ISSN: 2338-1345 – Vol. 12(1) 6-20 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Quality Evaluation of Bread Produced from Blends of Wheat and Acha Flour Complemented with Defatted Bambara Groundnut Flour.

Ayo, J. A[1], Esan, Y. O[2], Okpasu, A[1], Gbuusu, B[3], Mohammed, Z. A[4] and Tyvakase, T[1]

[1]*Department of Food Science and Technology, Federal University Wukari, Nigeria*
[2]*Department of Food Science and Technology, Joseph Ayo Babalola University, Ikeji Arakeji, Ilesa, Nigeria*
[3]*Department of Food Science and Technology, University of Mkar, Igboko, Nigeria*
[4]*Department of Home Science, Nasarawa State University Nigeria*
**Corresponding author's E-mail address: yoesan@jabu.edu.ng*

Received: 19 May 2024 | Revised: 13 June 2024 | Accepted: 28 June 2024

Abstract— The study investigated the quality of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour (DBGNF). Chemical composition, physicochemical properties and sensory evaluation were carried out on the breads while the flour blends were assessed for functional properties. DBGNF was incorporated into wheat-acha flour blends at 5, 10, 15, 20 and 25% respectively with 100% wheat and acha flour breads as controls. Moisture, crude protein, crude fibre, and ash content of the breads increased from 24.17 to 27.20, 11.69 to 13.12, 0.26 to 0.77 and 1.06 to 1.19% respectively while crude fat and carbohydrate content decreased from 8.67 to 7.66% and 54.20 to 50.20% with increased level of DBGNF. Phosphorus and iron increased from 162.2 to 229.82 and 0.87 to 1.24 mg/100g whereas zinc decreased from 0.52 to 0.09 mg/100g with addition of DBGNF. Phenol, flavonoid and carotenoid contents decreased from 45.50 to 41.96, 28.74 to 19.68 and 0.20 to 0.02 mg/100g respectively. The foaming, emulsifying, swelling, water and oil absorption capacity of the flour blends increased while bulk density decreased with addition. Vitamins B1 and B2 content decreased with increasing DBGNF inclusion. The loaf weight increased while loaf volume and loaf volume index decreased with increasing level of DBGNF. Bread sample containing 10% DBGNF was not significantly different from the 100% wheat bread in terms of sensory attributes. The research showed that the addition of DBGNF improved the functional quality and nutrient composition of the composite bread and the sample containing 10% DBGNF was the most preferred.

***Keywords*— false yam (*Icacina oliviformis*) tuber, boiling, nutrients, egg production, chicken.**

INTRODUCTION

Bread is one of the popular daily staple foods in many countries, with refined wheat flour commonly used in most white bread formulations (Issaoui *et al*., 2021). Bread is principally produce from mixture of wheat flour, sugar, baking fats, yeast, salts and water, fermented and baked. Wheat bread is high in carbohydrate, hence energy given food. However, it is relatively low in quantity and quality in terms of protein content (Seal *et al*., 2021). Nowadays with increasing health consciousness, consumers generally tend to purchase high nutritional valued foods (Dhen et al., 2018; Hsieh *et al*., 2017). This trend is also reflected in the bakery market, where products containing ingredients that have beneficial effects on health are attracting consumers' attention (Sajdakowska *et al*., 2021). Bread baking is a fickle process where the composition, structure, and physical properties of bread change during the baking process. Baking time, temperature and heating rate, source of heat, and oven air relative humidity are the prime factors that affect the quality of bread during the baking process.

Bread quality mainly depends on four parameters, i.e., texture, moisture content, bread surface color, and structure (volume, shape, and size) of the bread (Panirani et al 2023). Bambara groundnut (Vigna subterranea) is an indigenous African crop which produces an almost balanced food. It is a drought tolerant and an easy-to-cultivate crop which makes very little demand, if at all, on the soil (Effa and Uko, 2017). According to Adedayo (2017), it grows in soils of pH 5.0–6.5 with 600–1200 mm annual rainfall. It is very adaptable to hot temperatures but it also tolerates rainfall.

Hence, it is not prone to the risk of total crop failure, especially in low and uncertain rainfall regions. It serves as an important source of protein in the diets of a large percentage of the population in Africa, particularly to poorer people who cannot afford expensive animal protein, by being among the least expensive, most easily stored and most easily transported non-processed protein sources for rural and urban dwellers. It is ranked the third most important grain legume after groundnut (Arachis hypogaea L.) and cowpea (Vigna unguiculata) (Adedayo, 2017). Nutritionally, most researchers agree that its lysine is relatively high, while methionine and calcium are low (Effa and Uko, 2017). Studies by Effa and Uko (2017) had revealed that, nutritionally, it contains 17.4% protein, 53.1% carbohydrate, 6.1% fat, 6.1% fibre, 3.4% ash, 0.098% calcium, 0.007% iron, 1.2% potassium and 0.003% sodium.

Acha (Digitaria exilis) originated in West Africa. The plant acha, belongs to the monocotyledonous family the graminae family. As an annual grass, it is about 45 cm height with tiny, slightly elongated, yellow grains. It grows on poor sandy soil, which often will not support the growth of some of the more popular cereals (Ayo *et al*., 2018). It is an important crop in Southern Mali, Western Burkina Faso, Eastern Senegal, North East Nigeria and Southern Niger. D. exilis is commonly called acha, hungry rice or fonio (Ayo *et al*., 2018). It is a large genus and includes two cultivated West African species, which include Digitari exilis and Digitaria Ibura, the former being very close to the Wild West African specie Digitaria longiflora.

Acha is considered as one of the nutritious grains; its seeds contain 8.79% protein and may be up to 11.89% in some black fonio sample (Ayo et al., 2021). The grains are rich in amino acids; leucine (9.8%), methionine (5.6%) and valine (5.8%) and cysteine which are vital to human health but deficient in today's major cereals (Ayo et al., 2018). Acha grains contain substantial minerals (mostly iron, calcium and phosphorus) about 5% dry matter. The grains are commonly used in the production of local foods ('Caoscaus', 'gwate' or 'Tuwo') in some countries in West Africa and could be mixed with other cereal flours to make cookies, candy and fermented beverages

Wheat (Triticum aestivum) is known as one of the most important cereal crops and is extensively grown worldwide (McGuire, 2015). Wheat contributes to 30% and 50% of the production and global grain trade respectively (Akter and Rafigul, 2017). Wheat is also known as a staple food in more than 40 countries of the world. Wheat provides 82% of basic calories to the world population (Estrada et al., 2013). Wheat-based foods are rich in fiber. Therefore, its positive effects on controlling cholesterol, glucose, and intestinal functions in the body were observed (Giraldo et al., 2019). Primarily, wheat is being used to make Bread but it also contributes to other bakery products.

The high prices of wheat in the global markets have forced bakers and producers to search for alternative means of raw materials for their products. This has prompted the need for research of these alternative raw materials which have become burdensome and worrisome especially based on the low technological advancement of Africa compared to the developed countries (Ferronato and Torretta, 2019). The necessity became eminent based on the high cases of malnutrition and nutrient deficiency diseases domiciled on the African continent.

Wheat which is the main raw material for bread production is expensive and usually imported. Acha, an underutilized cereal which could be a possible alternative is relatively poor in nutrients and Bambara groundnut which can complement the nutrients deficiency is characterized by beany smell and high in anti-nutrients.

The acceptability of defatted bambara groundnut and wheat-acha flour blends in foods particularly in the production of bread will improve the nutritional intake (protein content), minimize the dependence on imported wheat, provide food varieties for people with celiac disease and consequently encourage optimum utilization of other staple crops in the food industry. Hence, this study to evaluate the quality of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour becomes imperative.

MATERIALS AND METHODS

A. Materials

Acha grains, bambara groundnut, wheat flour (golden penny), sugar (golden penny), Margarine (Simas), salt (Dangote table salt), Potable water, and instant dry yeast (STK royals) were purchased at New Market, Wukari, Taraba state. The reagents used were all of analytical and chromatography grades.

B. Preparation of Bambara groundnut flour

Bambara groundnuts seeds were cleaned manually to remove all foreign materials such as dust, dirt, and immature seeds. The seeds were soaked in distilled water for 24 hours, drained and dried at 50ºC for 6 hours then milled into powder (0.60 mm) form using (Braun KMM 30 mill), type 3045, Combi Max (Germany). The flour was defatted in Soxhlet apparatus, using Ethanol 99% for 9 hours at room temperature (25 ± 2°C). The defatted flour was air dried at room temperature and stored in an airtight polyethylene bag (Yang *et al*., 2022).

