academicJournals

Vol. 10(11) pp. 313-319, November 2016
DOI: 10.5897/AJFS2016.1422
Article Number: 8498B9660707
ISSN 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Chemical, functional, rheological and sensory properties of amaranth flour and amaranth flour based paste

Tanimola A. R.[1]*, Otegbayo B.[1] and Akinoso R.[2]

[1]Department of Food Science and Technology, Bowen University, Iwo, Osun State, Nigeria.
[2]Department of Food Technology, University of Ibadan, Nigeria.

Received 30 January, 2016; Accepted 15 July, 2016

Amaranth flour was prepared from amaranth grains, and the chemical, functional and rheological properties were investigated by standard methods, as well as the sensory attributes of the resulting amaranth flour based paste. The results of the proximate composition showed that amaranth flour has a protein content of 14.60%, crude fat content of 8.28%, ash content of 1.87%, total carbohydrate of 71.09% and a food calorific value of 417.28 kcal. Mineral analysis showed that the amaranth flour has 6.27 mg/100 g of Zn, 5.96 mg/100 g of Mn, 18.23 mg/100 g of Mg, 11.00 mg/100 g of Fe and 33.29 mg/100 g of Ca. The amylose and amylopectin content was 18.62% and 81.38% respectively. Pasting characteristics showed the Peak viscosity of amaranth flour to be 120.5 RVU. The color parameters of the flour and it resulting paste has the L* value to be 71.26 and 41.98 respectively and the brown index to be 28.74 and 58.02 respectively. Functional properties of the amaranth flour in terms of it water absorption capacity, swelling index, solubility, dispersibility and reconstitution index, showed it suitability for paste, as well as its acceptance in terms of appearance, smoothness, taste, aroma and overall acceptability. The properties of amaranth flour indicate its suitability for use as a substitute for other flour based paste commonly consumed by Nigerians as a staple food, in addition with its high nutritional value, which can help contribute to nutrition and food security in Nigeria.

Key words: Amaranth flour, paste, chemical properties, functional properties, sensory attributes.

INTRODUCTION

Grains have generally been classified as either cereal or legume grains. However, seeds of some vegetable for example, amaranth are gaining popularity in some countries because of their high nutritional value and properties which can be used in place of cereals. These seeds are classified as pseudocereals. Pseudocereals are seeds or fruits of plants consumed as cereal grains, but are not derived from grasses. The pseudocereals are also included in the list of grains recognized by the International American Association of Cereal Chemists as

*Corresponding author. E-mail: oladeleabiola12@gmail.com. Tel: +2348057203218.

cereals (Gordon, 2006).

Amaranth originated in the Americas, and has been cultivated for more than 8,000 years (Yarger, 2008). *Amaranthus* L. Species contains about 60 varieties on the American continent, and the most important varieties are: *Amaranthus caudatus*, *Amaranthus hypochondriacus* and *Amaranthus cruentus* (Kram and Szot, 1999). The seeds are small and mostly spherical, and are majorly classified as grain-type or vegetable-type seeds. The seed of the grain type has a pale colour, varying from off-white to pale pink, while the seed of the vegetable type is black and shiny; both types are edible and may be used as flour sources (Yarger, 2008). The seeds have been reported to be drought tolerant and highly adaptable to the tropics as a potential crop for improving food availability and food security in sub-Saharan Africa (Piha, 1995).

Amaranth grains can be popped like pop corn, or milled into flour (Ronoh et al., 2009; Yarger, 2008). Its high protein content, reported to be about 16 to 18% has attracted increasing interest by the international community (Ronoh et al., 2009), and its relatively well established essential amino acid patterns predict its high protein quality (Mugalavai, 2013). Amaranth protein is rich in lysine (exogenous amino acids), contains significant amounts of iron, calcium, B vitamins, vitamin A, E and C (Kram and Szot, 1999). Mburu et al. (2012) developed a complementary food based on Kenyan Amaranth grain, which had good amount of tocopherol which is important for infant growth and development; thiamine, riboflavin and pyridoxine. The environmental adaptability and nutritional composition of amaranth grain are quality attributes that can be used to attract and promote the utilization of the grain in Nigeria, especially by the vulnerable groups (women and children), to help sustain nutrition security.

