% in 50:50 (SF: AYBF) samples, while carbohydrate decreased. The mineral composition of the blends also showed that the phosphorus, potassium, iron and magnesium contents of the samples increased with increased supplementation with African yam bean flour while their calcium and zinc contents decreased. The physical properties of the blends showed that the samples had a range of bulk density, 0.94 - 0.98 g/ml, swelling capacity, 180.2-226.2%, oil absorption capacity, 6.84 - 8.86 ml/g, water absorption capacity, 13.27 -16.46 ml/g, foam capacity, 140.4 - 168.8% and viscosity, 10.2 - 16.8Cp, respectively. The proximate, mineral and functional properties observed suggested that the flour blends may be useful both as nutritional supplements and functional ingredients in the formulation of a variety of convenience baked products.

Key words: Proximate composition, mineral content, physical quality, supplementation, sorghum flour, African yam bean flour.

INTRODUCTION

Cereals and legumes are mainly used for the preparation of a wide range of complementary foods in Nigeria and other most developing countries of the world. Among cereals, sorghum (*Sorghum bicolor*) is considered to have better protein quality or amino acid scores (Okpala and Okoli, 2010). Sorghum grains like most other cereal grains have a low nutrient density because they are relatively high in unmodified starch and low in fat (Rooney and Waniska, 2004). Sorghum has a macromolecular composition similar to that of maize and wheat. However, sorghum contains resistant starch, which impairs its digestibility, notably for infants (Anglani, 1998). The presence of this resistant starch is desired in other applications to fight human obesity and to feed diabetic individuals. In addition, foods prepared from high tannin sorghum varieties have a longer passage in the stomach (Awika and Rooney, 2004). The substitution of cereal-based food products with inexpensive vegetable proteins derived from dietary staples such as legumes, nuts and oilseeds has greatly elicited the interest of nutritionists, food scientists and food product developers in Nigeria and other sub-Saharan African countries in recent times. This is because these grain legumes and oilseeds are relatively high in lysine, an essential amino acid deficient in most cereals (Achi, 2005). Legumes generally contain high amount of protein compared to other plant food stuffs. Legume proteins are mainly used in food formulations to complement for protein in cereal grains because of their chemical and nutritional characteristics (Okoye and Mazi, 2011). African yam

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bean (*Sphenostylis stenocarpa*) is one of the lesser known and underutilized edible grain legumes that are widely cultivated in Africa (Eke, 2002). Like most African indigenous grain legumes, African yam bean is one of the most important sources of protein, carbohydrate, crude fibre, vitamins and minerals (Enwere, 1998). The fortification of cereal-based diets with adequately processed African yam bean flour would help to enhance their protein content and quality. The objective of this study is to determine the proximate composition, mineral content and functional properties of sorghum and African yam bean flour blends.

MATERIALS AND METHODS

Mature white variety of sorghum (*Sorghum vulgare*) grains and African yam bean (*S. stenocarpa*) seeds used for the study were procured from Enugu Main Market, Enugu State, Nigeria.

Preparation of soaked sorghum flour

The soaked sorghum flour was prepared according to the method of Ihekoronye (1999). During preparation, one kilogram of sorghum grains which were free from dirt, damaged and contaminated grains were weighed, cleaned and soaked in 3 litres of potable water at room temperature (30 ± 2°C) for 96 h with occasional change of soak water at intervals of 18 h. The soaked grains were drained, rinsed and wet milled in a locally fabricated attrition mill with 2 litres of potable water into fine slurry. The slurry obtained was manually stirred continuously with a wooden stirrer for 5 min and sieved with a muslin cloth into a clean plastic bowl. The sieved slurry was transferred into a clean bag and allowed to drain at ambient temperature (30 ± 2°C) into a plastic bowl for 6 h after which the supernatant was decanted. The extracted slurry was manually dewatered, spread on the trays and dried in the tray dryer (Model HC 409G) at 60°C for 10 h. After that, the dried cake obtained was milled in the attrition mill and sieved through a 500 micron mesh sieve. The sorghum flour produced was packaged in an airtight plastic container for blending and analysis.