C. Preparation of defatted Bambara groundnut flour

Bambara groundnut flour 100 g was soaked in 600 ml of 99% ethanol for 16 hours and followed by soxhlet extraction (material to solvent ratio were 1:5) at extraction temperature 60°C. In order to remove all ethanol, defatted bambara groundnut flour was dried in an oven at 60°C for 12 hours. After that, it was ground in the grinder and sieved with 200 nm mesh screen to obtain a defatted flour in a powdery form (Zar Zar *et al*., 2017).

D. Preparation of acha flour

Acha flour was prepared according to the procedure reported by Olagunju *et al*., (2020). The acha grains were washed with tap water to separate stones and sand, then, they were dried in the cabinet dryer at 50ºC for 6 hours. The resultant dried acha was milled and sieved into flour using the hammer mill with 0.2 mm screen size.

E. Bread production

The method of Olaoye and Obidegwe (2018) was used for the production of bread from the different flour blends, involving a bulk fermentation process. A quantity (100g) each of the flour samples were weighed and an addition of required amount of water and other ingredients was done to obtain dough and kneaded on a pastry-board to smoothen.

The dough was initially fermented for 1 hour at 30°C before subsequently kneaded to expel carbon dioxide and then, it was tightened-up to ensure improvement in the textural properties of the bread. The dough was sized and molded into the baking pans for final proofing at 30°C for 2 hours. Baking of the dough was carried out in a forced air convection electric oven (380V, ROHS Deck Baking Oven, Hangzhou 311121, China) at 230°C for 30 minutes.

F. Formulation of composite flour blends

The blends of wheat and acha flour were prepared with increasing level of acha flour (0, 5, 10, 15, 20, and 25%) addition into the wheat flour as preliminary work to determine the acceptable recipe for the production of wheat-acha bread (Table 1). Defatted bambara groundnut flour was substituted into the acceptable recipe of wheat-acha flour blend at 0, 5, 10, 15, 20 and 25% as shown in Table 2. The flours were thoroughly mixed to obtain a homogenous blend and stored at ambient temperature (30±2°C) in air tight container until required for bread production.

G. Determination of the chemical composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Determination of moisture content

The moisture content was determined using the method of AOAC, (2015). A clean dish with a lid was dried in an oven at 100°C, it was cooled in a desiccator and weighed. Five grams of the sample was weighed into the dish. The dish with its content was put in the oven at 105°C and dried to a constant weight. The moisture content was calculated as:

$$\%Moisture\ content = \frac{(Weight\ of\ dish + sample\ after\ drying) - (Weight\ of\ empty\ dish)}{original\ sample\ weight} * 100$$

Determination of ash content

The ash content was determined by the standard method of AOAC, (2015). Two grams of the sample was weighed into a dried pre-weighed porcelain crucible. The sample was transferred into a preheated Muffle furnace (carbolite, Bamford S30AU) and heated at 550°C for 2 hours. The ash was then removed, cooled in a desiccator and weighed. The percentage ash was calculated as:

$$\%Ash\ content = \frac{(Weight\ of\ crucible + sample\ after\ ashing) - (Weight\ of\ empty\ crucible)}{original\ sample\ weight} * 100$$

Determination of crude protein content

The protein content was evaluated using Kjedahl method as described by AOAC (2015) as reported by Czubaszek *et al*. (2021). Two grams of samples was put into kjeldahl flask and sodium sulphate (7.68g), copper sulphate (0.28g), Selenium dioxide (SeO4) (0.04g) and 25ml of concentrated H2SO4 were added. The flask was heated on a heating mantle, until the solution became clear.

The digest was transferred into distillation flask, 100ml water and 15ml NaOH was added. The 3 drops of methyl red indicator were put into the distilling flask. They were boiled in the distillation apparatus to liberate ammonia into the receiving flask containing 50ml of 2% boric acid. This was titrated against 0.01N Hydrochloric acid (HCl). The protein was calculated as:

$$\%Nitrogen = \frac{Titrate \times 0.0014 \times Dilution\ factor}{original\ sample\ weight} * 100$$

$$\%Protein\ content = Nitrogen \times Conversion\ factor\ (6.25)$$

Determination of crude fiber content

The fiber content of the sample was determined according to the method of AOAC (2015). Two (2) gram of the prepared samples were extracted using diethyl ether. This was digested and filtered through the California Buckner system. The resulting residue was dried at 103±2°C in an oven (uniscope 5m 9053 laboratory oven) for about two hours and cooled in desiccators. The weighed residues was then transferred into a muffle furnace and ignited at 600 ± 100°C at 30 minutes, cooled in desiccators and reweighed. The percentage crude fiber was calculated as:

$$\%Crude\ fiber = \frac{M_{dry} - M_{ash}}{M_{sample}} * 100$$

Mdry = sample weight after drying
Mdry = sample weight after ashing
Mdry = sample weight

Determination of total fat content

The soxhlet solvent extraction method was used to determine fat content according to AOAC (2015). Two (2) grams of the sample were weighed into the extraction thimble and fixed into extraction flask of known weight. Extraction was carried out using diethyl ether in electro thermal model extractor for 5 hours. At the completion of the extraction, the ethyl ether was removed and the remaining fat in the flask was dried at 60°C for 30 minutes in the oven cooled for 15 minutes and weighed. The percentage fat was calculated as follows:

$$\%Total\ fat\ content = \frac{W_1 - W_2}{W_3} * 100$$

Where:
W1 = Weight of sample before extraction
W2 = Weight of sample after extraction
W3 = Original weight of sample

Determination of total fat content

Carbohydrate was calculated using the method of (AOAC, 2015). The carbohydrate content was calculated by difference as:

$$\%Carbohydrate = 100 - (\%Moisture + \%Fat + \%Ash + \%Protein + \%Crude\ fiber)$$

Determination of Iron

The Iron content was determined following the method of Tivde *et al*., (2021). Five milliliters of digested sample of composite four was placed in a 50 ml volumetric flask. Then 3ml of phenanthroline solution, 2 ml of hydrochloric acid and 1ml of hydroxylamine solution were added to the sample in sequence. The sample solution was boiled for 2 minutes and 9 ml of ammonium acetate buffer solution was added to the solution. The solution was diluted with water to 50ml volume. The absorbance was determined at 510 nm wavelength.

Iron standard solution was prepared in order to plot a calibration curve to determine the concentration of the sample. Standard solution containing 100 mg/ml of ferric irons was prepared from 1g pure iron wires. The wires were dissolved in 100 ml concentrated nitric acid, boiled in a water bath and diluted to 100 ml with distilled water after cooling. Standard solutions of known concentrations were prepared by pipetting 2, 4, 6, 8 and 10ml standard iron solution into 100ml volumetric flasks and made up to volume.

Determination of Phosphorus

The Phosphorus content was determined by a procedure described by Tivde *et al*., (2021). Using a flame photometer. Phosphorus standard was prepared. The standard solution was used to calibrate the instrument read out of composite four. The meter reading was at 100% E (emission) to aspire the top concentration of the standards.

The %E of all the intermediate standard curves were plotted on linear graph paper with these readings. The sample solution was aspired on the instrument and the readings (% E) were recorded. The concentration of the element in the sample solution was read from the standard curve.

$$Phosphorus = \frac{\text{Ppm} \times 100 \times DF}{1 \text{ million}}$$

Determination of Zinc

The Zinc content was determined by a procedure described by Tivde *et al*., (2021). Five milliliters (5 ml) of the test solution was pipetted into 50 ml graduated flask. Then 10 ml of molybdate mixture was added and diluted to mark with water. It was allowed to stand for 30 minutes for color development.