In Nigeria, flour based paste is consumed as an important part of the diet. This is prepared by continuous mixing flour in boiling water to make a stretchable paste, which can be eaten with various soups. This is commonly prepared from yam flour, wheat flour, garri or cassava paste. Many researches have been carried out, and are still on-going, with efforts to make available more varieties of flour, as whole or composite flour, for use as a paste, and most importantly improve the nutritional qualities of the resulting paste (Adegunwa et al., 2014; Jimoh and Olatidoye, 2009; Karim et al., 2013; Abioye et al., 2011)

There have been studies on potential use of amaranth grains for composite bread, complementary food (Mburu et al., 2012), popped corn (Yarger, 2008) and some others. However, the potential of amaranth flour as a paste has not been investigated. The study investigates the rheological, functional and chemical properties of grain amaranth flour; and also evaluates the sensory attributes of the amaranth flour based paste, as alternatives to common paste commonly consumed in Nigeria.

MATERIALS AND METHODS

A. cruentus L. grains used for this research work was obtained from National Horticultural Research Institute (NIHORT), Idi-ishin, Ibadan, Oyo State, Nigeria.

Preparation of grain amaranth flour

The amaranth grain seeds were properly cleaned, winnowed and sorted manually for removal of stones, sand and all forms of dirt. The grains were then finely ground using a disc attrition mill (Agrico Model, 0912293, Ibadan, Nigeria) followed by sieving. The flour was packaged in a well-sealed low density polyethylene bag.

Chemical composition determination

The proximate composition of the amaranth grain flour was determined using AOAC (2005) method for moisture content, crude fat content, ash content and crude protein content. The total carbohydrate was determined by difference (Low, 2002). The energy value of the amaranth grain flour was determined using the bomb calorimeter model method of Passmore and Eastwood (1986). All analyses were carried out in triplicates.

The mineral contents were analysed using AOAC (2005). Using dry ashing, the sample was ashed at 550°C for 3 h. 5 ml of 6N HCl was mixed with the ash and made up to 50 ml with distilled water. Selected minerals including iron (Fe), calcium (Ca), magnesium (Mg), manganese (Mn) and zinc (Zn) were determined by atomic absorption spectrophotometer.

Amylose and amylopectin content were determined using the method of Hoover and Ratnayake (2002). The method of Mbaeyi-Nwaoha and Onweluzo (2013) was used to determine the pH of the flour sample.

Functional properties determination

The amaranth flour sample was analyzed for water and oil absorption capacity (Sosulski et al., 1976), Loose and packed bulk density (Asoegwu et al. (2006), swelling index and solubility (Leach et al., 1959 and Kaur et al., 2011), dispersibility (Armstrong et al., 1979), Emulsifying Capacity and Emulsion Stability (Yatsumatsu et al*.,* 1972) and reconstitution index (Makinde and Ladipo, 2012).

The pasting properties of the amaranth flour were determined with the use of a Rapid Visco Analyzer (RVA). The parameters assessed include: pasting temperature, peak time, set back, final viscosity, trough (holding strength) and peak viscosity, which were read using thermocline for windows software connected to a computer, from the pasting profile (Newport Scientific, 1995).

Colour parameters determination

The colour parameters of the samples were measured using chroma meter (Color Tec PCMTM Color Tec Associates, Konica Minolta sensing, Inc., Japan). The colorimeter was standardized with a white paper and a black object (Lui-ping et al., 2005). The parameters recorded were **L*, *a and *b coordinates of the CIE scale. **L* (lightness) axis – 0 is black, while 100 is white; **a* (red-green) axis – positive values are red while negative values are green and 0 is neutral; **b* (yellow-blue) axis – positive values are yellow, while negative values are blue and 0 is neutral. From the

Table 1. Chemical composition of Amaranth grain flour.

