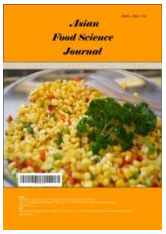


Asian Food Science Journal

21(6): 12-25, 2022; Article no.AFSJ.86203
ISSN: 2581-7752

Functional and Nutritional Properties of Various Flour Blends of Arrowroot Starch and wheat Flour

Aaron Mutlong Amak Damak [a,b,c], Peter Isah Akubor [b,c], Charles Chukwuma Ariahu [a,d] and Goodluck Obioma Okereke [a,e*]

[a] Department of Chemistry, Food Science and Technology, Centre for Food Technology and Research, Benue State University, Makurdi, PMB 102119 Makurdi, Benue State, Nigeria.
[b] Department of Food Science and Technology, Federal University, Wukari, PMB 1020 Wukari, Taraba State, Nigeria.
[c] Department of Food, Nutrition and Home Sciences, Kogi State University, P.M.B 1008, Anyigba, Kogi State, Nigeria.
[d] Department of Food Science and Technology, Federal University of Agriculture, Makurdi, Benue State, Nigeria.
[e] Coca-cola Hellenic Bottling Company, Owerri, Imo State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2022/v21i630432

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86203

Original Research Article

Received 12 February 2022
Accepted 21 April 2022
Published 28 April 2022

ABSTRACT

Flour blends of arrowroot starch and wheat flour were developed in the ratios of 100:0, 0:100, 10:90, 20:80, 30:70, 40:60, 50:50, and 60:40. These flour blends were investigated for their functional and nutritional properties to determine their potentials for utilizations in a variety of wheat flour-based products. The range of values of the results obtained were for: bulk density (0.37 – 0.91 g/cm^3), foaming capacity (21.20 – 82.00%), foaming stability (20.80 – 80.00%), emulsion capacity (18.27 – 54.85 %), emulsion stability (12.39 – 60.29%), water absorption capacity (101.41 - 106.77%), oil absorption capacity (94.70 – 107.80%), least gelation capacity (6.00 – 10.00%), protein (6.5 – 11.28%), ash (1.37 – 3.60%), moisture (4.30 – 10.50%), fat (1.63 – 4.60%), crude fibre (2.60 – 4.20%), carbohydrate (69.70 – 78.81%), vitamin C (0.70 – 2.80 mg/100g), vitamin A (0.00 – 0.66 mg/100g), zinc (1.6 – 3.3 mg/100g), iron (0.3 – 1.2 mg/100g), copper (2.6 – 5.0 mg/100g), sodium (10.4 – 43.0 mg/100g), potassium (16.2 – 74.6 mg/100g), calcium (5.2 – 33.2

**Corresponding author: Email: gocoke79@gmail.com;*

mg/100g), magnesium (4.9 – 13.6 mg/100g) and phosphorus (45.0 – 317 mg/100g). Bulk density, foaming capacity, foaming stability, emulsion capacity, emulsion stability and least gelation capacity of the flour blends decreased as the incorporation of arrowroot starch increased, while the water absorption capacity of the flour blends increased as the concentration of the arrowroot starch increased. Protein, carbohydrate, vitamin C, vitamin A, sodium, potassium, calcium, magnesium and phosphorus contents of the flour blends decreased as the substitution with arrowroot starch increased; whereas ash, moisture, fat, crude fibre, zinc, iron and copper contents increased with increased substitution. These results obtained highlighted the potentials of arrowroot starch in substituting wheat flour in wheat flour based products.

Keywords: Wheat, arrowroots; formulation of flour blends; proximate and mineral composition; flour-based products.

1. INTRODUCTION

Wheat flour is experiencing upsurge in demand due to its growing utilizations in food industries. It is utilized in many flour based products such as bread, cakes, biscuits, *chin-chin*, noodles, confectioneries, snack foods, cookies, pasta, puddings, sauces etc. It is the main ingredient in making bread because of its exclusive ability to form elastic dough when mixed with water due to the presence of gluten in it. Unfortunately, wheat flour is exorbitantly imported into Nigeria since her climatic conditions do not support large scale growth of wheat crop and this really places severe burden on the country's resources, thus hugely depleting the nation's foreign exchange reserve. In order to tackle this economic drain, Nigerian government is relentlessly supporting continuous strategic research aimed at identifying, developing and promoting indigenous raw materials that could partially or totally replace wheat flour in all wheat flour based products [1].

In view of this, food scientists have adopted composite flour technology in formulations of flours, for the manufacture of flour-based products [1]. Of course, many studies have investigated the potentials of substituting wheat flour with other flours from breadfruit, cassava, cocoyam, plantain, sweet potato, malted sorghum, pigeon pea, cowpea, taro and yams for production of bread and other bakery products [2,3,4,5,6,7,8,9,10,11,1]. Interestingly, formulations of composite flours with starches have shown better baking responses than those with flours [12,13,14,1]. Besides, researchers have revealed that starch is an important component of bakery products, functionally and nutritionally since it constitutes about 65 - 85% of grain based flour [15,16,17, 18].

Starch (a polymer of glucose molecules) is the most important human diet and it is contained in such staple foods as potatoes, sweet potatoes, wheat, cocoyam, yam, maize, rice, cassava and arrowroots [19], Damak, 2014; [1]. Shockingly, among all these starch sources mentioned, arrowroots (*Tacca leontopetaloides*), a tropical edible rhizomes, have received the poorest research attention irrespective of their rich potentials and popularity in Northern part of Nigeria. Arrowroots are widely distributed in Nigeria and eaten as food in many states, but have not been domesticated as in East Africa and Asia [20,21]. Arrowroots have potentials for utilizations in food, pharmaceutical and other industrial purposes but there is very little information on its uses other than energy sources among communities that cultivate them. Thus continuous studies are being promoted to find out other potentials of these lesser-known crops [22,23,1] for efficient utilization and application in the industrial sector. There is no doubt that the use of arrowroot starch for the production of baked products would help reduce Nigeria's dependence on wheat flour importation, thereby advancing its utilizations in Nigeria. Furthermore, celiac disease has been implicated in excessive consumption of wheat flour based products [24,25] due to the presence of gluten (protein in wheat flour) which is allergic to some people. For instance, gluten free bread is a trending choice in Europe and America. Thus, identifying and developing starches with good physico-chemical and nutritional potentials will help to realize the vision of expendable utilization of under-utilized crops in Nigeria, thereby promoting food security, increasing employment and contributing to economic growth. Functional properties which are those characteristics that govern the behavior of nutrients in foods during processing, storage and preparation as they affect food quality and acceptability [26] are required to evaluate and possibly help to predict

how nutrients may behave in specific food systems. More so, there is need to undertake strategic research to identify, develop and promote some lesser-known and non-conventional crops whose starches can meet the standards of starch-based industries for high quality starches at affordable prices.