The absorbance was measured at 660 nm against a blank. A curve relating absorbance to mg zinc present was constructed. Using the zinc standard solution, and following the same procedure for the test sample, a standard curve was plotted to determine the concentration of zinc in the composite flour sample.

$$Zinc = \frac{\text{graph reading} \times solution\ volume}{100}$$

Determination of vitamins content of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Determination of vitamin B_1 (thiamine)

The thiamine content was determined using the scalar analyzer method of AOAC, (2015). Five grams (5 g) of each sample of composite four was homogenized in 5 ml normal ethanoic sodium hydroxide solution. The homogenate was filtered and made up to 100 ml with the extract solution. A 10ml aliquot of the extract was dispensed into a flask and 10ml of potassium dichromate solution added. The resultant solution was incubated for 15 minutes at room temperature (25oC±3oC). The absorption was read from the spectrophotometer at 360 nm using a reagent blank to standardize the instrument at zero. The thiamine content was calculated as follows:

$$Vitamin\ B_1\ (mg/100g) = \frac{100}{Sample\ weight} + \frac{sample\ absorbance \times concentration \times Dilution\ factor}{Concentration}$$

Determination of vitamin B_2 (riboflavin)

The riboflavin content was determined according to AOAC, (2015) method. Two grams (2 g) of composite four samples were placed in a conical flask and 50 ml of 0.2N HCl was added to the sample, boiled for 1 hour, and then cooled. The pH was adjusted to 6.0 using sodium hydroxide 1N HCl was added to the sample solution to lower the pH to 4.5. The solution was filtered into 100 ml measuring flask and made to volume with water.

In order to remove interference, two tubes were taken, labeled 1 and 2. Ten milliliter of filtrate and 1ml of riboflavin standard were added to test tube 2. About 1 ml of glacial acetic acid was added to each tube and mixed, and then 0.5ml of 3% KMnO4 solution was added to each tube. They were allowed to stand for 2 minutes, after which 0.5ml of 3% H_2SO_4 was added and agitated.

The fluorimeter was adjusted to excitation wavelength of 470 nm and emission wavelength of 525 nm. The fluorimeter was adjusted to zero deflection against 0.1N H_2SO_4 and 100 against tube 2 (standard).The fluorescence of tube 1 was read. Two milliliter of sodium hydrogen sulphate was added to both tubes and the fluorescence measured within 10 seconds. This was recorded as blank reading.

$$Vitamin\ B_2\ (mg/100g) = \frac{sample\ read - blank\ read}{(sample\ read - blank\ read) - (sample\ read + standard\ tube - sample\ read + standard\ blank)} \times \frac{1}{sample\ weight}$$

Determination of phytochemical composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Determination of phenolic content

Total phenolic content of the bread samples were using the procedure described by Ali et al., (2020). The samples (2 g each) were separately mixed with 16 ml of aqueous ethanol (70% ethanol–30% water), containing 1% HCl for 24 hours at room temperature (25°C). The ethanolic extract was then centrifuged at 5000 g for 20 minutes, and then the resulting supernatant was filtered through a Whatman No. 41 filter paper.

The ethanolic extract (0.5 ml) was then mixed with 5 mL of freshly prepared Folin–Ciocalteu reagent, and 4ml of sodium carbonate solution (75 g/l). The mixture was incubated at room temperature for 2 hours. The absorbance at 765 nm was measured using a UNICO UV/VIS-2100A spectrophotometer (Dayton, USA). The total phenolic content (TPC) is expressed as milligrams of gallic acid equivalent per gram of dried sample.

Determination of flavonoid content

The total flavonoid content was determined by the aluminum chloride colorimetric method as described by Shoib and Shahid, (2015). Fifty milliliters (50ml) of crude extract (1mg/ml ethanol) were made up to 1ml with methanol, mixed with 4ml of distilled water and then 0.3ml of 5% $NaNO_4$ solution; 0.3ml of 10% AlCl3 solution was added after 5 minutes of incubation, and the mixture was allowed to stand for 6 minutes.

Then, 2 ml of 1mol/l NaOH solution were added, and the final volume of the mixture was brought to 10ml with double-distilled water. The mixture was allowed to stand for 15 minutes, and absorbance was measured at 510 nm. The total flavonoid content was calculated from a calibration curve, and the result was expressed as mg rutin equivalent per g dry weight.

Determination of flavonoid content

This was carried out in accordance with the method described by Orafa *et al*., (2023). A measured weight of the sample was homogenized in methanol using a laboratory blender. (1:10, sample:methanol). The homogenate will be filtered to obtain the initial crude extract using about 20 ml of distilled water in separating funnel. The other layer will be recovered and evaporated to dryness at low temperature (35-50ºC) in vacuum desiccator. The dry extract was saponified with 20ml of ethanoic potassium hydroxide and left overnight in a dark cupboard.

After a day, the carotenoid was taken up in 20 ml distilled water. The carotenoid extract (ether layer) was dried in a desiccator and treated with a light petroleum (Petroleum spart) and allowed to stand overnight in a freezer. The next day, the precipitated steroid was removed by centrifugation and the carotenoid extract evaporated to dryness in a desiccator and weighed. The weight of carotenoid was determined and expressed as percentage of the sample weight

Determination of functional properties of blends of wheat and acha flours complemented with defatted bambara groundnut flour

Water absorption and oil absorption capacity was determined using the method of Tivde *et al*., (2021). The bulk density was determined as according to the method described by Godswill, (2019). The swelling capacity was evaluated using the method of Kumar *et al*., (2017). Foaming capacity was determined by the method of Olaoye and Obidegwe (2018). Emulsification capacity was determined as according to the method of Zhang *et al*. (2022).

Determination of Physical properties of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Loaf weight was measured 30 minutes after the loaves were removed from the oven using a laboratory scale (CE-410I, Camry Emperors, China) and the readings recorded in grams (Ayo et al., 2023).

Determination of loaf volume

The loaf volume was determined by using rape seed displacement method as described by (Olaoye and Obidegwe, 2018). This was done by loading 3000 ml of sorghum grains into a calibrated container, mark until it reached the marked level and unloaded back, the bread sample was put into the container and the measured sorghum was loaded back again, the remaining sorghum gains left outside the container was measured using measuring cylinder and recorded as loaf volume in cm^3.

Determination of loaf volume index

Loaf volume index was determined by dividing the volume of loaf sample by weight of loaf sample of the bread as described by Ayo *et al*. (2023).

$$Volume\ index\ \left(\frac{cm^3}{g}\right) = \frac{\text{Volume of loaf sample}}{\text{Weight of loaf sample}}$$

Sensory evaluation of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

A panel of 20 judges (6 male and 14 female students) were selected randomly from the staff and students (25 – 28 years of age) of the Department of Food Science and Technology, Federal University Wukari, Taraba State. All the judges / panellist were duly informed and have consented prior to the exercise. The samples were presented to the panelists to assess the breads including the control for color, flavor, texture and overall acceptability as described by Olaoye and Obideqwe (2018). The evaluation was carried out on a 9-point Hedonic scale where 9 = like extremely and 1= dislike extremely. Clean water was provided to the panelists to rinse their mouth in between the evaluation. The evaluation was carried out in a sensory evaluation laboratory under controlled conditions of adequate lighting and ventilation.

Statistical Analysis

The results obtained from the various analyses were done in triplicate and subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 20.0. Means were separated with Duncan's Multiple Range Test (DMRT) at 5% level of significance ($p<0.05$).

RESULTS AND DISCUSSIONS

Proximate composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

The result of the proximate composition of bread is presented in Table 3. The moisture, protein, fiber and ash content of the flour blend breads increased from 24.17 to 27.20%, 6.95 to 13.12%, 0.26 to 0.77%, 0.80 to 1.19% respectively, while the carbohydrate and fat content decreased from 54.41 to 50.83% and 7.66 to 5.47%, respectively, with increase in added defatted Bambara groundnut flour (DBGNF).The effect of the added DBGF on the proximate composition of the blend breads is significant, p<0.05.

The moisture contents increased from 24.17 to 27.20% with increasing level of DBGNF. Bread formulated with 25% DBGNF flour blend (Sample G) had the highest moisture content value (27.20%). The bread samples generally had relatively low moisture content, which suggest improved shelf life of the bread. The moisture content of the bread agreed with the results of Adeyeye *et al*., (2019) who reported moisture content of 24.81 to 28.61 in bread produced from blends of wheat and rice composite flours, however the moisture content was higher compared to the 9.47% reported by Ayo *et al*. (2023). The difference could be due to the method of drying or the pretreatment method given to the flours. The relative increase in the moisture content with increase in the added DBGNF could be due to the relatively high fibre content (1.03-22.29 g/100g) peculiar to legumes (Oyeyinka *et al*., 2017).

The protein content of the flour sample increase with increasing DBGNF. This was expected since Bambara groundnut is a legume while wheat is a cereal grain and legumes naturally contain more protein than cereals although the prevalent protein in wheat occurs as gluten which is needed in baking. The protein content of wheat-bambara groundnut are lower than the values (21–28 g/100g) reported from past studies (Arise *et al*., 2015; Oyeyinka *et al*., 2019). The least value of protein in sample B (100% acha) could be attributed to non-incorporation of DBGNF which contains substantial amount of protein. Protein is crucial to the regulation and maintenance of the body.