Chemical component	Amaranth grain flour (%)
Crude protein content (%)	14.60±0.13
Moisture content (%)	4.17±0.28
Crude fat content (%)	8.28±1.05
Ash content (%)	1.87±0.04
Total carbohydrates (%)	71.09±1.32
Energy (kcal)	417.28
Amylose (%)	18.62
Amylopectin (%)	81.38
pH	5.90 ± 0.10

***Results show means of triplicates ± standard deviation.

data obtained, *delta*Chroma (ΔC), colour intensity (ΔE) and hue angle were calculated using Eqs. i, ii and iii, respectively (Hunt, 1991), and the brown index (BI) using Eq iv (Babajide et al., 2006).

$$s\Delta C = \sqrt{(\Delta a*)^2 + (\Delta b*)^2} \quad (1)$$

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} \quad (2)$$

$$\text{Hue angle } \text{Tan}^{-1}\frac{b}{a} \quad (3)$$

$$BI = 100 - L* \quad (4)$$

Sensory evaluation

The amaranth flour was reconstituted into paste using about 50 g of flour and 150 ml of boiling water. This was thoroughly stirred with a wooden spoon for smooth consistency, covered and cooked for about 5 minutes, stirred and wrapped in polyethylene and then kept in a Styrofoam box prior to sensory evaluation. A control was prepared from wheat flour, using the same preparation method described above. The evaluation was carried out by twenty panelists selected from people conversant with the consumption of pastes. The panelists evaluated the samples using questionnaires for scoring the sensory attributes of appearance, smoothness, taste, aroma and overall acceptability on a 9-point hedonic scale, presented to them in an environment with no interference for bias expression, and under bright lighting.

RESULTS AND DISCUSSION

Chemical properties of amaranth grain flour

The protein content of amaranth grain flour was 14.60% (Table 1) which showed a high level of protein as compared with most other flour used for making paste. Such include: 4.28 – 6.11% protein content reported for yam flour (used for *amala)* by Ojokoh and Gabriel (2010) and 1.8% by Oyeyiola et al*.* (2014). Karim et al*.* (2015) also reported 3.52% for plantain flour, a range of 4.54 - 8.40% for soy-plantain flour blends (Abioye et al*.,* 2011) and also a range of 5.73 – 8.46% for moringa fortified yam flour (Karim et al., 2013). The protein content of the amaranth grain flour is comparable to earlier studies on amaranth grain, 13.57% (Kunyanga et al., 2013) and 14.44% (Njoki et al., 2014). The high protein content of amaranth flour shows that it could be a cheap source of nutrients in a developing country like Nigeria. Moreover, the reconstitution of the amaranth flour to paste may be said to increase its protein quality, according to previous research on effect of thermal processing on amaranth nutritive value. The protein quality of amaranth grain processed by extrusion cooking increased from 17 to 18.1% This increase in its nutritive value was probably because it contains heat-labile growth inhibitors, increase in dry matter or that heat processing increases nutrient availability (Mendoza and Bressani, 1987).

The moisture content of the amaranth flour was determined to be 4.17% (Table 1), which is in the range of acceptable limit for shelf life stability of dry products (Kayisu et al., 1981), hindering the growth of microorganisms. The amaranth flour had a crude fat content of 8.28%, which is similar to that of soy-plantain flour blend (7.05%) for paste (Abioye et al., 2011). This could be said to have a significant effect in contributing to the flavor and palatability of the resulting dough, since dietary fats have a role of increasing food palatability by absorbing and retaining flavors (Lindsay, 1996). The flour had an ash content of 1.87% (Table 1), comparable to amaranth grain grown in Uganda, 2.85% (Muyonga et al., 2008) and similar to that of yam flour, 1.74% (Karim et al., 2013). The total carbohydrate content (71.09%) of amaranth grain flour is similar to that of yam flour observed by Ojokoh and Gabriel (2010) (78.20%) and Oyeyiola et al*.* (2014). The food calorific value of the amaranth flour was calculated to be 417.28 kcal (Table 1), which could be said to be balance enough to meet the energy requirement of an adult. Similar results were obtained for plantain flour, 384.33 to 394.09 Kcal (Oluwalana and Oluwamukomi, 2011).