Preparation of boiled African yam bean flour

The boiled African yam bean flour was prepared according to the method of Eneche (2006). During preparation, one kilogram of African yam bean seeds which were free from dirt, damaged and contaminated seeds were weighed, cleaned and soaked in 3 litres of potable water containing 0.1% sodium metabisulphite solution ($Na_2S_20_5$) at room temperature (30 ± 2°C) for 12h. The soaked seeds were drained, rinsed and dehulled manually by rubbing in between palms. The dehulled seeds were boiled with 2 litres of potable water in an electrically heated pot at 100°C for 30 min. The boiled seeds were drained, spread on the trays and dried in the tray dryer (Model HC 409G) at 60°C for 8h. The dried seeds were milled in a locally fabricated attrition mill and sieved through a 500 micron mesh sieve. The African yam bean flour produced was packaged in an airtight plastic container for blending and analysis.

Flour blend formulation

The sorghum flour (SF) was blended with African yam bean flour (AYBF) in the ratios of 90:10, 80:20, 70:30, 60:40 and 50:50 in a Kenwood mixer (Model NX 908G, Kenwood, Britain, UK) to produce sorghum / African yam bean composite flours. The composite flours produced were packaged individually in an airtight plastic container for analysis.

Chemical analysis

The moisture, crude protein, fat, ash and crude fibre contents of the samples were determined in triplicate according to the method of AOAC (2006). Carbohydrate was determined by difference (Giami, 2005). The energy content of the blends was calculated from the proximate composition using the Atwater factor 4xprotein, 9x fat, 4 x carbohydrate (Okaka et al., 2002). The potassium and iron contents of the blends were determined after ashing by the use of a flame photometer (Model 405, Corning, UK) according to the method of Onwuka (2005). The calcium, magnesium and zinc contents of the samples were determined using atomic absorption spectrophotometer (Perkin-Elmer, Model 1033, Norwalk, CT, USA) according to the method of AOAC (2006). Phosphorus was determined by the Vanadomolybdate colorimetric method of Okpala and Okoli (2010).

Functional properties

The bulk density, oil absorption capacity and viscosity of the blends were determined in triplicate according to the method of Odo and Ishiwu (1999). Swelling capacity, water absorption and foam capacities were determined according to the method of Onwuka (2005).

Statistical analysis

The data obtained were subjected to Analysis of variance (ANOVA) using special package for social science (SPSS, version 20, 2013) to detect significant differences ($p < 0.05$) among the sample means. The Turkey's least

Table 1. Proximate composition of sorghum / african yam bean flour blends.

Samples	Moisture (%)	Crude Protein (%)	Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)	Energy (KJ/100g)
A	$9.68^{f}\pm0.28$	$7.84^{g}\pm1.18$	$0.82^{a}\pm0.04$	$0.64^{e}\pm0.05$	$1.66^{f}\pm0.08$	$81.05^{a}\pm0.10$	$362.94^{a}\pm2.82$
B	$12.36^{d}\pm1.22$	$16.84^{a}\pm1.56$	$0.88^{a}\pm0.02$	$2.06^{b}\pm0.10$	$5.04^{a}\pm1.04$	$67.84^{f}\pm0.44$	$346.64^{f}\pm1.36$
C	$11.26^{e}\pm0.18$	$8.46^{f}\pm0.16$	$0.84^{a}\pm0.02$	$0.68^{e}\pm0.05$	$2.64^{e}\pm0.07$	$78.72^{b}\pm0.90$	$356.26^{de}\pm2.63$
D	$12.74^{d}\pm0.99$	$9.68^{e}\pm0.28$	$0.88^{a}\pm0.04$	$1.24^{d}\pm0.11$	$3.22^{d}\pm0.34$	$75.46^{c}\pm1.39$	$357.48^{d}\pm2.68$
E	$13.64^{c}\pm0.35$	$10.82^{d}\pm0.64$	$0.86^{a}\pm0.04$	$1.86^{c}\pm0.12$	$3.88^{c}\pm0.14$	$72.82^{d}\pm1.72$	$359.84^{bc}\pm2.76$
F	$14.22^{b}\pm0.09$	$12.02^{c}\pm0.86$	$0.84^{a}\pm0.02$	$2.18^{b}\pm0.16$	$4.14^{b}\pm0.10$	$70.74^{e}\pm1.66$	$360.42^{b}\pm1.58$
G	$14.78^{a}\pm0.22$	$14.18^{b}\pm0.9$	$0.82^{a}\pm0.02$	$2.46^{a}\pm0.20$	$4.66^{a}\pm0.02$	$67.78^{f}\pm0.34$	$361.28^{a}\pm2.29$

Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

A – Composite flour made with 100% sorghum flour
B – Composite flour made with 100% African yam bean
C – Composite flour made with 90% sorghum flour and 10% African yam bean flour
D – Composite flour made with 80% sorghum flour and 20% African yam bean flour
E – Composite flour made with 70% sorghum flour and 30% African yam bean flour
F – Composite flour made with 60% sorghum flour and 40% African yam bean flour
G – Composite flour made with 50% sorghum flour and 50% African yam bean flour.

significant difference (LSD) test was used in separating significant means (Iwe, 2002).