Fat content decreases from Sample C with 8.67% to sample G with 7.66% and sample A and B (100% wheat and acha) had 5.47% and 6.26% respectively. The decrease in fat content with increasing DBGNF inclusion could be due to the removal of fat from the flour. The level of rancidity would be low because of the moderate fat content of the product which is important in extending the shelf life of the flours. High levels of fat in food products should be <25%, since this could lead to rancidity in foods and development of unpleasant and odorous compounds (Ikumola et al., 2017).

Fats acts as flavours retainers and helps improves sensory properties of baked products. However, diets high in fat predispose consumers to different illness such as obesity and coronary heart diseases (Okpala and Chinyelu, 2011). The highest crude fibre content in sample G (25% DBGF) could be attributed to the high crude fibre contents of bambara groundnut. The high crude fiber content will improve digestion in the body (Ayo and Andrew, 2016). The increased fiber content was due to the increase in DBGNF, confirming that bambara groundnut is a good source of dietary fiber.

In contrast, the present crude fiber contents obtained in this study (0.77%) is lower than the 1.47% reported by Oyeyinka and Oyeyinka (2018) and this could be influenced by difference sources, origin and processing conditions respectively. The increase in fibre was observed as an improvement in the nutrient status since they are agents in food which aids in absorption during digestion process (Ubbor *et al*., 2022).

The ash content of the flours which is an indication of their mineral profile of the flours increased progressively as the level of supplementation increased. Increase in the ash content indicates that the samples with high percentage of ash will be good sources of minerals (Akubor and Ishiwu, 2013). Carbohydrate content decreased from sample C to G with increased substitution. There was significant difference (p<0.05) between the carbohydrates content of the flour samples. The decreasing trend of carbohydrate content as the substitution level increases could be due to the relatively low carbohydrate in DBGNF. The result is in accordance with the findings of Okoye and Obi (2017).

Minerals composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Table 4 showed the minerals composition of the bread samples. The phosphorus content in the blended flours increased from 162.2 to 229.82 mg/100 g. It was significantly higher than control samples (A and B) with 141.62 and 148.02 mg/100g respectively. The variations among blending levels and difference from the control, (p<0.05) was observed because DBGNF is reported to be high in phosphorus content (173.97 to 563.00 mg/100g) (Halimi *et al*., 2019) Phosphorus is widely distributed in foods. Phosphorus is an abundant mineral in the human body at large, next to calcium, and it is found in the bones (85%) and teeth, structural components of cell membranes, parts of nucleic acids (DNA and RNA), cell energy production and energy storage (ATP) and the maintenance of buffer pH systems in the bodily fluids (Kobue-Lekalake *et al*., 2022).

Iron content among the bread samples increased from 0.87 to 2.46 mg/100g with significant difference (p<0.05). But a significantly low iron content (1.2 and 1.01 mg/100g) was observed in the control samples A and B respectively. The results of this research agreed with the findings of Abdualrahman *et al*. (2019) and Semba *et al*., (2021) that DBGNF contains 2.45 mg/100g and 3.8 mg/100g respectively. Iron is vital in human nutrition for the various redox reactions taking place for cellular metabolic functions; particularly, it is a component of hemoglobin and myoglobin and a co-factor for more than 200 enzymatic systems. The iron bioavailability from plant-based diets can range from 5 to 10% (Kobue-Lekalake *et al*., 2022).

The composite bread showed a significant decrease, p < 0.05 in the zinc content (0.52 to 0.09 mg/100 g) as compared to control samples with 2.09 and 0.26 mg/100 g respectively. The decrease in zinc could be due to lower zinc content in bambara groundnut (2.5 mg/100g) compared to wheat with (3.5 mg/100g) reported by Adegbanke *et al*., (2020). Zinc is vital in human nutrition, as it is distributed throughout all human tissues and body fluids and is indicated to be a co-factor for more than 1000 enzymatic reactions in the cellular functions, among others, that are required for normal growth and development, the regulation of gene expression and proper immune functions (Chasapis *et al*., 2020). The phosphorus and iron content increased while zinc decreased with increased level of DBGNF.

Vitamins compositions of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

The vitamin content of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour as presented in Table 5 showed that the inclusion of DBGNF in wheat-acha flour had significant, p<0.05 decrease in vitamins content of bread samples. The vitamin content decreased with inclusion of DBGNF in the blends.

The inclusion of DBGF in the blends resulted to significant (p<0.05) decrease in thiamine content. The finding by this study with Vitamin B1 value of 0.12 to 0.18 do not agree with the report of Ahure et al. (2020) who reported increase in thiamine content (1.52 – 2.45 mg/100 g) with inclusion of almond seed and carrot flour in the blends. The control sample with 10 % DBGF inclusion had high thiamine content (0.18 mg/100g) as compared to other bread samples. Vitamin B1 (also known as thiamine) functions as the coenzyme thiamine pyrophosphate (TPP) in the metabolism of carbohydrates and branched-chain amino acids.

Vitamin B2 (also known as Riboflavin) decreased with the inclusion of DBGNF in the blends. Vitamin B2 was found to be high in the control sample compared to other bread samples. Ahure *et al*. (2020) reported a different trend in vitamin B2 with values ranging from 0.65 – 0.92 mg/100g. The B vitamins are needed for carbohydrate and protein metabolism, and are essential for growth, well structuring and functioning of the cells (Ahure *et al*., 2020).

Phytochemicals composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

The phytochemicals composition of bread is presented in Table 6. Phenol, flavonoids and carotenoids decreased with addition of DBGNF from 45.50 to 41.96, 28.74 to 19.68 and 0.2 to 0.02 mg/100g respectively.The total phenolic content (TPC) values decreased from 45.50 to 41.96 mg/100g with 56.77 and 14.70 mg/100g for control samples A and B respectively. The TPC content decreased slightly in the blends bread compare to the control sample A. The slight decrease in TPC of the blends bread could be related to the initial pretreatment of bambara groundnut by removing the epicarp (Okafor *et al*., 2022).

A similar trend of decrease in TPC of composite flour blends was reported by Abdel-Gawad *et al*. (2014). In addition, the formation of Maillard reaction products with the structure of phenolic compounds during baking could partially explain the decrease of TPC in composite bread (Semba *et al*., 2021).The total flavonoids content (TFC) of the composite bread and control samples varied significantly (p<0.05). TFC values decreased from 28.74 to 19.68 mg/100g with 32.17 and 7.05 mg/100g for the control samples A and B respectively. This could be due to the low flavonoid content in DBGNF and the pretreatment of the grains prior to milling.

Flavonoids are heat sensitive and heating at 75ºC can destroy enzyme activity and block the synthesis pathway of flavonoids (Kulczyński and Gramza-Michałowska, 2019) Carotenoids content in the bread samples decreased from 0.2 to 0.02 mg/100g. A significant decrease (p<0.05) was observed for the highest DBGNF blend, but very high in the control (0.4 mg/100 g). This shows the poor carotenoid content in DBGNF. This results disagrees with the report of Megwas *et al*., (2021).

Carotenoids, a pro-vitamin A, to impart high vitamin A activities (12 µg beta-carotene = 1 µg retinol activity equivalent (RAE)). Adequate intake of carotenoids are vital for normal eye vision, immune functions to fight infectious diseases and gene regulation, and as an antioxidant in the protection of cell components (DNA, RNA, proteins, and lipids) from oxidative stress damage (Böhm *et al*., 2020).

Functional properties of the composite flour from blends of wheat and acha flours complemented with defatted bambara groundnut

Presented in Table 7 are the data on the Functional properties of the composite flour from blends of wheat and acha flours complemented with defatted bambara groundnut. The oil absorption capacity, water absorption capacity, foaming capacity, emulsifying capacity and swelling capacity, increased from 29.05 to 78.95 g/ml, 131.34 to 175.13 g/ml, 8.10 to 29.00 g/ml , 2.02 to 2.18 g/ml, 32.50 to 41.00 g/ml respectively while bulk density decreased from 0.80 to 0.70 g/ml with increasing DBGNF inclusion level.