The results showed the amylose content and amylopectin content of amaranth grain flour to be 18.62 and 81.38% respectively (Table 1). The amylose fraction in amaranth grain was high when compared with the fraction obtained for white trifoliate yam and yellow trifoliate yam flour (15.38 and 15.51%) (Abiodun and Akinoso, 2014). Amylose content has been observed to have a high effect on the swelling power, viscosity, solubility, pasting and other textural qualities of starchy foods (Otegbayo et al., 2013; Satin, 1998 According to Otegbayo et al*.* (2011), swelling power increases as amylose content is lowered, implying that the amylose content observed in amaranth flour indicates lower swelling power than white and yellow trifoliate yam flour (Abiodun and Akinoso, 2014) and most other yam flour and starches (Oke et al., 2013; Wireko-Manu et al., 2011). The pH of the amaranth grain flour was 5.90 showing that the amaranth flour is slightly acidic.

Amaranth grain flour has mineral contents of 6.27 mg/100 g for Zinc, 5.96 mg/100 g for manganese, 18.23

Table 2. Mineral composition of Amaranth grain flour.

Minerals	Amounts (mg/100 g)
Zn	6.27
Mn	5.96
Mg	18.23
Fe	11.00
Ca	33.29

Table 3. Functional properties of Amaranth grain flour.

Functional parameter	Proportion
Water absorption capacity (g/g)	1.60 ± .04
Loose bulk density (g/cm^3)	0.45 ± 0.00
Packed bulk density (g/cm^3)	0.57 ± 0.00
Swelling index	7.76 ± 0.03
Solubility (%)	6.53 ± 0.81
Dispersibility (%)	14.92 ± 0.25
Reconstitution index (ml/g)	0.40 ± 0.02
Emulsion capacity	0.09 ± 0.01
Emulsion stability	0.07 ± 0.01

*****Results show means of triplicates ± standard deviation.

Table 4. Pasting properties of Amaranth flour.

RVA parameters	Amaranth flour
Peak viscosity (RVU)	120.5 ± 1.00
Trough viscosity (RVU)	112.1 ± 1.15
Breakdown viscosity (RVU)	8.5 ± 1.00
Final viscosity (RVU)	132.2 ± 3.05
Setback viscosity (RVU)	201.4 ± 1.15
Peak time (min)	5.90 ± 0.03
Pasting temperature (°C)	81.47 ± 0.03

*****Results show means ± standard deviation.

mg/100 g for magnesium, 11.00 mg/100 g for iron and 3.39 mg/100 g for calcium (Table 2). The iron content is five times higher than the one in soy plantain flour, but with similar calcium content (Abioye et al., 2011). Minerals are necessary for normal cellular activity and growth. The results showed that amaranth grain flour can be utilized as a good source of micronutrient to meet the need of the vulnerable groups in Nigeria.

Functional properties of amaranth grain flour

The water absorption capacity of amaranth grain flour was determined to be 1.60 g/g (Table 3). Water absorption capacity is the ability of the flour to associate with water under a condition where water is limiting, which is mainly dependent on proteins at room temperature (Otegbayo et al*.,* 2013), and to a lesser extent on starch and cellulose. This relationship is shown in the water absorption capacity (80.05 to 86.50 %) of soy-plantain flour (Abioye et al*.,* 2011) which has lower protein content than amaranth grain flour. The degree of association of starch granules in different flour samples could also cause variation in water absorption capacity (Falade and Kolawole, 2011; Abiodun and Akinoso, observed to be 0.45 g/cm^3 and 0.57 g/cm^3 respectively (Table 3). An understanding of this is useful in determining the packaging requirement, application in wet processing and material handlings of flours (Adebowale et al., 2008). In comparism with other flour for paste preparation, these values are similar to the one observed by Abioye et al*.* (2011) for soy-plantain flour (0.42 – 0.46 g/cm^3), and higher than those observed by (Oluwalana and Oluwamukomi, 2011) for plantain flour blanched at different temperature (0.159 – 0.420 g/cm^3). When compared with yam flour (0.71 – 0.88 g/cm^3), the bulk density of the amaranth flour could be said to be lower, indicating a lesser packaging requirement than yam flour (Adebowale et al., 2008).