Thus in view of this, starch will be extracted from arrowroots and utilized in formulations of arrowroot starch and wheat flour blends at percentage ratios of 100:0, 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 60:40, in order to evaluate their functional and nutritional properties for utility expansion of arrowroots.

2. MATERIALS AND METHODS

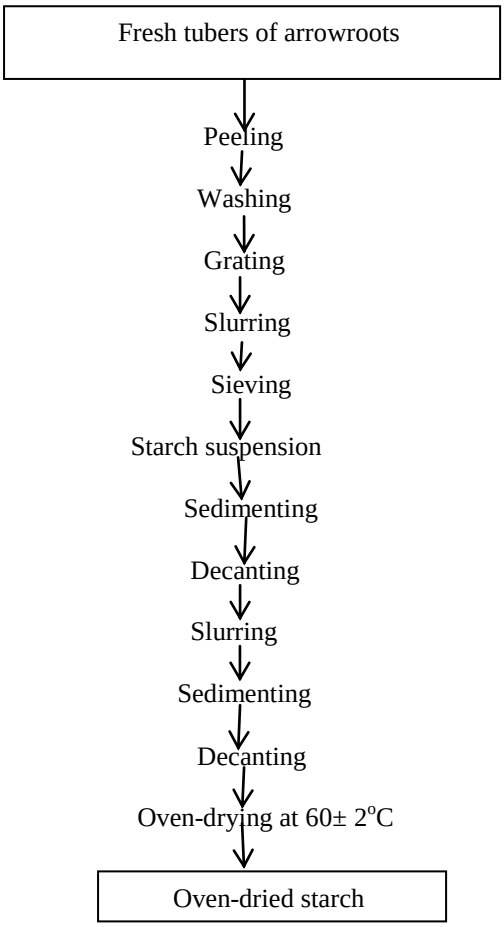
2.1 Materials

Fresh tubers of arrowroot (identified by a staff of Ministry of Agriculture, Shendam, Plateau State, Nigeria) were harvested from a wild bush in Shendam, Plateau State, Nigeria. Wheat flour was purchased from Anyigba market in Anyigba town, Kogi state, Nigeria.

2.2 Methods

2.2.1 Starch extraction

Starch was extracted from cleaned, peeled and macerated arrowroot tubers using the method of Okereke *et al*., [1].



Flow chart for production of arrowroot starch
Source: Modified Okereke et al., [1]

2.2.2 Formulation of the flour blends

The arrowroot starch and the wheat flour were sieved through a 40 mm mesh sieve (British standard). Arrowroot starch was used to substitute 10, 20, 30, 40, 50 and 60% of wheat flour in a food blender operated at full speed for 10 minutes. The flour blends were packaged in high density polyethylene bags prior to use.

2.3 Determinations of the Functional Properties of the flour blends

2.3.1 Bulk density (BD)

Bulk densities of the flour blends were determined as described by Onwuka [26]. A weighed 10 ml capacity graduated measuring cylinder was filled with the sample. The bottom of the cylinder was tapped gently on the laboratory bench several times until there was no further decrease in volume of the sample after filling to the 10 ml mark. The bulk density was calculated as:

$$Bulk\ Density\ (BD) = \frac{Weight\ of\ sample}{Volume\ of\ sample}$$

2.3.2 Foam capacity (FC) and foam stability (FS)

The method of Onwuka [26] was used for the determination of foam capacity and foam stability of the flour blends. Sample (2 g) was blended with 100 ml of distilled water in a warring blender and the suspension was whipped at 1600 rpm for 5 minutes. The mixture was poured into a 250 ml measuring cylinder and the volume was recorded after 30 seconds. The foam capacity was expressed as percent increase in volume.

$$Foam\ Capacity, FC\ (\%) = \frac{Volume\ after\ whipping - Volume\ before\ whipping}{Volume\ before\ whipping} \times 100$$

Then foam volumes at 15, 30. 60 and 120 minutes after whipping were recorded to determine the foam stability as follows.

$$Foam\ Stability, FS\ (\%) = \frac{Foam\ volume\ after\ 2hrs}{\text{Initial foam volume}} \times 100$$

2.4 Emulsion Capacity (EC) and Emulsion Stability (ES)

The method of Onwuka [26] was used for the determination of Emulsion capacity and Emulsion stability of the flour blends. Sample (2 g) was blended with 25 ml of distilled water (at room temperature) for 30 seconds in a warring blender at 1600 rpm. After complete dispersion, 25 ml of groundnut oil was added and blended for 30 seconds. The mixture was transferred into a centrifuge tube and centrifuged at 1600 rpm for 5 minutes. The volume of oil separated from the sample after centrifuge was read directly from the tube. Emulsion Capacity (EC) was expressed as the amount of oil emulsified and held per gram of sample.

$$Emulsion\ Capacity, EC\ (\%) = \frac{Height\ of\ emulsified\ layer}{\text{Height of the whole solution in the centrifuge tube}} \times 100$$

To determine the Emulsion Stability (ES), emulsions prepared by the above procedure, were heated at 85^0C for 15 minutes, cooled to room temperature and centrifuged at 1500 rpm for 5 minutes. The Emulsion Stability was calculated as follows:

$$Emulsion\ Stability, ES\ (\% = \frac{Volume\ of\ remaining\ emulsified\ layer}{\text{Volume of original emulsion}} \times 100$$

2.5 Water Absorption Capacity

The method of Onwuka [26] was used for the determination of Water Absorption Capacity of the flour blends. Sample (1 g) was put into a weighed conical graduated centrifuge tube. Distilled water (10 ml) was added to the sample and mixed thoroughly with a waring whirl mixer for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000 rpm for 30 minutes. The volume of free water (the supernatant) was read directly from the graduated centrifuge tube. The water absorption capacity was expressed as grams of water absorbed per gram of sample.