There was significant (p<0.05) difference in the bulky density, Oil absorption capacity, water absorption capacity, foaming capacity, emulsifying capacity and swelling capacity. Functional properties of a food material are parameters that determine its application and end use (Adeleke and Odedeji, 2010). Functional properties of food substances depends on the quality attributes of their macro molecules such as protein, starch, carbohydrate, sugars, fibre and fat, and influence their utilization and industrial applications (Fetuga *et al*., 2014).

According to Bhat and Yahya (2014) functional properties of legume flour and cereal flour mixed with legume flour are regarded as very important parameters to consider in food product development due to their effects on texture and mouth feel as well as the consistency of the product. Understanding some of these intrinsic behaviors helps in setting the parameters for producing different products (Rahman *et al*., 2011).

Bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. The result of the bulk density showed a progressive decrease with increase in substitution of wheat flour with DBGNF as the least bulk density (0.70 g/ml) was recorded in sample G (25% DBGNF). The findings of the bulk density of wheat-acha and defatted Bambara groundnut composite flours collaborates to that of Zhang *et al.* (2022) who reported that pretreatment leads to decrease in the bulk density of foods. Determining the bulk density of flours and flour blends is important for consumer expectation of a filled package as well as for shipping purposes (Yeboah-Awudziet *et al*., 2018).

The result of the oil absorption capacity showed a significant increase with increase in the substitution of wheat-acha flours with DBGNF. The least oil absorption capacity of (25.17.83 g/ml) was observed in sample B (100% acha) while the highest oil absorption capacity (78.95 g/ml) was recorded in sample G (25% DBGF). There was significant ($p<0.05$) different among the composite flours. This result disagrees with data reported by Ubbor *et al*., (2022) who examined the physiochemical and sensory evaluation of cookies produced from composite flours of wheat, bambara groundnut and orange fleshed sweet potato. Higher oil absorption capacity was reported in 100% wheat flour as compared to bambara groundnut composites (Ubboret *et al*., 2022). Findings from this present study suggests that pretreatment of bambara groundnut which was carried out significantly improved oil absorption capacity of composite flours, Oil flavors and gives soft texture to food as absorption of oil by food products improves mouth feel and flavor retention. The increase in oil absorption may be attributed to the presence of more hydrophobic proteins which show superior binding of lipids (Issoufou *et al*., 2017).

The water absorption capacity (WAC) of flour increased with increase in DBGNF inclusion, higher water absorption capacity was recorded in sample G (25% DBGF) as compared to the control. This result agrees to the work of Ihembe *et al*. (2023) where the WAC increases significantly ($p<0.05$) with increasing protein content. The amount and nature of hydrophilic constituents such as proteins and to some extent the pH value favorably influence the water absorption capacity of a flour (Onimawo and Akubor, 2012). Water absorption characteristic represents the ability of the product to associate with water under conditions when water is limiting such as dough and pastes. Water absorption capacity is important in the development of ready to eat foods. It has been observed that a high absorption capacity assure product cohesiveness Ihembe *et al*., (2023) also reported that water absorption capacity is important in bulking and consistency of products as well as baking applications.

Foaming capacity is used to determine the ability of flour to foam which is dependent on the presence of the flexible protein molecules which decrease the surface tension of water (Asif-Ul- Alamet *et al*., 2014). Proteins have been reported to enhance foam formation (Ojinnaka *et al*., 2016) and hence, the highest foaming capacity recorded in sample G (25% DBGF) could be attributed to its high flour protein content. Protein foams are important in many processes in the beverage and food industries and this has stimulated interest in their formulation and stability. Foams are used to improve texture, consistency and appearance of foods (Ajani *et al*., 2016). Good foam capacity is a desirable attribute for flours in the food system due to its high percentage of porosity intended for the production of a variety of baked products such as cakes, muffins, akara, and also act as functional agents in other food formulations (Onabanjo and Ighere-Dickson, 2014).

Emulsion capacity of the various flour blends in this study increased significantly with increase in the level of DBGNF inclusion from 2.02% observed in sample C to 2.18% in sample G. Emulsions and foams are two phase systems commonly found in food systems whose formation is significantly affected by protein surface activity (Kiin-Kabari *et al*., 2015). The swelling capacity of flour granules is an indication of the extent of associative forces within the granules and water absorption index of the granules during heating (Ihembe *et al*., 2023). Increase in the swelling index could be due to strong bond forces in wheat-acha and bambara groundnut flour and reduction in the carbohydrate content of the composite flours (Ihembe *et al*., 2023). The swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations. Swelling capacity of the composite flour increased with increase in the level of substitution

Physical properties of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

The physical properties of the bread samples are presented in Table 8.The loaf weight of the composite bread samples increased from 222.55 to 229.45g with 233.00 and 221.10 respectively for the control samples. The present study showed a significant increase in weight in all bread samples compared to the control sample (A). The values however were significantly, $p>0.05$ higher than 134.40g for bread fortified with green leafy vegetables (Odunlade *et al*., 2017). The increase in loaf weight could be attributed to increase moisture absorption and less retention of carbon dioxide gas in the blended dough resulted in heavy dough and thus heavy loaves (Yusufu and Ejeh, 2022).

The loaf volume of the bread decreased from 655.00 to 595.00 cm^3 for composite bread samples, 685.00 and 255.00cm3 respectively for the control samples (A and B) as shown in Appendix I. This trend is in line with the report of Nwosu (2013) on the production of bread using wheat-cassava flour blends. Loaf volume is considered as the most important bread characteristic since it provides a quantitative measurement of baking performance Yusufu and Ejeh, 2022).

The loaf volume index of the bread decreased from 2.95 to 2.60 cm^3/g and the control samples A and B with 2.94 and 1.15 cm^3/g respectively. This result is in line with Makinde and Akinoso, (2014) during the production of bread from wheat and black sesame. The findings are contrary to report of Ayo *et al*., (2014) that showed increased in specific volume of bread produced from soya beans and acha composite flours. The decrease in loaf volume index of bread produced in this research could be due to the dilution effects on gluten with the addition of DBGNF (Makinde and Akinoso, 2014). The loaf weight increased while loaf volume and loaf volume index decreased with increases in the level of DBGNF.

Sensory profile of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

The sensory evaluation result of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour is presented in Figure 1. The average mean scores of aroma, taste, texture and color ranged from 6.40 to 5.80, 6.80 to 6.25, 6.50 to 6.36 and 7.40 to 7.30 respectively. In terms of aroma and taste, sample A with 100% wheat flour was rated highest. Sample B, 100% acha was rated the lowest, the aroma and taste of composite bread were most acceptable at sample D (10% DBGNF), however decreases with increase in addition of DBGNF. This could be attributed to the strong beany flavor of bambara groundnut (Yusufu and Ejeh, 2018). In terms of color, sample A with 100% wheat flour was rated highest than any of the other samples. It was noted that as the level of substitution of bambara groundnut increased, the color rating decreased. The color of the samples with 10% and 20% Bambara groundnut were not significantly, $p<0.05$ different. The lowest color rating in composite bread was recorded for sample G. The lowest rating in color of bread as the percentage of substitution of wheat flour with defatted Bambara groundnut flour increased could be attributed to the color imparted by DBGNF. The texture of the bread decreased with increased substitution level of DBGNF. Sample A with 100% wheat flour has the highest value 7.25 followed by sample D (10% DBGNF). There was a progressive significant decrease as DBGNF increases from 10-25%. The general acceptability indicates that the control sample (100% wheat) was significantly higher than any other samples. This followed by sample D with 10% defatted bambara groundnut flour.