The swelling index and solubility of amaranth flour were determined to be 7.76 and 6.53% respectively (Table 3). These values are closely related to those of some other flour for paste: 7.48 – 7.96 swelling index and 6.31 – 6.83 solubility for soy-plantain flour (Abioye et al*,* 2011). However, the swelling index of trifoliate yam flour was observed to be 1.46 – 2.28 (Abiodun and Akinoso, 2014).The high swelling index of amaranth flour and soy-plantain flour could be as a result of their high protein content, as against that of yam flour. The solubility showed the rate and extent to which the components of the powder particles dissolve in water, which depends on the chemical composition and physical state of the product.

The reconstitution index and dispersibility of amaranth flour were observed to be 0.40 ml/g and 14.92% respectively (Table 3). Reconstitution index and dispersibility are temperature and particle size dependant (Igyor et al., 2011). Dispersibility is the ability of flour to be wet without the formation of lumps, with simultaneous disintegration of agglomerates. The importance of dispersibility is that it indicates the reconstitution ability of the sample (Otegbayo et al., 2013).

Pasting properties of amaranth flour

The pasting properties of amaranth flour are shown in Table 4. The term 'pasting' is referred to as changes

Table 4. Pasting properties of Amaranth flour.

RVA parameters	Amaranth flour
Peak viscosity (RVU)	120.5 ± 1.00
Trough viscosity (RVU)	112.1 ± 1.15
Breakdown viscosity (RVU)	8.5 ± 1.00
Final viscosity (RVU)	132.2 ± 3.05
Setback viscosity (RVU)	201.4 ± 1.15
Peak time (min)	5.90 ± 0.03
Pasting temperature (°C)	81.47 ± 0.03

*****Results show means ± standard deviation.

Table 5. Colour parameters of Amaranth grain flour and it reconstituted paste.

Sample	Amaranth flour	Amaranth paste
L*	71.26 ± 0.03	41.98 ± 0.38
a*	3.75 ± 0.01	4.44 ± 0.08
b*	17.24 ± 0.01	11.36 ± 0.15
Brown index	28.74	58.02
Tan^{-1} b/a	77.73	68.65
ΔE	23.05	8.56
ΔC	5.62	0.76

*****Results show means of triplicates ± standard deviation..

in viscosity during gelation (Zeng et al., 1996), mainly dependent on the starch content of gelatinized food (Adeyemi and Beckley, 1986). The peak viscosity of the flour was 120.5 RVU, trough viscosity was 112.1 RVU, breakdown viscosity was 8.5 RVU, final viscosity was 132.2 RVU, setback viscosity was 201.4 RVU, peak time was 5.9 min and pasting temperature was 81.47°C. Amaranth flour had higher peak viscosity than blanched/soaked white and yellow trifoliate yam flour, 89.50 RVU and 84.08 RVU resp. but lower than those of the unblanched white and yellow trifoliate yam flour, 213.33 RVU and 173.50 RVU resp. (Abiodun and Akinoso, 2014). The peak viscosity points to the water binding capacity and viscosity of the flour sample (Abiodun and Akinoso, 2014), which also reflects the ability of starch granules to swell freely before been broken down physically (Wireko-Manu et al., 2011). The high pasting temperature of amaranth flour, 81.47°C (Table 4) implies longer cooking time, since the onset of rise in viscosity and gelatinization temperature is as a result of the pasting temperature (Otegbayo et al., 2013). The pasting temperature was similar to those of soy plantain mixes, 89.20-92.40°C (Abioye et al., 2011). In the food industry, pasting and gelatinization of flour or starch are important because they influence the texture, stability and digestibility of starchy foods. Hence need for their determination, because they influence the applications and output of flours and starches in various foods (Oke et al., 2013).