$$Water\ Absorption\ Capacity\ (\%) = \frac{Weight\ of\ water\ absorbed\ by\ sample}{\text{Weight of sample}} \times 100$$

2.6 Oil Absorption Capacity

The method of Onwuka [26] was used for the determination of Oil Absorption Capacity of the flour blends. Sample (1 g) was put into a weighed conical graduated centrifuge tube. Vegetable oil (10 ml) was added to the sample

and mixed thoroughly with a waring whirl mixer for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000 rpm for 30 minutes. The volume of free oil (the supernatant) was read directly from the graduated centrifuge tube. The water absorption capacity was expressed as grams of water absorbed per gram of sample.

$$Oil\ Absorption\ Capacity\ (\%) = \frac{Weight\ of\ oil\ absorbed\ by\ sample}{Weight\ of\ sample} \times 100$$

2.7 Viscosity

The method of Onwuka [26] was employed. Sample (25 g) was dispersed in 250 ml distilled water in order to make 10% starch suspension. The mixture was stirred magnetically for 2 h at room temperature. The apparent viscosity of the dispersion was measured using Oswald type viscometer (model 350).

2.8 Gelation Capacity

The method of Onwuka [26] was used for the determination of gelation capacity of the flour blends. Sample suspensions of 2.0 – 20.0% (W/V) in 5.0 ml distilled water in test tubes were prepared. The sample test tubes were heated for 1.0 hour in a boiling water bath and then rapidly cooled under running cold tap water. The test tubes were further cooled for 2.0 hours at 4^0C. The gelation capacity was the least gelation concentration determined at that concentration when the sample from the inverted test tube did not fall down or slip.

2.9 pH

Sample suspension of 10.0 % (W/V) in distilled water was prepared. The suspension of the sample was thoroughly mixed in a warring micro-blender and then pH was measured with a good pH meter.

2.9.1 Determination of the proximate composition of the flour blends

Proximate analyses were carried out on the samples to determine the moisture, ash, crude fibre, fat, protein and carbohydrate contents using the method outlined by the Association of Official Analytical Chemists (AOAC, 2010).

2.9.2 Moisture content

Moisture content was determined by the hot oven method [27]. Sample was dried in the oven at 105^0C for six hours (until constant weight was obtained). The sample was then cooled in a desiccator and the dry weight of sample dish taken using a weighing balance.
The moisture content was calculated as:

$$\%\ Moisture = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

W_1= Initial weight of empty crucible
W_2= Weight of crucible +sample before drying
W_3= Final weight of crucible +sample after drying.

2.9.3 Ash content

The ash content was determined as described by the AOAC [27] method. One gram of the sample was weighed into a previously weighed dish. It was then heated in a Muffle furnace (CARBOLITE) at 550^oC and left for 12hrs until ashing was attained. The dish was cooled in a desiccator and weighed. The total ash was calculated as percentage of the original sample weight:

$$\%\ Ash = \frac{W_3 - W_1}{W_2 - W_1}\ X\ 100$$

Where: W_1 =Weight of empty dish
W_2 =Weight of empty dish + sample before drying
W_3 =Weight of empty dish + ash after ashing.

2.9.4 Fat content

The Soxhlet fat extraction method as described by the AOAC [27] method was used to determine the fat content. 250ml clean flask was dried in an oven at 110^0C for 30miuntes and transferred into a desiccator and allowed to cool. 2g of sample was weighed into an accurately labelled thimble and correspondingly pre-heated and cooled flask was weighed and labelled. The flask was filled with 300ml of petroleum ether (bp,40-60^0C).The extraction thimble was plugged lightly with cotton wool while the Soxhlet apparatus was assembled and allowed to reflux for 6 hours. Petroleum ether was collected into a flask for reuse after the removal of the thimble. The flask was then removed and dried at 105^0C for one hour when the petroleum ether was drained completely. The flask was transferred into the desiccator, cooled and then weighed. The fat content was calculated as:

$$\%\ Fat\ content = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times 100$$

2.9.5 Protein content

The method described by Onwuka [26] was used for protein content determination. The nitrogen content was determined by the micro-Kjeldahl apparatus equipped with Kjeldahl digester and distilling system. Sample (2 g) was weighed into Kjeldahl flask and 5 g of anhydrous sodium sulphate was added. Then, copper sulphate (1 g) was added. Into the mixture, 25 ml of concentrated Sulphuric acid was introduced and 5 glass beads was added for prevention of bumping during heating. In the fume cupboard, the mixture was heated very gently first and then increased with occasional shaking till solution assumed green colour (temperature of the digester was above 420^0C for about 30 minutes). The sample was cooled and every black particle that showed at the mouth and neck of the flask was washed down with distilled water. The sample was gently re-heated till the green colour disappeared and the cooled. The cooled sample (digest) was transferred into a 250 ml volumetric flask after several washings. The volume was made up to 250 ml mark with distilled water. Distillation was carried out using Markham distillation apparatus which was first steamed for about 15 minutes. Then, a 100 ml conical flask (that contained 5 ml of boric indicator such that the condenser tip was under the liquid) was placed under the condenser. The digest (5 ml) was pipetted into the body of the apparatus via a small funnel aperture and washed down with distilled water and followed by 5 ml of 60% NaOH solution. The mixture was steamed through for about 5-7 minutes to collect enough ammonium sulphate. The receiving flask was removed and washed down the tip of the condenser into the flask before the condensed water was removed. Then the solution in the receiving flask was titrated using 0.01N hydrochloric acid and the titre value was recorded. The blank was run along with sample. The nitrogen content and hence the protein content of the sample was calculated:

$$\%\ Nitrogen = \frac{Vs - Vb \times Nacid \times 0.014 \times 10 \times 100}{W}$$