Table 1. Recipe formulation for bread produced from blends of wheat and acha flours

Sample	Wheat flour (g)	Acha flour (g)	Margarine (g)	Sugar (g)	Yeast (g)	Salt (g)	Water (ml)
A	100	0	5	10	1.5	1	52
B	95	5	5	10	1.5	1	52
C	90	10	5	10	1.5	1	52
D	85	15	5	10	1.5	1	52
E	80	20	5	10	1.5	1	52
F	75	25	5	10	1.5	1	52

Table 2. Recipe formulation for bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Sample	Wheat flour (g)	Acha flour (g)	*Wheat-Acha flour (g)	Defatted Bambara groundnut flour(g)	Margarine (g)	Sugar (g)	Yeast (g)	Salt (g)	Water (ml)
A	100	0	0	0	5	10	1.5	1	52
B	0	100	0	0	5	10	1.5	1	52
C	0	0	95	5	5	10	1.5	1	52
D	0	0	90	10	5	10	1.5	1	52
E	0	0	85	15	5	10	1.5	1	52
F	0	0	80	20	5	10	1.5	1	52
G	0	0	75	25	5	10	1.5	1	52

*Wheat-acha flour = 85:15% wheat flour: acha flour (preliminary investigation)

Table 3. Proximate composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Sample	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude Fibre (%)	Ash (%)	*Carbohydrate (%)
A	$24.49^{cd}\pm0.55$	$10.79^{c}\pm0.10$	$5.47^{c}\pm0.13$	$0.08^{e}\pm0.04$	$1.02^{a}\pm0.01$	$58.23^{b}\pm0.54$
B	$25.01^{bcd}\pm0.23$	$6.95^{d}\pm0.51$	$6.26^{bc}\pm0.97$	$0.40^{c}\pm0.07$	$0.80^{f}\pm0.00$	$60.98^{a}\pm1.64$
C	$24.17^{a}\pm0.09$	$11.69^{b}\pm0.10$	$8.67^{a}\pm0.41$	$0.26^{d}\pm0.01$	$1.06^{b}\pm0.00$	$54.41^{c}\pm0.66$
D	$25.37^{bc}\pm$|0.19	$12.34^{ab}\pm0.21$	$8.21^{a}\pm0.62$	$0.32^{cd}\pm0.03$	$1.08^{c}\pm0.01$	$53.00^{cd}\pm0.21$

E	25.86^{b}±0.08	12.98^{a}±0.51	7.75^{ab}±0.83	0.40^{c}±0.01	1.09^{d}±0.00	52.32^{cd}±0.41
F	26.18^{ab}±|0.01	13.07^{a}±0.49	7.71^{ab}±0.85	0.53^{b}±0.04	1.11^{d}±0.01	51.93^{de}±0.39
G	27.20^{a}±1.09	13.12^{a}±0.44	7.66^{ab}±0.86	0.77^{a}±0.04	1.19^{e}±0.01	50.83^{e}±1.46

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour
*Fibre included

Table 4. Minerals composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

SAMPLE	Zinc (mg/100g)	Phosphorus (mg/100g)	Iron (mg/100g)
A	2.09^{a}±0.01	141.62^{e}±1.51	1.89^{a}±0.35
B	0.26^{d}±0.00	148.02^{d}±0.21	1.27^{b}±0.06
C	0.52^{b}±0.01	162.2^{c}±4.74	0.87^{c}±0.06
D	0.39^{c}±0.00	191.74^{b}±1.56	0.94^{bc}±0.00
E	0.26^{d}±0.00	197.37^{b}±1.15	1.04^{bc}±0.08
F	0.18^{e}±0.00	224.11^{a}±3.85	1.12^{bc}±0.01
G	0.09^{f}±0.00	229.82^{a}±2.68	1.24^{b}±0.11

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

Table 5. Vitamins composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Sample	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)
A	0.18^{a}±0.01	0.06^{a}±0.05
B	0.12^{a}±0.08	0.05^{a}±0.09
C	0.17^{a}±0.00	0.05^{a}±0.06
D	0.17^{a}±0.01	0.05^{a}±0.05
E	0.16^{a}±0.00	0.04^{a}±0.04
F	0.14^{a}±0.00	0.03^{a}±0.01
G	0.13^{a}±0.01	0.03^{a}±0.05

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

Table 6. Phytochemicals composition of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Sample	Phenol (mg/100g)	Flavonoid (mg/100g)	Carotenoid (mg/100g)
A	56.77^{a}±0.00	32.17^{a}±0.14	0.01^{f}±0.00000
B	14.70^{f}±0.16	7.05^{g}±0.42	0.01^{e}±0.00000
C	45.50^{b}±0.38	28.74^{b}±0.28	0.20^{d}±0.00000

D	44.11^{c}±0.51	27.98^{c}±0.14	0.04^{c}±0.00000
E	43.22^{d}±0.06	27.21^{d}±0.00	0.03^{c}±0.00000
F	42.59^{de}±0.45	23.45^{e}±0.14	0.02^{b}±0.00071
G	41.96^{e}±0.45	19.68^{f}±0.28	0.02^{a}±0.00071

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

Table 7. Functional properties of the composite flour from blends of wheat and acha flours complemented with defatted bambara groundnut

Sample	Bulk Density (g/ml)	Oil absorption capacity (g/ml)	Water absorption capacity (g/ml)	Foam Capacity (g/ml)	Emulsify-ing Capacity (g/ml)	Swelling Capacity ((g/ml)
A	0.70^{c}±0.01	27.83^{e}±0.57	101.67^{e}±2.52	19.00^{a}±1.41	2.15^{ab}±0.02	31.00^{b}±0.71
B	0.91^{a}±0.07	25.17^{d}±0.97	86.67^{f}±1.15	11.00^{bc}±1.41	2.11^{bc}±0.01	32.00^{a}±1.41
C	0.80^{b}±0.05	29.05^{g}±1.18	131.34^{d}±0.34	8.1.50^{b}±0.71	2.02^{a}±0.02	32.50^{ab}±0.71
D	0.77^{bc}±0.01	39.99^{f}±1.71	163.38^{c}±2.07	8.7.00^{b}±0.00	2.08^{ab}±0.04	36.50^{b}±1.41
E	0.73^{bc}±0.02	63.60^{c}±1.82	164.86^{c}±1.26	18.00^{cd}±1.41	2.16^{ab}±0.04	37.00^{c}±0.71
F	0.72^{bc}±0.02	68.54^{b}±0.81	170.39^{b}±0.09	22.00^{d}±0.00	2.17^{cd}±0.04	38.50^{c}±1.41
G	0.70^{c}±0.03	78.95^{a}±0.81	175.13^{a}±0.28	29.00^{d}±0.00	2.18^{d}±0.01	41.00^{c}±1.41

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

Table 8. Physical properties of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

Sample	Loaf weight (g)	Loaf volume (cm^3)	Loaf volume index (cm^3/g)
A	223.00^{a}±3.54	685.00^{a}±7.07	2.94^{a}±0.01
B	221.10^{d}±0.85	255.00^{e}±7.07	1.15^{d}±0.03
C	222.55^{cd}±0.35	655.00^{b}±7.07	2.95^{a}±0.04
D	223.85^{cd}±0.07	635.00^{c}±7.07	2.84^{b}±0.04
E	225.20^{c}±1.27	625.00^{c}±7.07	2.78^{b}±0.02
F	228.80^{b}±0.28	605.00^{d}±7.07	2.64^{c}±0.03
G	229.45^{ab}±1.06	595.00^{d}±7.07	2.60^{c}±0.02

*Values are means ± standard deviation of triplicate determinations. Means differently superscripted along the vertical columns are significantly (p<0.05) different from each other using Duncan multiple range test.
*Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF
*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

Figure 1. Sensory profile of bread produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour

*WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut flour

CONCLUSIONS

The findings from this research established that bread can be produced from blends of wheat and acha flours complemented with defatted bambara groundnut flour. The bread produced from the flour blends were generally acceptable but most preferred at 10% inclusion of defatted bambara groundnut which improves the functional properties and the nutritional composition of the product. Based on the results from this study, Defatted bambara groundnut flour could be incorporated with wheat and acha flour blends for bread production up to 10% for improved nutritional composition. Further studies should be carried out to evaluate the storage stability of the composite breads for improved keeping quality.

REFERENCES

Journal

Abdel-Gawad M., Abdel-Aziz M., El-Sayed M., El-Wakil E. and Abdel-Lateef E. 2014. In-vitro antioxidant, total phenolic and flavonoid contents of six allium species growing in Egypt. Journal of Microbiology, Biotechnology and Food Sciences, 3(4): 343-346.

Abdualrahman MAY, Ma H, Yagoub AEA, et al. 2019. Nutritional value, protein quality and antioxidant activity of Sudanese sorghum-based kisra bread fortified with bambara groundnut (Voandzeia subterranea) seed flour. J Saudi Soc Agric Sci 18: 32–40.

Adedayo, O. A. 2017. Genetic polymorphism of prevalent root nodules bacterial strain from Bambara nut (Doctoral dissertation, North-West University (South Africa)).

Adegbanke O. R., Osundahunsi O. F., and Enujiugha V. N. 2020. “Chemical and Mineral Composition of Biscuit Produced from Wheat and Bambara Groundnut Flour". Acta Scientific Nutritional Health, 4(10): 03-09.