Colour parameters of amaranth grain flour and paste

Table 5 provided an average evaluation of the colour characteristics of amaranth flour and paste in terms of the CIE tristimulus colour parameters, brown index, and calculated deltachroma (*ΔE*), colour difference (*ΔC*) and hue angle. These colour parameters are objective means of evaluating the colour characteristics of the flour and paste. The L* value of the flour (71.26) was higher than that of the paste (41.98) which was is as expected for flour colour the had a light colour and that of the paste, was slightly brown. The ‘a*’ and ‘b*’ values were 3.75, 17.24 for flour and 4.44 and 11.36 for paste respectively. The brown index of the flour and paste were 28.74 and 58.02 respectively. Brown index shows the extent of discoloration and can be linked to the total phenols of the flour and paste (Babajide et al., 2006). The brown index of the flour increased in the paste during reconstitution as a result of the thermal degradation of the originally colourless complex phenols in the flour to coloured phenols in the paste (Akissoe et al., 2006). The colour of flour as well as that of the resulting dough has high influence on it acceptability.

Sensory evaluation of amaranth flour based paste

The sensory properties of the paste from amaranth flour and wheat flour (control) are presented in Table 6. The smoothness attribute of amaranth paste (7.05) and control paste (6.45) were closely related. However, the scores of appearance taste, aroma and overall acceptability were also similar. The control sample had the highest score in terms of appearance, smoothness, taste, aroma and overall acceptability, which could be as a result of familiarity of the panelists with the control sample which made a good number of them prefer it than the amaranth paste. However, amaranth paste also received acceptable scores in terms of all the sensory attributes, suggesting its acceptability and suitability for consumption.

Conclusion

The chemical, functional and pasting properties of amaranth grain flour were comparable to those of other flour useful for making paste in Nigeria, as stated in literatures, with better protein content and some other functional properties. The sensory evaluation conducted showed moderate acceptability, which can be made better by increasing the awareness about the nutritional

Table 6. Result of sensory evaluation.

Sample	Control reconstituted paste	Amaranth reconstituted paste
Appearance	7.15±0.81	6.25±1.48
Smoothness	7.05±1.20	6.45±1.80
Taste	7.20±1.36	5.50±1.28
Aroma	7.00±1.41	5.65±1.39
Overall acceptability	7.40±0.82	6.15±0.99

*****Results show means of 20 panelists ± standard deviation.

value of the grain flour. The properties of amaranth grain flour showed its suitability for use as a substitute for other paste commonly consumed by Nigerians as a staple food, in addition with its high nutritional value, which can help contribute to nutrition and food security in Nigeria.

Conflict of Interests

The authors have not declared any conflict of interest.

REFERENCES

Abiodun OA, Akinoso R (2014). Textural and sensory properties of trifoliate yam (Dioscorea dumetorum) flour and stiff dough 'amala. J. Food Sci. Technol. 52(5):2894-2901.

Abioye VF, Ade-Omowaye BIO, Babarinde GO, Adesigbin MK (2011). 'Chemical, physico-chemical and sensory properties of soy-plantain flour'. Afr. J. Food Sci. 5(4):176-180.

Adebowale AA, Sanni, SA, Oladapo FO (2008). Chemical, functional and sensory properties of instant yam bread fruit flour. Niger. Food J. 26(1):2-12.

Adegunwa MO, Adebowale AA, Bakare HA, Ovie SG (2014). Compositional characteristics and functional properties of instant plantain-breadfruit flour. Int. J. Food Res. 1:1-7.

Adeyemi IA, Beckley O (1986). Effect of period of maize fermentation and souring on chemical properties and Amylograph pasting viscosity of ogi. J. Cereal Sci. 4:353-360.

Akissoe N, Akissoes C, Hounhouigan J, Nago, M (2006). Prediction of the sensory texture of a yam thick paste (amala) using instrumental and physicochemical parameters. J. Texture Stud. 37(4):393-402.

AOAC (2005). Official Methods of Analysis of the Association of Analytical Chemists, 18th Ed., Association of Analytical Chemists, Gathersburg, MD., USA.

Armstrong BI, Stanley DW, Maurice TJ (1979). Functionality and protein Structure. Ed. Akiva pour EL ACS Symposium series 92, American Chemical society, Washington. D.C.

Asoegwu SN, Ohanyere SO, Kanu OP, Iwueke CN (2006). Physical properties of African Oil Bean seed (*Pentaclethra macrophylla*). Agricultural Engineering International: the CIGR Ejournal, Manuscript FP 05 006. Vol. 8.