Where V_s = Vol (ml) of acid required to titrate sample
V_b = Vol (ml) of acid required to titrate the blank
N_{acid} = normality of acid (0.1N)
W= Weight of sample in grams

$$\%\ Protein = \%\ Nitrogen\ X\ Conversion\ factor$$

Conversion factor = (100/%Nitrogen) = 6.25

2.9.6 Crude fibre content

The method as described by Onwuka [26] was followed to determine the fibre content. Two grams of defatted sample was added petroleum ether and boiled under reflux for 30 minutes with 200ml of a solution containing 1.25g of H_2SO_4 per 100ml solution.
The solution was then filtered through linen cloth on a fluted funnel and washed with boiling water until residue was no longer acidic. The residue was then transferred into a beaker and boiled for 30 minutes with 200ml. of a solution containing 1.25g of carbonate-free NaOH/100ml. Final residue was filtered through a thin but close pad of washed and ignited asbestos in Gooch Crucible. It was dried in an electric oven and weighed, incinerated, cooled and weighed. The crude fibre content (%) was calculated as:

$$\%\ \text{Crude fibre} = \frac{w_2 - w_1}{w_3} \times \frac{100}{1}$$

Where W_1 =Weight of crucible dish + ash
W_2 =Weight of crucible dish + residue
W_3 =Weight of sample

2.9.7 Carbohydrate content

The total carbohydrate content was determined by difference as:

Total carbohydrate (%) = 100 – (% Ash + % Fat + Crude fibre + % Moisture+ % Protein).

2.10 Determination of Vitamins (A and C) Contents of the Flour Blends

Vitamin A content

Vitamin A content of the sample was determined using the procedure described by Singh *et al*. [28]. The sample (5 g) was crushed in 10 ml acetone and a few crystals of anhydrous sodium sulphate were added and the mixture was allowed to settle. This process was repeated twice. The supernatant was decanted into a beaker and transferred to a separator funnel. Petroleum ether (10 ml) was added to the supernatant, mixed thoroughly and allowed to separate into two layers. The lower layer was

discarded and the upper layer was collected in a 100 ml volumetric flask and the volume was made up to 100 ml with petroleum ether. The optical density (OD) of the solution was determined at 452 nm, using petroleum ether as blank.

$$\beta - Carotene = \left(\frac{OD\ X\ 13.9\ x\ 10000\ x\ 100}{wt\ of\ sample\ X\ 560\ X\ 100}\right)$$

Where OD = Optical Density of the solution

$$\text{Vitamin A} = \left(\frac{\beta - \text{ Carotene (µg/100)}}{0.6}\right)$$

Vitamin C content

Vitamin C (ascorbic acid) contents of the samples were determined using the method for vitamin assay (inter-science publishers, 2006) as described by Agomuo *et al*. [29]. This method is based on the reduction of the dye (2, 6 dichloroindophenol) by an acid solution of ascorbic acid. The capacity of an extract of the sample to reduce a standard solution of the dye, as determined by titration is directly proportional to the ascorbic acid content. Sample (200 g) was blended with 6% HPO_3 to yield homogenous slurry. Ten grams (10 g) of the sample slurry was weighed into a 100 ml volumetric flask and diluted to 100 ml mark with 3% meta phosphoric acid solution (0.0033M EDTA). The diluted sample was filtered, pipette into a small flask and then titrated immediately with a standardized solution of 2, 6 dichloroindophenol to a faint pink end point which persisted for about 15 sec. The ascorbic acid content of the flour blend sample was calculated from the relationship below.

$$Ascorbic\ acid\ (mg/100g) = \left(\frac{V}{W} \times \frac{T}{1} \times \frac{100}{1}\right)$$

Where:

V= Volume of dye in ml used for titration of aliquot of the diluted sample.
T= Ascorbic acid equivalent of dye solution expressed in mg per ml of dye
W= Weight of aliquot sample titrated.

2.11 Determination of Minerals (zinc, iron, copper, potassium, calcium, magnesium, and phosphorous) Contents of the Flour Blends

2.11.1 Iron content

The iron content of the sample was determined using the method described by AOAC [28]. The ash (2 g) obtained from the ash analysis earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The iron content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 248.3 nm wavelength.

2.11.2 Calcium content

The calcium content of the sample was determined using the method described by AOAC [28]. The ash (2 g) obtained from the ash analysis earlier was boiled in in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The calcium content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 422.7 nm wavelength.

2.11.3 Magnesium content

The magnesium content of the sample was determined using the method described by AOAC [28]. The ash (2 g) obtained from the ash analysis earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The magnesium content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 285.2 nm wavelength.

2.11.4 Phosphorus content

The phosphorus content of the sample was determined using the method described by AOAC [28]. The ash (2 g) obtained from the ash analyses earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The total phosphorus content was obtained using ascorbic blue colour procedure of Okalebo *et al*. [30] by reading the absorbance at a wavelength of 880 nm on a Helia Gamma Spectrophotometer (Helios Gamma UV-vis Spectrophotometer, thermo Spectronic, Cambridge, UK).

2.11.5 Sodium and Potassium contents

The method as described by Onwuka [26] was followed to determine the sodium and potassium contents. Sample (1.0 g) was digested with 20.0 ml of acid mixture (650 ml of concentrated HNO_3;

80 ml PCA; 20 ml concentrated H_2SO_4). The aliquots of the diluted clear digest were taken for photometry using flame analyzer. Absorbance for sodium was read at 767nm while that for potassium was read at 589nm. The concentrations of sodium and potassium were obtained from the calibration curves obtained from the standards.

2.11.6 Zinc and Copper contents

The method as described by Onwuka [26] was followed to determine the sodium and potassium contents. Sample (1.0 g) was digested with 20.0 ml of acid mixture (650 ml of concentrated HNO_3; 80 ml PCA; 20 ml concentrated H_2SO_4). The digest was diluted with distilled water to 500 ml mark. The aliquots of the diluted clear digest were taken for photometry using Atomic Absorption Spectrophotometer. Absorbance for zinc was read at 435nm while that for copper was read at 485nm. The concentrations of zinc and copper were obtained from the calibration curves obtained from the standards.