RESULTS AND DISCUSSION

The proximate composition of sorghum / African yam bean flour blends are shown in Table 1. The moisture contents of sorghum and African yam bean flours were between 9.68 – 12.38 %, while the moisture content of the blends increased as the proportion of African yam bean flour increased. The moisture content of sorghum – African yam bean composite flours were comparable with the reports on moisture contents of kidney bean/wheat flour blends and moisture contents above 14 % are likely to affect the storage stability of the products (Akubor et al., 2000; Okoye and Mazi, 2011). The crude protein content of sorghum flour was the least, while the blends with African yam bean flour substitutions had higher protein contents. This showed that the addition of African yam bean flour resulted in increase in the protein content of the composite flours. This observation is not in doubt as African yam bean has been reported to be a good source of protein (Eneche, 2006; Nzelu, 2008). The fat content of the blends decreased as the proportion of African yam bean flour increased. This is in agreement with the reports (Ojukwu et al., 2012; Nwosu, 2013) that African yam bean has low oil content. The low fat content of the samples is an indication that they could be stored for a long period without the problem of peroxidation which is a major cause of fat instability (Tharanathan and Mahadevamma, 2003). The ash content of the samples increased significantly ($p \leq 0.05$) with increased level of African yam bean inclusion in the blends. Akpapunam and Darbe (1994) reported an increased in ash content of maize – bambara groundnut composite flours with increasing substitution of Bambara groundnut flour. The high ash content of the samples is an indication that they are good sources of minerals (Ogbonna et al., 2001). The fibre contents of the blends were within the recommended FAO/WHO (1994) level of not more than 5%. Fibre has been credited for promotion of increased excretion of bile acids, sterols and fat which have been implicated in the etiology of certain ailments in humans (Okaka et al., 2006). The carbohydrate content of the sorghum flour was the highest, while the blends had lower carbohydrate contents. This signified that the addition of African yam bean flour resulted in decrease in the carbohydrate content of the blends. Such decrease in carbohydrate with increase in kidney bean flour has been reported in kidney bean /wheat composite flours (Okoye and Mazi, 2011). The energy contents of sorghum and African yam bean flours were between 346.64 – 362.94 KJ/100g, while the energy values of the blends ranged from 356.25 to 361.28KJ/100g. The variation in the energy content of the samples could due to differences in their protein and carbohydrate contents (Enwere et al., 1990). Generally, the fortification of sorghum flour with adequately processed African yam bean flour at a level up to 50% greatly enhanced the protein, ash, crude fibre and energy contents of the blends which will in turn improve the nutrient density of the products made from them.

Table 2 shows the mineral composition of sorghum/African yam bean flour blends. The calcium contents of sorghum and African yam bean flours varied from 12.16 – 15.04 mg/100g, while the calcium content of the blends decreased significantly ($p \leq 0.05$) with

Table 2. Mineral composition of sorghum / african yam bean flour blends.

Samples	Calcium (mg/100g)	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Magnesium (mg/100g)
A	15.04^{a}±0.62	2.86^{d}±0.02	3.18^{d}±0.10	2.98^{e}±0.08	4.22^{a}±0.48	2.08^{c}±0.28
B	12.16^{b}±1.20	5.22^{a}±0.24	5.46^{a}±0.46	4.38^{a}±0.28	3.18^{cd}±0.08	4.88^{a}±0.52
C	11.20^{bc}±0.42	3.02^{cd}±0.01	4.38^{c}±0.06	3.12^{e}±0.06	3.65^{b}±0.03	3.27^{bc}±0.07
D	10.46^{c}±0.48	3.34^{c}±0.11	4.63^{bc}±0.01	3.52^{d}±0.04	3.49^{bc}±0.04	3.96^{ab}±0.14
E	10.32^{cd}±0.19	3.74^{c}±0.14	4.70^{b}±0.35	3.80^{cd}±0.03	3.32^{c}±0.08	3.97^{c}±0.21
F	9.86^{d}±0.39	4.06^{b}±0.09	4.74^{b}±0.03	3.98^{bc}±0.6	3.25^{c}±0.34	4.10^{a}±0.08
G	9.02^{e}±0.23	4.24^{b}±0.16	4.82^{ab}±0.57	4.08^{ab}±0.08	2.90^{d}±0.06	4.18^{a}±0.17

Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

A – Composite flour made with 100% sorghum flour
B – Composite flour made with 100% African yam bean
C – Composite flour made with 90% sorghum flour and 10% African yam bean flour
D – Composite flour made with 80% sorghum flour and 20% African yam bean flour
E – Composite flour made with 70% sorghum flour and 30% African yam bean flour
F – Composite flour made with 60% sorghum flour and 40% African yam bean flour
G – Composite flour made with 50% sorghum flour and 50% African yam bean flour.

increased supplementation with African yam bean flour. This observation showed that African yam bean is not a rich source of calcium (Adeparusi, 2001). Calcium plays significant roles in blood clothing and muscle contraction in humans (Abbey and Berezi, 1988). The phosphorus content of sorghum flour was the least, while that of the blends increased with increasing substitution with African yam bean flour. This showed that African yam bean flour had higher phosphorus content. This is in agreement with the report that African yam bean is a good source of phosphorus (Onyeike et al., 2001). Phosphorus helps in the formation of Adenosine Triphosphate (ATP) in the body (Okaka et al., 2002). The potassium content of the blends increased significantly ($p \leq 0.05$) with increased level of African yam bean flour in the blends. The result, however, indicates that African yam beans are good source of potassium (Eneche, 2006). Potassium is very essential in blood clothing and muscle contraction. The iron content of the samples ranged from 3.12 to 4.08 mg/100g with the blends containing 10 and 50 % African yam bean flour having the least and highest values, respectively. This is in line with the report that African yam bean has high iron content (Ene-Obong and Obizoba, 1996). Iron is an important component of heamoglobin which is an oxygen–carrying pigment in the blood (Okaka et al., 2006). The zinc content of the blends decreased significantly ($p \leq 0.05$) with increased supplementation with African yam bean flour. The result, however, indicates that African yam beans are not good source of zinc (Enwere, 1998). Zinc acts as an activator of many enzyme systems in humans (Apata and Ologhobo, 1994). The magnesium content of sorghum flour was the lowest, while that of the blends increased significantly ($p \leq 0.05$) as the proportion of African yam bean flour increased. This is in line with the report that African yam bean is a rich source of magnesium (Obatolu et al., 2007). Magnesium helps in the maintenance of electrical potential in nerves (Okaka et al., 2006). In effect, the substitution of sorghum flour with African yam bean flour at a level up to 50% drastically improved the phosphorus, potassium, iron and magnesium contents of the blends.

Table 3 shows the functional properties of sorghum / African yam bean flour blends. The bulk density of the blends showed no significant ($p \geq 0.05$) variation between the samples. The values obtained in this study were higher than the values (0.97-0.92 g/ml) reported by Okoye et al. (2007) for cornstarch/soybean flour blends. The high bulk density of the blends indicates that they can be used extensively in the preparation of confectionery products. The swelling capacity of the samples ranged from 180.2 to 226.2%. The variation in the swelling capacity of the blends could be attributed to differences in the amylase and amylopectin contents of their starch (Banigo and Akpapunam, 1987). The excellent swelling capacity of the composite flours suggests that they may be useful in the preparation of sources, soups and gravies. The oil absorption capacity of the blends showed significant ($p \leq 0.05$) difference between the samples. The values obtained in this study were similar to that (6.78 – 8.76 ml/g) reported by Hugo et al. (2003) for fermented sorghum/wheat composite flours. Flours with excellent oil absorption capacity will be useful in the preparation of pastries and piecrust mixes. The water absorption capacity of the samples ranged from 13.27 to 16.46 ml/g. The differences could be due to the destruction of the matrix of macromolecules which have the ability to entrap large amount of water during processing (Chen and Lin, 2002). The high water absorption capacity of the blends will be an advantage in the preparation of pastries and

Table 3. Functional Properties of Sorghum / African yam bean flour blends.