Babajide JM, Oyewole OB, Henshaw FO, Babajide SO, Olasantan FO (2006). Effect of local preservatives on quality of traditional dry yam slices 'Gbodo' and its products. World J. Agric. Sci. 2(3):267-273.

Falade KO, Kolawole TA (2011). Effect of Irradiation Dose on Physical, Functional and Pasting Properties of Cowpea (*Vigna Unguiculata* [L.] Walp) Cultivars. J. Food Process Eng. 36(2):147-59.

Gordon E (2006) Analyzing the versatility and complexity of cereal grains. Food Sci. Newsl. 88:1-5.

Hoover R, Ratnayake WS (2002). Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars. Food Chem. 78:489-498.

Hunt RWG (1991). Measuring Colour. Ellis Horwood,New York, NY. 2nd Ed. pp.75-76.

Igyor MA, Yusufu PA, Sengev IA (2011). Functional and Sensory Properties of fermented fura powder supplemented with soy. Niger. Food J. 29:113-121.

Jimoh KO Olatidoye OP, (2009). Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. J Appl. Biosci. 13:703-706.

Karim OR, Kayode RMO, Oyeyinka SA, Oyeyinka AT (2013). Proximate, Mineral and Sensory Qualities of 'Amala' Prepared from Yam flour fortified with Moringa leaf powder. Food Sci. Qual. Manage. 12:10-23.

Karim OR, Kayode, RMO, Oyeyinka SA, Oyeyinka AT (2015). Physicochemical properties of stiff dough "amala" prepared from Plantain (*musa paradisca*) flour and moringa *(moringa oleifera)* leaf Powder, *Hrana u zdravlju i bolesti, znanstveno-stručni časopis za nutricionizam i dijetetiku* 4(1):48-58.

Kaur M, Oberoi DPS, Sogi DS, Gill BS (2011). Physicochemical, morphological and pasting properties of acid treated starches from different botanical sources. J. Food Sci. Technol. 48:460-465.

Kayisu K, Hood LF, Vansoest PJ (1981). Characterization of Starch and Fiber of Banana. Fruit J. Food Sci. 46:1885-1890.

Kram B, Szot B (1999). Aerodynamic and geometric properties of amaranth seeds. Int. Agrophys. 13:227-232.

Kunyanga CN, Imungi JK, Vellingri V (2013). Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. J. Appl. Biosci. 67:5277-5288.

Leach HW, McCowen LD, Schoch TJ (1959). Structure of the Starch Granule: Swelling and Solubility Patterns of Various Starches. Cereal Chem. 36:534-544.

Lindsay RC (1996). Flavours. In. Fennema R. O., Karel M, Sanderson, G. W., Tannenbaum S. R., Walstra P., Witaker J. R. (eds). Food Chemistry, Marcel Dekker Inc. New York. pp. 611-612.

Low NH (2002). Carbohydrate Analysis. In. Introduction to the Chemical Analysis of Foods Nielsen SS. ed CBS Publishers and distributors, Daryaganj, New Delhi.

Lui-ping F, Min T, Gong-nian X, Jin-Cai, Qian T (2005). The optimization of vacuum frying to dehydrate carrot chips. Int. J. Food Sci. Technol. 40:911-919.

Makinde FM, Ladipo AT (2012). Physicochemical and Microbiological quality of sorghum-based complementary food enriched with soybean (Glycine max) and sesame (Sesamum indicum). J. Food Technol. 10(2):46-49.

Mbaeyi-Nwaoha IE, Onweluzo JC (2013). Functional Properties of Sorghum (*S. Bicolor* L.) - Pigeonpea (*Cajanus cajan)* Flour Blends and Storage Stability of a Flaked Breakfast Formulated from Blends. Pak. J. Nutr. 12(4):382-397.

Mburu MW, Gikonyo NK, Kenji GM, Mwasaru AM (2012). Nutritional and functional properties of a complementary food based on kenyan amaranth grain (*Amaranthus cruentus*). Afr. J. Food Agric. Nutr. Dev. 12:5959-5977.