3. RESULTS AND DISCUSSION

3.1 Functional Properties of the Flour Blends

The functional properties of arrowroot starch, wheat flour and their blends are presented in Table 1. Functional properties dictate the requirements and suitability of a flour blend for a given purpose. The bulk densities of the flours ranged from 0.37 g/cm^3 to 0.91 g/cm^3. Arrowroot starch (0.5 g/cm^3) was less dense than wheat flour (0.91 g/cm^3). The bulk density (i.e density without the influence of compression) of the flour blends decreased with increasing inclusion of arrowroot starch in the blends. Bulk density is a very complex property of great economic and

"Functional importance to flours. Flour blends with low bulk densities can be utilized in the formulations of complementary foods" [31,32,33]. "The lowering of bulk density of the flour blends resulting from the addition of arrowroot starch could also be advantageous in transportation, storability and selection of packaging material for the flour blends" [34]. "High bulk density is desirable in reducing shipping and packaging costs. High bulk density of flours indicate high fat assumption [35], mixing quality, ease of dispersibility and also suitability for use as thickeners in food products and food preparation such as in convalescent and child feeding since they help to reduce paste thickness, limit caloric and nutrient intake" [32,33]. "Foaming capacity of the flour blends gradually decreased with increased level of arrowroot starch in the blends. For example, at 10% arrowroot starch inclusion, the foaming capacity was 67.5% but it was 21.5% at 60% arrowroot inclusion. Foaming capacity of a flour measures the amount of interfacial area created by whipping the flour" [36]. "Good foam capacity and stability are desired attributes for flours intended for use in the production of various baked products such as angel cakes, muffins, *akara*, cookies, etc., and also perform as functional agents in many other food formulations" [36]. "The same trend was observed with foam stability. At 10% arrowroot starch addition, flour blends gave 73% foam stability while 60% of arrowroot starch inclusion, gave 20.8% foam stability. Foam stability is a measure of the time required to lose 50 percent of the volume from the foam" [37]. "Protein majorly aids foaming. Foaming capacity and stability depend on the interfacial film formed by the proteins. Although, there was a gradual reduction in foaming capacity and stability, the flour blends could find application in baked and confectionary products. The emulsion capacity and emulsion stability of arrowroot starch were 18.6% and 12.2% respectively while those of the flour blends decreased with increasing levels of arrowroot starch. The lower emulsion capacity could be as a result of lower protein content" [38]. The relatively low levels of emulsion capacity and stability of the flours suggested that arrowroot starch and wheat flour blends would not be desirable for preparing committed meat products such as sausages, cake battlers, mayonnaise and salad dressing without improvers. The high emulsifying property exhibited by wheat flour could be due to the type, incinerations and solubility of the protein [39,38]. "Arrowroot starch had higher ability to absorb water than oil. The water absorption capacity (WAC) of arrowroot starch (ARS) of 106.7% was higher than that of wheat flour (WF) of 101.7%. However, the oil absorption capacity (OAC) (107%) for wheat flour (WF) was higher than that of arrowroot starch (94.7%). Thus, while water absorption capacity (WAC) decreased, oil absorption capacity increased with increased concentration of wheat flour in the flour blends. The higher hydrophilic constituents of arrowroot starch in comparison to wheat flour would contribute to its higher water absorption capacity than wheat flour. Water absorption is mainly dependent on the amount and nature of the hydrophilic constituent and to some extent on pH and nature of protein" [40,41,36].

Table 1. Functional properties of the flour blends of arrowroot starch and wheat flour

ARS: WF	Bulk density (g/cm3)	Foaming capacity (%)	Foaming stability (%)	Emulsion capacity (%)	Emulsion stability (%)	Water absorption capacity (%)	Oil absorption capacity (%)	Least gelation capacity (%)
100:0	0.50^{b}	30.00^{f}	27.0^{g}	18.27^{h}	12.39^{h}	106.77^{a}	94.70^{f}	10.00^{a}
0:100	0.91^{a}	82.00^{a}	80.0^{a}	54.85^{a}	60.29^{a}	101.41^{d}	107.80^{a}	6.00^{b}
10:90	0.37^{c}	67.50^{b}	73.00^{b}	50.90^{b}	55.40^{b}	101.64^{d}	106.22^{b}	10.00^{a}
20:80	0.83^{a}	57.40^{c}	60.90^{c}	47.41^{c}	50.54^{c}	102.74^{c}	102.20^{c}	10.00^{a}
30:70	0.76^{a}	44.60^{d}	58.40^{d}	43.46^{d}	45.26^{d}	102.81^{c}	101.30^{c}	8.00^{b}
40:60	0.75^{a}	36.00^{e}	45.80^{e}	40.27^{e}	40.98^{e}	103.48^{b}	97.30^{d}	8.00^{b}
50:50	0.71^{a}	29.00^{g}	33.30^{f}	36.67^{f}	36.18^{f}	103.86^{b}	94.70^{e}	6.00^{b}
60:40	0.66^{b}	21.20^{h}	20.80^{g}	32.94^{g}	31.39^{g}	104.62^{b}	107.54^{a}	6.00^{b}

Values are means of 3 replications. Means within a column with the same superscript were not significantly different (p<0.05)
Where ARS = Arrowroot starch
WF = Wheat flour

Table 2. Proximate and vitamin composition of the flour blends of arrowroot starch and wheat flour

ARS: WF	Protein (%)	Ash (%)	Moisture (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)	Vitamin C (mg/100g)	Vitamin(mg/10g)
100:0	6.5	3.6	10.5	5.5	4.2	69.7	2.07	0.66
0:100	11.28	1.37	4.3	1.63	2.61	78.81	ND	ND
10:90	11	1.6	5	2	2.8	77.6	2.8	0.6
20:80	10.5	1.8	5.5	2.7	3	76.5	1	0
30:70	9.5	2	6.2	3	3.1	76.2	1	0.5
40:60	9.2	2.5	7	3.4	3.4	74.5	0.9	0.4
50:50	8.5	2.8	7.6	4.1	3.7	73.3	0.8	0.3
60:40	8	3	8	4.6	3.9	72.5	0.7	0.2

Values are Means of 3 replications. Means within a column with the same superscript were not significantly different (P >0.05)
Where ARS = Arrowroot starch.
WF = Wheat flour

"The arrowroot starch and wheat flour blends may be useful in food formulations such as bakery products (i.e doughs, doughnuts, pancakes, sausages etc.) and custards where hydration is required to improve handling characteristics" [41]. "The low fat binding capacity of arrowroot starch suggests the presence of large proportion of hydrophilic groups as compared to the hydrophilic groups in the wheat flour. The mechanism of fat binding of proteins appears to be affected by lipid protein complexes. The availability of lipophilic groups may also contribute to higher binding of fat to protein. Moreover, oil absorption capacity is useful in structure interaction in food especially in flavour retention and improvement of palatability and extension of shelf life particularly in bakery or meat products" [42,38, 1]. The least gelation concentration of the arrowroot starch and wheat flours were 6 and 10% respectively and a range of 6 - 10% was obtained for the flour blends. Sathe *et al*., [43] associated the variation in the gelling properties of flours to the relative variations of the different constituents such as protein, carbohydrate and lipids. Arrowroot starch on the other hand contained higher amount of starch than wheat flour which enhanced its gelling ability. This result suggested that arrowroot starch and wheat flour blends of the ratios of 50:50 and 60:40 would be better gelling agents, and would be useful in food systems such as puddings, porridge and snacks which require thickening and gelling as in use in some parts of the country.