Adeleke, R. O., & Odedeji, J. O. 2010. Functional properties of wheat and sweet potato flour blends. Pakistan Journal of nutrition, 9(6), 535-538.

Adeyeye, S. A. O., Bolaji, O. T., Abegunde, T. A., Adebayo-Oyetoro, A. O., Tiamiyu, H. K., & Idowu-Adebayo, F. 2019. Quality characteristics and consumer acceptance of bread from wheat and rice composite flour. Current Research in Nutrition and Food Science, 7(2), 488-495.

Ahure, D., Guyih, M. D. and Eke, M.O. 2020. Vitamin Content and Storage Studies of Cookies Produced from Wheat, Almond and Carrot Flour Blends. Asian Food Science Journal 15(3): 31-41

Ajani, A. O., Fasoyiro, S. B., Arowora, K. A., Ajani, O. O., Popoola, C. A. and Zaka, K. O. 2016. Functional Properties of Composite Flour made from Wheat and Breadfruit. Journal of Applied Tropical Agriculture, 21(2): 89-93.

Akter, N., & Rafiqul Islam, M. 2017. Heat stress effects and management in wheat. A review. Agronomy for sustainable development, 37, 1-17.

Akubor P. I. and Ishiwu C. 2013. Chemical composition, physical and sensory properties of cakes supplemented with plantain peel flour. International Journal of Agricultural Policy and Research, 1(4): 87-92

Ali, R. F., El-Anany, A. M., Mousa, H. M., & Hamad, E. M. 2020. Nutritional and sensory characteristics of bread enriched with roasted prickly pear (Opuntia ficus-indica) seed flour. Food & function, 11(3): 2117-2125.

Arise, A. K., Amonsou, E. O., & Ijabadeniyi, O. A. (2015). Influence of extraction methods on functional properties of protein concentrates prepared from S outh

A frican bambara groundnut landraces. International Journal of Food Science & Technology, 50(5), 1095-1101.

Asif-Ul-Alam, S. M., Islam, M. Z., Hoque, M. M., and Monalis, K. (2014). Effect of Drying on the Physicochemical and Functional Properties of Green Banana (Musa Sapientum) Flour and Development of Baked Product. American Journal of Food Science and Technology, 2: 128-133.

Ayo J. A., Orafa P. , Odudu J. H. b., James P. B. (2023). Chemical Composition, Physical and Sensory Properties of Sweet Orange Pulp-Pineapple Pomace-wheat Flour Blend Breads. Asian Journal of Food Research and Nutrition. 4(2), 695-707

Ayo J.A, Ayo V.A, Popoola C, Omosebi M and Joseph L (2014). Production and evaluation of malted soybean-acha composite flour bread and biscuit. Africa Journal of. Food Science and Technology, 5(1):21-28.

Ayo, J. A., & Andrew, E. (2016). Effect of added Bambara groundnut on the quality of acha-date palm based biscuit. International Journal of Biotechnology and Food Science, 4(3), 34-38.

Ayo, J. A., Ojo, M. O., Popoola, C. A., Ayo, V. A., Okpasu, A. (2018). Production and Quality Evaluation of Acha-tigernut Composite Flour and Biscuits. Asian Food Science Journal. 1(3): 1-12

Ayo, J. A., Zakariya, M. I., & Gimba, D. J. (2021). Chemical Composition, Functional and Sensory Properties of Acha-Cowpea Flour Blends. Asian Food Science Journal. 2(3) pp.323.

Bhat R., and Yahya N. (2014) Evaluating belinjau (Gnetum gnemon L.) seed flour quality as a base for development of novel food products and food formulations. Food Chem 156:42–49.

Böhm V, Lietz G, Olmedilla-Alonso B, et al. (2020) Lead article: From carotenoid intake to carotenoid blood and tissue concentrations-implications for dietary intake recommendations. Nutr Rev 79: 544–573.

Chasapis CT, Ntoupa PSA, Spiliopoulou CA, et al. (2020). Recent aspects of the effects of zinc on human health. Arch Toxicol 94: 1443–1460.

Czubaszek, A., Wojciechowicz-Budzisz, A., Spychaj, R., & Kawa-Rygielska, J. (2021). Baking properties of flour and nutritional value of rye bread with brewer's spent grain. LWT, 150, 111955.

Dhen, N., Rejeb, I. B., Boukhris, H., Damergi, C., & Gargouri, M. (2018). Physicochemical and sensory properties of wheat-Apricot kernels composite bread. Lwt, 95, 262-267.

Effa, E. B., & Uko, A. E. (2017). Food security potentials of Bambara groundnut (Vigna subterranea (L.) Verdc.). Int. J. Dev. Sustain, 6, 1919-1930.

Estrada, G. C. D., Soares, M. L. G., de Oliveira Chaves, F., & Cavalcanti, V. F. (2013). Analysis of the structural variability of mangrove forests through the physiographic types approach. Aquatic Botany, 111, 135-143.

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health, 16(6), 1060.

Fetuga, G., Tomlins, K., Henshaw, F. and Idowu, M. (2014). Effect of Variety and Processing Method on Functional Properties of Traditional Sweet Potato Flour (elubo) and Sensory Acceptability of Cooked Paste (amala).Food Science and Nutrition, 2(6): 682-691.

Giraldo, P., Benavente, E., Manzano-Agugliaro, F., & Gimenez, E. (2019). Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy, 9(7), 352.

Godswill, A. C. (2019). Proximate composition and functional properties of different grain flour composites for industrial applications. International Journal of Food Sciences, 2(1), 43-64.

Hsieh, J. J., Purdue, M. P., Signoretti, S., Swanton, C., Albiges, L., Schmidinger, M., ... & Ficarra, V. (2017). Renal cell carcinoma. Nature reviews Disease primers, 3(1), 1-19.

Ihembe, W., Eke, M. O., & Ahure, D. (2023). Physicochemical Properties of Flours from Blends of Wheat, Fermented and Roasted Bambara Nut Flours. Journal of Clinical and Metabolism Studies, 02(2)

Ikuomola, D. S., Otutu, O. L. and Oluniran, D. D. (2017). Quality Assessment of Cookies Produced from Wheat Flour and Malted Barley (Hordeum Vulgare) Bran Blends. Cogent Food and Agriculture, 3:1-12.

Issaoui, M., Flamini, G., Delgado, A. (2021). Sustainability opportunities for Mediterranean food products through new formulations based on carob flour (Ceratonia siliqua L.). Sustainability. 13(14), 8026.

Issoufou, A., Mahamadou, E.G., Tidjani, A., Moutaleb, O. H., & Guo-Wei, L. (2017). Functional and sensory properties of tuwan aduwa: A traditional meal made from foxtail millet and desert date. Nigerian Food Journal, 35(1), 1-7.

Issoufou, A., Mahamadou, E.G., Tidjani, A., Moutaleb, O. H., & Guo-Wei, L. (2017). Functional and sensory properties of tuwan aduwa: A traditional meal made from foxtail millet and desert date. Nigerian Food Journal, 35(1):1-7.

Kin-Kabari D. B.,Uzoamaka M., and Akusu O. M. (2021). Production, nutritional evaluation and acceptability of cookies made from a blend of wheat, African walnut and carrot flours. Asian Food Science Journal, 20(6):60-76.

Kobue-Lekalake R, Bultosa G, and Gopadile O. D. (2022). Effects of Bambara groundnut and Butternut blending on functional and sensory properties of sorghum flour porridge. AIMS Agric Food 7: 265–281.

Kulczyński B, and Gramza-Michałowska A (2019). The profile of secondary metabolites and other bioactive compounds in Cucurbita pepo L. and Cucurbita moschata pumpkin cultivars. Molecules 24: 2945.

Kumar, K., Chandra, S., Samsher, N. C., Singh, J., & Kumar, M. (2017). Functional properties of food commodities (wheat, kidney bean, cowpea, turnip, cauliflower) flours. Int J Crop Sci, 5:1199-1202.

Makinde, F.M. and Akinoso, R. (2014). Physical, nutritional and sensory qualities of bread samples made with wheat and black sesame (Sesamum indicum Linn) flours. Int. Food Res. J., 21:1635–1640.

McGuire, S. (2015). FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015. Advances in Nutrition, 6(5), 623-624.

Megwas AU, Akunne PN, Oladosu NO, et al. (2021) Effect of Bambara nut consumption on blood glucose level and lipid profile of Wistar rats. Int J Res Rep Hemat 4: 30–41.