Mendoza CM, Bressani R (1987). Nutritional and Functional Characteristics of Extrusion-cooked Amaranht Flour. Cereal Chem. 64(4):218-222.

Mugalavai VK (2013). Effect of Amaranth: Maize Flour Ratio on the Quality and Acceptability of U*gali a*nd *Porridge* (Kenyan Cereal Staples). ARPN J. Agric. Biol. Sci. 8(1):6-12.

Muyonga JH, Nabakabya D, Nakinbugwe DN, Masinde D (2008). Efforts to promote amaranth production and consumption in Uganda to fight malnutrition. International Union of Food Science & Technology, Chp. P 8.

Newport Scientific (1995). Operation Manual for the series 4 Rapid Visco Analyzer. Australia Newport Scientific Pty, Ltd, P 93.

Njoki JW, Sila DN, Onyango AN (2014). Impact of Processing Techniques on Nutrient and Anti-Nutrient Content of Grain Amaranth (*A. albus)*. Food Sci. Qual. Manage. 25:10-17.

Ojokoh AO, Gabriel RAO (2010). A comparative study on the storage of yam chips (gbodo) and yam flour (elubo). Afr. J. Biotechnol. 9(21):3175-3177.

Oke MO, Awonorin SO, Workneh TS (2013). Effect of varieties on physicochemical and pasting characteristics of water yam flours and starches. Afr. J. Biotechnol. 12(11):1250-1256.

Oluwalana, IB, Oluwamukomi, MO (2011). Proximate composition, rheological and sensory qualities of plantain (*Musa parasidiaca)* flour blanched under three temperature regimes. Afr. J. Food Sci. 5(14):769-774.

Otegbayo B, Bokanga M, Asiedu R (2011) Physicochemical properties of yam starch: effect on textural quality of yam food product (pounded yam). J. Food Agric. Environ. 9(1):145-150.

Otegbayo BO, Samuel FO, Alalade T (2013). Functional properties of soy-enriched tapioca. Afr. J. Biotechnol. 12(22):3583-3589.

Oyeyiola GP, Oyeniyi OR, Arekemase MO Ahmed RN (2014). A comparative study on the microbiological and nutritional properties of stored chips and flours. World J. Biol. Res. 6(2):1-6.

Passmore R, Eastwood WA (1986). Human Nutrition and Dietetics. English Language Book Society, Churchill. UK.

Piha MI (1995). Yield potential, fertility requirements, and drought tolerance of grain amaranth compared with maize under Zimbabwean conditions. Trop. Agric. 72:7-12.

Ronoh EK, Kanali CI, Mailutha JT Shitanda D (2009). Modeling Thin Layer Drying of Amaranth Seeds under Open Sun and Natural Convection Solar Tent Dryer. Agricultural Engineering International: the CIGR Ejournal. Manuscript 1420. Vol. 11.

Satin M (1998). Functional properties of starches. In: Spotlight tropical starch misses market. AGSI report, Agriculture 21, FAO-Magazine, pp.1-9.

Sosulski FW, Humbert ES, Bui ES Jones JI (1976). Functional properties of rapeseed flours, concentrates and isolates. J. Food Sci. 41:1349-1351.

Wireko-Manu FD, Ellis WO, Oduro I, Asiedu R, Maziya-Dixon B (2011). Physicochemical and Pasting Characteristics of Water Yam (D. alata) in Comparison with Pona (D. rotundata) from Ghana. Euro. J. Food Res. Rev. 1(3):149-158.

Yarger L (2008). Amaranth grain and vegetable types. Echo Technical Note, 17391 Durance Road, North Fort Myers, FL 33917, USA.

Yasumatsu K, Sawad L, Moritaka LS, Mikasi SM, Wada MT, Ishi K (1972). Whipping and emulsifying properties of soybean products. Agric. Biol. Chem. 36:719-727.

Zeng M, Craig FM, Batey I, Wrigley CW (1996). Sources of variation for starch gelatinization, pasting, and gelation properties in heat. Cereal Chem. 74:63-71.