3.2 Proximate and Vitamin Composition of the Flour Blends

The proximate and vitamin composition of arrowroot starch, wheat flour and their blends are given in Table 2.

The protein contents of arrowroot starch (ARS) and wheat flour (WF) were 6.50 and 11.28%, respectively. The protein contents of the blends decreased steadily with increased level of arrowroot starch (ARS) in the blends. This was probably due to addition-effect, since wheat contained more protein than arrowroot starch. These flour blends of low protein contents could be utilized in food preparations for consumers at risk of celiac disease due to its low gluten contents [1]. However, arrowroot starch had higher amount of ash (3.60%) than wheat flour (1.37%). The ash content of the blends increased with the increasing level of arrowroot starch level. The result is in agreement with the report of Sudaryati *et al*., [44]. Ash is an indication of mineral content of a food product [45]. This showed that the blends contained higher minerals than wheat flour. The moisture content of wheat flour was lower (4.30%) than that of arrowroot starch (10.50%). The lower moisture contents of the flour blends wound improve their storage stability [1]. Moisture influences many chemical and biochemical reactions in a food material. The arrowroot starch had fat content of 5.50% which was higher than that of wheat flour (1.63%). The fat contents of the blends ranged between 2.0 and 4.6%. The fat content of the blends increased as the level of arrowroot starch increased in the blend, probably due to the higher fat content of arrowroot starch. The arrowroot starch had higher levels of crude fibre than wheat flour. The crude fibre content increased from 2.61% in wheat flour to 4.6% in the blend that contained 60% arrowroot starch. The importance of fibre in human nutrition has been widely documented: Studies have it that increased intake of dietary fibre significantly reduces the risks for obesity, type-2 diabetes, constipation, coronary heart diseases and colon cancer [1].

Table 3. Mineral composition (mg/100 g)of the flour blends of arrowroot starch and wheat flour

ARS:WF	Zn	Fe	Cu	Na	K	Ca	Mg	P
100:0	3.3	1.2	5	10.4	16.2	5.2	4.9	45
0:100	1.6	0.3	2.6	43	74.6	33.2	13.6	317.3
10:90	1.8	0.4	2.8	40	69.4	31.4	12.1	291.2
20:80	1.9	0.5	3.2	38	64	28.2	11	261.7
30:70	2.1	0.6	3.5	34	58.4	26.1	10.1	237.2
40:60	2.3	0.8	3.8	30	51	21.8	9	208
50:50	2.4	0.9	3.9	25	46.5	19	8.1	182.7
60:40	2.7	1	4.3	24	40.3	15.9	7.5	155.8

Values are Means of 3 replications. Means within a column with the same superscript were not significantly different (P >0.05)
Where ARS = Arrowroot starch
WF = Wheat flour

The carbohydrate content of arrowroot starch of 69.70% was lower than that of wheat flour of 78.89%. This may be due to the higher contents of other components in arrowroot starch, especially that carbohydrate was obtained by difference. Arrowroot starch contained 2.01 mg/100g vitamin C and 0.66 mg/g vitamin A. These constituents were not detected in wheat flour. Trace amounts of these vitamins were found in the flour blends. Vitamin A plays an important role in vision, bone formation, cell division and differentiation [46,1]. "It also helps to regulate immune system which helps to fight infections by making white blood cells that destroy harmful bacteria and viruses. Vitamin C is needed for collagen production, the substance which gives structure to muscles, vascular tissues, bones and cartilages for the health of teeth and gums while assisting in iron absorption" [46,1].

3.3 Mineral Composition of the Flour Blends

The mineral composition of arrowroot starch, wheat flour and their blends are presented in Table 3. The arrowroot starch and wheat flour contained 3.3 and 1.6 mg/100g Zinc (Zn) respectively. "A range of 1.6 to 2.7mg/100g for Zn contents was obtained for the flour blends. The Zn contents of the flour blends increased steadily with the increased level of arrowroot starch, due to its higher content of Zn than wheat flour. Zn is needed by over 300 enzymes of which are involved with metabolism of blood glucose and are so important that lack of zinc can cause type 1 and type 2 diabetes" [47,48]. Meals rich in zinc, protect the body from incident of diabetes and reduces the inflammatory signals that damage the cells (Jason *et al*., 1999). Deficiency of zinc in our diet can lead to poor storage and release of insulin, poor appetite, dermatitis, alopecia, hypogonadism, impaired immune function [48, 49].

Arrowroot starch contained higher amounts of iron (Fe) and copper (Cu) but lower levels of sodium (Na) and potassium (K) than wheat flour. From the results, as the iron and copper contents increased with increased levels of arrowroot starch in the blends, the levels of Sodium (Na), calcium (Ca), Mg and potassium (K) decreased steadily. The major nutritional problems affecting people in many developing countries include protein energy malnutrition (PEM) and iron deficiency anemia (IDA). Intake of iron can be increased by judicious selection of iron rich plant foods in all meals and by consuming iron fortified breakfast cereals and paste when possible. "The level of potassium (K) in the blends is almost twice that of sodium (Na). American diabetes association (2002) has suggested that the amount of sodium in the diet should be limited since sodium helps to increase blood pressure and the tendency to retain fluid. Potassium is frequently supplied in limited quantities and is usually lost by persons taking diuretics. For these reasons, the diet which contains low levels of Na and high levels of K is encouraged. Diets high in K are associated with lower blood pressure thereby reducing the risk of heart disease and stroke" [50]. Thus with this revelation from the results, consumption of bakery products containing arrowroot starch (i.e. characteristic of low sodium content) in disease conditions such as hypertension and cardiac should be encouraged. According to Busch [51] food which contains 140mg sodium or less is considered as low sodium food. "The levels of calcium (Ca) in the blends (15.9 – 31.4 mg/100gm) were higher than that of arrowroot starch (5.2 mg/100). Calcium is very important for strong bone formation, essential for maintaining total body health, proper functioning of muscles and nerves, and for blood clothing" [52,1]. Arrowroot starch and wheat flour contained phosphorus (P) content of 45 mg/100 and 317.3 mg/100g respectively. "The high content of Phosphorus in wheat could significantly ($P < 0.05$) improve the level of the mineral element in the blends. Phosphorus is needed for formation, maintenance and growth of bones. It is also useful in tooth formation and in metabolic reactions, metabolism of carbohydrate and fats, lipid transport and acid – based balance" [Jason et al., 1999,[1].