Nwosu, J.N, (2013). Production and Evaluation of biscuits from blends of Bambara Groundnut and Wheat Flour‖ International Journal of Food and Nutrition Science, 2:

Odunlade, T. V., Famuwagun, A. A., Taiwo, K. A., Gbadamosi, S. O., Oyedele, D. J. & Adebooye, O. C. (2017). Chemical Composition and Quality Characteristics of Wheat Bread Supplemented with Leafy Vegetable Powders. Journal of Food Quality, 1, 1-8.

Ojinnaka, M. C., Ihemeje, A. and Ugorji, C. O. (2016). Quality Evaluation of Cookies Produced from African Breadfruit, Wheat and Pigeon Pea Flour Blends. American Journal of Food and Nutrition, 3(1): 101-106.

Okafor JNC, Jideani VA, Meyer M, et al. (2022). Bioactive components in Bambara groundnut (Vigna subterraenea (L.) Verdc) as a potential source of nutraceutical ingredients. Heliyon 8: e09024.

Okoye, J. I., & Obi, C. D. (2017). Nutrient composition and sensory properties of wheat-African bread fruit composite flour cookies. Sky Journal of Food Science, 6(3), 027-032.

Okpala LC and Chinyelu VA. (2011). "Physicochemical, nutritional and organoleptic evaluation of cookies from pigeon pea (Cajanus cajan) and cocoyam (Xanthosoma sp.) flour blends". African Journal of Food, Agriculture Nutrition and Development 11.6 5431-5443.

Olagunju, A. I., Ekeogu, P. C., & Bamisi, O. C. (2020). Partial substitution of whole wheat with acha and pigeon pea flours influences rheological properties of composite flours and quality of bread. British Food Journal, 122(11), 3585-3600.

Olaoye OA, Obidegwe F (2018) Chemical Composition, Anti-Nutrients and Functional Properties of Composite Flours Formulated from Wheat and Three Cultivars of Cocoyam Corms (Xanthosoma sagittifolium) commonly found in Nigeria. Journal of Food Science and Nutrition, 4: 029.

Onabanjo O.O and Ighere Dickson A, (2014). "Nutritional, Functional and Sensory Properties of Biscuit Produced from Wheat-Sweet Potato Composite," Journal of Food Technology Research, Conscientia Beam, vol. 1(2), pages 111-121.

Orafa, P. N., Ogundele, O. O., Ayo, J. A., & Zephaniah, A. (2023). Quality Evaluation Of Acha-Based Biscuits Incorporated With Defatted Melon Seed Cotyledon. Asian Journal of Food Research and Nutrition, 2(4), 695-707

Oyeyinka A. T., Pillay K., Tesfay S., and Siwela M. (2017). Physical, nutritional and antioxidant of Zimbabwean Bambara groundnut and effects of processing methods on their chemical properties. International Journal of Food Science and Technology, 52: 2238-2247.

Oyeyinka A.T., Pillay K, and Siwela M. (2019). In-vitro digestibility, amino acid profile and antioxidant activity of cooked Bambara nut grain. Food Biosci. 31:10.

Oyeyinka, S. A., & Oyeyinka, A. T. (2018). A review on isolation, composition, physicochemical properties and modification of Bambara groundnut starch. Food Hydrocolloids, 75, 62-71.

Panirani, P. N., & Ghanbari, J. (2023). Design and optimization of bio-inspired thin-walled structures for energy absorption applications. International Journal of Crashworthiness, 28(1), 1-12.

Rahman A, Eltayeb SM, Ali AO, Abou-Arab AA, Abu-Salem FM (2011) Chemical composition and functional properties of flour and protein isolate extracted from bambara groundnut (Vigna subterranean). Africa Journal of Food Science, 5:82–90

Sajdakowska, M., Gębski, J., Gutkowska, K. (2021). Directions of changes in the health values of dairy products in the opinion of consumers. Nutrients, 13(6), 1945.

Seal, C. J., Courtin, C. M., Venema, K., de Vries, J. (2021). Health benefits of whole grain: Effects on dietary carbohydrate quality, the gut microbiome, and consequences of processing. Comprehensive Reviews in Food Science and Food Safety, 20(3), 2742-2768.

Semba, R. D., Ramsing, R., Rahman, N., Kraemer, K., & Bloem, M. W. (2021). Legumes as a sustainable source of protein in human diets. Global Food Security, 28, Article 100520. https://doi.org/10.1016/j.gfs.2021.100520.

Shoib A. Baba & Shahid A. Malik (2015) Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of Arisaema jacquemontii Blume, Journal of Taibah University for Science, 9(4), 449-454

Tivde, B.V., Igbabul, B. D., Eke, M. O., Oladapo, O. O., Adetunji, O (2021). Proximate, Chemical and Functional Properties of Wheat, Soy and Moringa Leaf Composite Flours. Journal of Agricultural Sciences. 12. pp18-38.

Ubbor, S. C., Ezeocha, V. C., Okoli, J. N., Agwo, O. E., Olaoye, O. A., & Agbai, I. E. (2022). Evaluation of biscuits produced from wheat (Triticum aestivum), tiger nut (Cyperus esculentus) and orange fleshed sweet potato (Ipomea batatas) flours. FUDMA JOURNAL OF SCIENCES, 6(4), 254-261.

Yang, J., de Wit, A., Diedericks, C. F., Venema, P., van der Linden, E., & Sagis, L. M. (2022). Foaming and emulsifying properties of extensively and mildly extracted Bambara groundnut proteins: A comparison of legumin, vicilin and albumin protein. Food Hydrocolloids, 123, 107190.

Yeboah-Awudzi, M., Lutterodt, H. E., Kyereh, E., Reyes, V., Sathivel, S., Manful, J., & King, J. M. (2018). Effect of bambara groundnut supplementation on the physicochemical properties of rice flour and crackers. Journal of food science and technology, 55 (9), 3556-3563. https://doi.org/10.1007/s13197-018-3281-0.

Yusufu, M. I., and Ejeh, D. D. (2018). Production of Bambara Groundnut Substituted Whole Wheat Bread: Functional

Properties and Quality Characteristics. Journal of Nutrition & Food Sciences. 10(8), pp731.

Zar Zar, O. O., Thwe Linn, K. O., Soe Soe T. (2017). Physico chemical and functional properties of chickpea protein isolate. EPH-International Journal of Biological & Pharmaceutical Science, 3(1), 11-20.

Zhang, K., Shi, Y., Zeng, J., Gao, H., & Wang, M. (2022). Effect of frozen storage temperature on the protein properties of steamed bread. Food Science and Technology, 42.

Book

AOAC .2015. Official Methods of Analysis. Association of of officialAnalytical Chemists. 18th edition, AOAC. Arlington. P. 806-814

Onimawo, I. A. and Akubor, P. I. (2012). Food Chemistry (Integrated Approach with Biochemcial background). 2nd edn. Joytal printing press, Agbowo, Ibadan, Nigeria

Book chapter

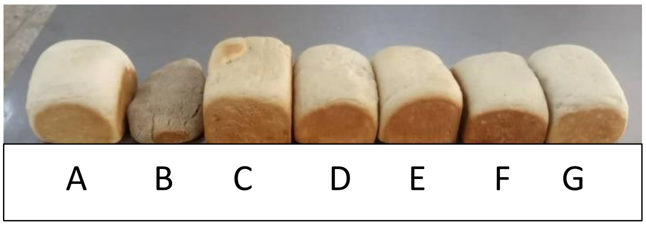
MacDonald, P., Edwards, R.R., Greenhalgh, J.F.D. and Morgan, C.A. 2002. Animal Nutrition, 6th Edition, Pearson Education Ltd, Essex, U.K. pp. 201-312.

Proceedings

Abiola, S.S. 1999. Comparative utilization of toasted and cooked soyabean in broiler rations. Proceedings of the 26thAnnual Conference of the Nigerian Society for Animal Production, pp. 84-86.

APPENDIX

Plate 1: PHYSICAL STATE OF THE BREAD SAMPLES



Key: A= 100% WF + 0% DBGNF, B= 100% AF + 0% DBGNF, C= 95% WAF + 5% DBGNF, D= 90% WAF + 10% DBGNF, E= 85% WAF + 15% DBGNF, F= 80% WAF + 20% DBGNF, G= 75% WAF + 25% DBGNF.

WF= Wheat four, AF= Acha flour, WAF= Wheat-acha flour, DBGNF= Defatted Bambara groundnut fl