Samples	Bulk Density (g/ml)	Swelling Capacity (%)	Oil absorption capacity (ml/g)	Water absorption capacity (ml/g)	Foam capacity (%)	Viscosity (Cp)
A	0.98^{a}±0.12	180. 2^{e}±1.68	6. 48^{d}±0.29	13. 72^{e}±0.18	140.4^{e}±1.22	10.2^{d}±0.42
B	0.96^{a}±0.11	188.4^{d}±1.74	7.24^{c}±0.33	13.84^{d}±0.22	148.2^{d}±1.26	12.4^{c}±0.13
C	0.94^{a}±0.09	196.4^{c}±1.96	7.26^{c}±0.36	14.46^{c}±0.16	154.6^{c}±1.30	14.6^{b}±0.16
D	0.94^{a}±0.10	202.6^{b}±2.10	8.34^{b}±0.62	15.28^{b}±0.19	162.2^{b}±1.33	14.4^{b}±0.16
E	0.96^{a}±0.11	226.2^{a}±2.18	8.86^{a}±0.68	16.46^{a}±0.21	168.8^{a}±1.38	16.8^{a}±0.21

Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

A – Composite flour made with 90% sorghum flour and 10% African yam bean flour, B – Composite flour made with 80% sorghum flour and 20% African yam bean flour, C – Composite flour made with 70% sorghum flour and 30% African yam bean flour, D – Composite flour made with 60% sorghum flour and 40% African yam bean flour, E – Composite flour made with 50% sorghum flour and 50% African yam bean flour.

sausages. The foam capacity of the blends differed significantly ($p \leq 0.05$) from each other. The result, however, is in agreement with the report of Thaoge et al. (2003) for fermented pearl millet flour. Flours with good foam capacity will be useful in the preparation of whipped creams and salad dressings. The viscosity of the blends ranged from 10.2 to 16.8Cp with the samples fortified with 10 and 50% African yam bean flour having the least and highest values, respectively. The high viscosity recorded by the blends could be due to the breakdown of the structural networks of their protein and starch as a result of heat during processing (Aboubacar and Hamaker, 1999). The high viscosity of the flours will make them perform excellently as gelling and stabilizing agents in the preparation of chopping and deserts. Generally, the excellent functional properties exhibited by the blends revealed that they can be used as functional ingredients in the formulation of a wide range of food products.

Conclusion

The study showed that the nutrient content and functional properties of sorghum flour can be drastically improved by supplementing the flour with adequately processed African yam bean flour. The observation from the study also revealed that the protein, ash, crude fibre, phosphorus, potassium, iron and magnesium contents of the composite blends increased gradually with increased supplementation with African yam bean flour. Furthermore, the study equally showed that sorghum / African yam bean composite flours have the potential to be used both as nutritional supplements and functional ingredients in the preparation of a number of snacks and other convenience food products.

REFERENCES

Abbey BW, Berezi PE (1988). Influence of processing on the digestibility of African yam bean (*Sphenostylis stenocarpa*) flour. Nutrition Reports International 32: 819-827.

Aboubacar A, Hamaker BR (1999). Physico-chemical properties of flours that related to sorghum viscous quality. J. Cereal Chem. 76: 308-313.

Achi OK (2005). The potential for upgrading traditional fermented foods through biotechnology. Afr. J. Biotechnol. 4: 375 – 380.

Adeparusi EO (2001). Effect of processing on some minerals, anti-nutrients and nutritional composition of African yam bean (*Sphenostylis stenocarpa*). J. Sustainable Agric. And Environ., 3: 101 – 108.

Akpapunam MA, Darbe JW (1994). Chemical composition and functional properties of maize and bambara groundnut flour blends for cookie production. Plant Foods for Human Nutr., 46: 147 – 155.

Anglani C (1998). Sorghum for human food: a review. Plant Foods for Human Nutr., 52: 85 – 89.

AOAC (2006). Official Methods of Analysis. Association of Official Analytical Chemists. 18th edn. Washington D.C. pp. 216 – 246.

Apata DF, Ologhobo AD (1994). Biochemical evaluation of some Nigerian legume seeds. J. Food Chem., 49: 333 – 338.

Awika JM, Rooney LW (2004). Sorghum phytochemical and their potential aspects on human health. Phytochem. 65: 1199 – 1221.

Banigo EB, Akpapunam MA (1987). Physico-chemical and nutritional evaluation of protein-enriched fermented maize flour. Nigerian J. Food Sci. Technol., 5: 30 – 36.

Chen LA, Lin CS (2002). Sensory characteristics of sorghum composite bread. International J. Food Sc. Technol., 35: 465 – 471.

Eke OS (2002). Effects of malting on the dehulling characteristics of African yam bean (*Sphenostylis stenocarpa*) seeds and the functional properties of the flour. J. Food Sci. Technol., 39(40): 466 – 409.