4. CONCLUSION

Flour blends, formulated with arrowroot starch and wheat flour at varying ratios were developed; and they exhibited various functional and nutritional properties that projected them as alternatives to wheat flour in utilizations for various wheat flour based products such as bread, cakes, biscuits, *chin chin,* doughnuts, cookies, noodles, confectioneries, snack foods, pasta, puddings, custards, doughs, sauces, thickeners, complementary foods etc. This study has revealed the expandable utility of arrowroots in food industries, and provides a veritable way to cut down depletion of our foreign exchange

reserve through reduced importation of wheat flour into Nigeria. Of course, by employing such composite flour technology, cost of nutritious wheat flour based products will be affordable, and also indigenous agriculture and employment opportunities will be promoted in Nigeria, thereby growing the weak economy.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Okereke GO, Igbabul BD, Ikya JK. Evaluation of breads made from wheat flour, modified white yam/trifoliate yam/sweet potato starches and Moringa oleifera seed flour blends. International Journal of Food Science and Nutrition. 2021;6(2):107-119.
2. Olaoye OA, Onilude AA, Idowu OA. Quality characteristics of bread produced from composite powders of wheat, plantain and soybeans. African Journal of Biotechnology. 2006;5 (11):1102-1106.
3. Oyeku OM, Kupoluyi CF, Osibanjo AA, Orji CU, Ajuebor FN, Ajiboshin IO, Asiru WB. An economic assessment of commercial production of 10% Cassava – wheat composite flour bread.Journal of Indust. Res. Technol. 2008;2(1):13-20.
4. Ade-Omowaye BIO, Akinwande BA, Bolarinwa IF, Adebiyi AO. Evaluation of tigernut (*Cyperus esculentus*)–wheat composite flour and bread. Afri. J. Food Sci. 2008;2:087-091.
5. Adeleke RO, Odedeji JO. Acceptability studies on bread fortified with tilapia fish flour. Pakistan J. Nutr. 2010;9(6):531-534.
6. Sanful RE, Darko S. Utilization of soybean flour in the production of bread.Pakistan Journal of Nutrition. 2010;9(8):815-818.
7. Abdelghafor RF, Mustafa AI, Ibrahim AMH, Krishnan PG. Quality of bread from composite flour of sorghum and hard white winter wheat. Adv. J. Food Sci. Technol. 2011;3(1):9-15.
8. Onuegbu NC, Ihediohanma NC, Odunze OF, Ojukwu M. Efficiency of wheat: maize composite flour as affected by baking method in bread and cake production. Sky J. Food Sci. 2013;2(8):005-013.
9. Udofia PG, Udoudo PJ, Eyen NO. Sensory evaluation of wheat-cassava-soybean composite flour (WCS) bread by the mixture experiment design. African Journal of Food Sciience. 2013;7(10):368-374.
10. Igbabul BD, Num G, Amove J. Quality Evaluation of Composite Bread Produced from Wheat, Maize and Orange Fleshed Sweet Potato Flours. American Journal of Food Science and Technology. 2014;2(4):109-115.
11. Nwosu JN, Owuamanam CI, Omeire GC, Eke CC. Quality parameters of bread produced from substitution of wheat flour with cassava flour using soybean as an improver. Am. J. Res. Commun. 2014;2(3):99-180.
12. Khali A, Mansour E, Dawodu FM. Influence of malt on rheological and baking properties of wheat-cassava composite flours. Dept. of Food Science and Technology, Faculty of Agriculture, Menosiya University, Shibin El-kom, Egypt;1999.
13. Damak AMA. Production and quality evaluation of bread from tacca leontopetaloides (Mulehem) starch and wheat flour blends. M.Sc. Thesis. Kogi State University, Anyigba,, Nigeria;2014.
14. Iwe MO, Okereke GO, Agiriga AN. Production and Evaluation of bread made from modified cassava starch and wheat flour blends. Agrotechnology. 2014;4:133.
15. Peter RS, Malcom JH, Vieno P, Ann-Maija L, Kurt DB, Annica AMA, Per A, Marlann R, Zoltan B, Jane LW. Natural Variation in Grain Composition of Wheat and Related Cereals;2013.
16. Peter RS, Sandra JH. The Contribution of Wheat To Human Diet and Health. Food and Energy Security. 2015;4(3):178-202.
17. Ryan R, Ms RD. 19 Foods That Are High in Starch. Nutrition News Letter;2017.
18. Xie WQ, Gong YX, Yu KX. Qualitative Analysis of Total Starch Content in Wheat Flour by Reaction Headspace Gas Chromograph. Anal Bioanalytical

Chemistry. 2017;409(22):5195-5200.
19. Lawal OS. Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acetylated and acid-thinned new cocoyam (Xanthosoma sagittifolium) Starch. Food Chemistry. 2004;87:205–218.
20. Shweta S, Katewa SS. Nutritional evaluation of some wild roots and tubers from tribal areas of Rajasthan. Ethno botany and Agrostology, Department of Botany College of Science, Mohan Lal Sukhadia University, Udaipur, Rajasthan India;2007.
21. Olojede AO, Akinpelu AO, Dalyop TY, Lenka D, Iluebbey P, Dixon AGO. Survey of production, utilization and proximate composition of some minor root and tuber crops in Nigeria: Niger Agric Journal. 2009;40(1):125-131.
22. Baguma Y, Kawuki R. Cassava Industrialization in ACP Region – Myth or Feasible Option?. CTA, Wageningen, Netherlands;2006.
23. Ukpabi UJ, Ukenye E, and Olojede AO. Raw material potentials of Nigerian wild Polynesian arrowroot (*Tacca leontopetaloides*) tubers and starch. Journal of Food Technology. 2009;7 (4):135-138.
24. Kristina AH, Penny MK. Effects of whole grains on coronary heart disease risk. Current Atherioclerosis Reports. 2010;12(6):368-376.
25. Akhtar S, Anjum FM, Anjum MA. Micronutrient fortification of wheat flour: Recent development and strategyies. Food Research International. 2011;44(3):652-659.
26. Onwuka GI. Food Analysis and Instrumentation: Theory and Practices. Naphthali Prints, Surulere, Lagos. 2005;104-128.
27. AOAC. Official Methods of Analysis, 18th edn. Association of Official Analytical Chemists (A. O. A. C) Washington DC;2010.
28. Singh MK, Paul J, De T, Chakraborti T. Bioactivity guided fractionation of Moringa oleifera Lam. flower targeting Leishmania donovani. Indian J. Exp. Biol. 2015;53:747–752.
29. Agomuo JK, Alaka IC, Akajiaku LO, Taiwo M. Effect of traditional methods of de-bittering on the proximate and vitamin contents of fresh and squeezedwashed bitter leaf. International Journal of Nutrition and Food Sciences. 2015;4(1):103-110.
30. Okalebo JR, Gathua KW, Woomer PL. Laboratory Methods for Soil and Plant Analysis: A Working Manual. TSBF, Nairobi;2002.
31. Akapata MI, Akubor PI. Chemical composition and selected functional properties of sweet orange (*Citrus sinensis*) seed flour. Plant Food Hum Nutr. 1999;54:353–362.
32. Chandra S, Singh S, Kumari D. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology. 2015;52(6):3681–3688.
33. Olosunde OO, Adedeji TO, Amanyunose AA, Oluoti OJ. Development and quality evaluation of a typical flour blend from Orange –fleshed Sweet potato (Ipomea batatas) and Soy-bean (*Glycine max* L). Journal of Nutritional Health & Food Engineering. 2020;10(1):23–29.
34. Omimawo IA, Akubor PI. Food Chemistry (Integrated Approach with Biochemcial background). 2nd edn., Joytal Printing Press, Agbowo, Ibadan, Nigeria;2012.
35. Kalyankar SD, Deshmukh MA, Chopde SS, Khedkar CD, Lule VK, Deosarkar SS. Milk Powder, In: Encyclopedia of Food and Health. Editor(s): Benjamin Caballero, Paul M. Finglas, Fidel Toldrá, Academic Press. 2016;724-728.
36. Awuchi CG, Igwe VS, Echeto CK. The functional properties of foods and flours. International Journal of Advanced Academic Research, Sciences, Technology and Engineering. 2019;5(11):139–160.
37. Mauer L. Encyclopedia of Food Sciences and Nutrition (Second Edition), Science Direct;2003.
38. Iwe MO, Onyeukwu U, Agiriga AN. Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. Cogent Food and Agriculture. 2016;2.
39. Gaikwad BV, Koli JM, Sharangdher ST, Patange SB. Physicochemical and functional properties of chitosan extracted from crab (*Scylla serrata*) by different chemical processing sequence. International Journal of Sciences and Applied Research. 2015;2(7):77-85.
40. Li-Chan ECY, Nakai S, Wood DF. Relationship between functional (fat binding, emulsifying) and physicochemical

properties of muscle proteins; Effects of heating, freezing, pH and species. Journal of Food Science. 2006;50(4):1034-1040.
41. Okereke GO. Modification of starches from selected cassava species and application in baked goods. M.Sc. Thesis. Michael Okpara University of Agriculture, Umudike;2012.
42. Ikegwu OJ, Okechukwu PE, Ekumankama EO. Physicochemical and pasting characteristics of flour and starch from Achi (*Brachystegia eurcoma*). Seed. Journal of Food Science. 2010;8:58–66.
43. Sathe S, Desphande S, Salunkhe K. Dry beans of phaseolus. A review. Part 1. Chemical Composition: Proteins. Critical Reviews in Food Science and Nutrition. 1984;20(1):1-46.
44. Sudaryati E, Nasution E, Ardiani. Nutritional Quality of Bread from Mixture of Arrowroot flour (*Marantha arundinacea* L.) and Wheat Flour. Advances in Health Sciences Research, volume 9, 2nd Public Health International Conference (PHICo 2017);2018.
45. Igbabul B, Ogunrinde MD, Amove J. Proximate, Micronutrient Composition, Physical and Sensory properties of Cookies Produced from Wheat, Sweet Detar and Moringa Leaf Flour Blends. Current Research in Nutrition and Food Science. 2018;06 (3):690-699.
46. Babarinde GO, Adeyanju TA, Ogunleve KY, Adegbola GM, Ebun AA, Wadele D. Nutritional composition of gluten-free flour from blend of fonio (Digitaria ibunia) and pigeon pea (*Cajanus cajan*) and its suitability for breakfast food. J. Food Sci. Technol. 2020;57(10):3611–3620.
47. Jansen AAJ, Parkinson S, Robertson AFS. Food and Nutrition in Fuji: A Historical Review vol.1. Published by the Dept. of Nutrition and dietetics, Fuji school of Medicine and the Institute of Pacific studies of the University of South Pacific. 1990;479.
48. Huang L, Drake VJ. Zinc. Advances in Nutrition. 2015;6(2):224 - 226.
49. Daniels L, Williams SM, Gibeon RS, Taylor RW, Sammon S, Heath AM. Modifiable 'Predicyiors' of Zinc Status in Toddlers. MDPI. 2018;10(3):306.
50. Palmer BF, Clegg DJ. Blood Pressure Lowering and Potassium Intake. Journal of Human Hypertension. 2020;34:671–672.
51. Busch S. What is considered low sodium on a nutrition panel? Healthy Eating, SFGATE Newsletter;2018.
52. Inyang UE, Effiong CF, Edima-Nya AP. Physical Properties, Nutritional Composition and Sensory Evaluation of Cookies Prepared from Rice, Unripe Banana and Sprouted Soybean Flour Blends. International Journal of Food Science and Biotechnology. 2018;3(2):70-76.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/86203