Eneche HE (2006). Production and evaluation of cakes from African yam bean and wheat flour blends. Proceedings of the Nigerian Institute of Food Science and Technology. Pp. 46 – 47.

Enwere NJ (1998). Foods of Plant Origin. Afro-Obis Publications Ltd, Nsukka, Nigeria. pp. 78 – 96.

Enwere NJ, Hung YC, Ngoddy PO (1990). Texture and Microstructure of African yam bean (*Sphenostylis stenocarpa*) products. J. Textural Studies. 21: 377 – 394.

Giami SY (2005). Compositional and nutritional properties of selected newly developed lines of cowpea (*Vigna unguiculata L. (Warp*) flour. J. Food Comp. Anal. 18: 665 – 673.

Hugo IF, Rooney LW, Taylor JRN (2003). Fermented sorghum as a functional ingredient in composite bread. J. Cereal Chem., 80: 495 – 499.

Ihekoronye AI (1999). Manual of small-scale food processing. Macmillian Publishers Ltd, London and New York. pp. 108 – 176.

Iwe MO (2002). Handbook of Sensory Methods and Analysis. Rojoint Communication Services Ltd, Enugu, Nigeria. pp. 70 – 78.

Nwosu JN (2013). Evaluation of proximate composition and nutritional properties of African yam bean (*Sphenostylis stenocarpa*) using malting treatment. Int. J. Basic and Appl. Sci., 2(4): 157 – 169.

Obatolu VA, Fasoyiro SB, Ogunsunmi IO (2007). Processing and functional properties of African yam bean (*Sphenostylis stenocarpa*).

J. Food Proc. Preservation. 31: 240 – 249.
Odo FO, Ishiwu CN (1999). Experimental procedure for food and water analysis. Amazing Grace Publishing Company Ltd, Enugu, Nigeria. Pp. 56 – 66.
Ogbonna DN, Sokari TG, Achinewhu SC (2001). Development of an Owoh type product from African yam bean (*Sphenostylis stenocarpa*) by solid substrate fermentation. Plant Foods for Human Nutr., 56: 183 – 194.
Ojukwu M, Olawuni IA, Ibeabuchi C, Amandikwa C (2012). Physical, proximate and functional properties of "Nsamu" a local variety of African yam bean (*Sphenostylis stenocarpa*) grown in Southern states in Nigeria. Afr. J. Food Sci. and Technol., 3(10): 260 – 267.
Okaka JC, Akobundu ENT, Okaka ANC (2002). Human Nutrition: An Integrated Approach. 2nd Edn. Ocjanco Academic Publishers, Enugu, Nigeria. pp. 176 – 182.
Okaka JC, Akobundu ENT, Okaka ANC (2006). Food and Human Nutrition: An Integrated Approach. 3rd Edn. Ocjanco Academic Publishers, Enugu, Nigeria. pp. 132 – 142.
Okoye JI, Mazi EA (2011). Proximate composition and functional properties of kidney bean/wheat flour blends. ABSU J. Environ. Sci. Technol., 1: 113 – 118.
Okoye JI, Nkwocha AC, Ogbonnaya EA (2007). Functional and sensory properties of cornstarch/soybean flour blends. International J. Food and Agric. Res., 4(2) 263 – 270.
Okpala LC, Okoli EC (2010). Formulation and evaluation of cookies containing germinated pigeon pea, fermented sorghum and cocoyam flour blends using mixture surface methodology. Advance J. Food Sci. Technol., 3(5): 366 – 375.
Onwuka GI (2005). Food Analysis and Instrumentation: Theory and Practice. Naphthali Publishers Ltd, Lagos, Nigeria. pp. 90 – 96.
Rooney LW, Waniska RD (2004). Changes in the concentrations of the phenolic constituents of sorghum during malting and mashing. J. Sc. Food and Agric., 84: 752 – 758.
Thaoge ML, Adams MR, Sibara MM, Watson TG, Taylor JRN, Goyvaerts EM (2003). Production of improved infant porridges from pearl millet using a lactic acid fermentation step and addition of sorghum malt to reduce viscosity of porridges with high protein, energy and solids (30%) content. World J. Microbiol. Biotechnol., 19: 305 – 3010.
Tharanathan RN, Mahadevamma NC (2003). Grain Legumes – a boon to human nutrition. J. Food Sci. Technol., 14: 507 – 518.