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FUNCTIONAL AND NUTRITIONAL PROPERTIES OF ACHA (*Digitaria exilis*), BAMBARA NUT *(Vigna subterranean),* AND BEETROOT *(Vulgaris ruba)* FLOUR BLENDS AND PHYSICAL PROPERTIES OF THE BISCUITS

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ABSTRACT

This study evaluated the functional, nutritional, and sensory properties of biscuits produced from composite flours of acha (Digitaria exilis), Bambara groundnut (Vigna subterranea) and beetroot (Beta vulgaris). Composite flour blends were formulated by substituting the beetroot flour (0, 5, 10, 15, 20, 25%) into the acha-Bambara nut flour blend and used to produce biscuits. The blend flour was analysed for its functional properties, while the biscuits were analysed for their chemical (proximate, mineral, and vitamin) composition and sensory quality using standard methods. The water absorption and the forming capacity increased from 1.75 - 3.40 g/cm3 and 46.00 - 57.00 %, while the bulk density, swelling capacity and the oil absorption capacity decreased from 6.35 - 5.05, 4.15 - 3.75 g/cm3 and 2.75 – 1.40 mg/100g, respectively with increase in the percentage added beetroot powder (0 -25%). The fibre, ash and moisture content of the products increased from 2.60 to 2.95, 5.70 to 6.16 and 7.50 to 13.03 %, respectively, while the protein, fat and carbohydrate decreased from 14.20 to 13.05, 4.30 to 2.51 and 65.70 to 59.74 %, respectively, with an increase (0 -25 %) in added beetroot flour. The vitamin A and B content of biscuits made from different blends increased from 5.42 to 6.12 µg/100 g and from 48.84 to 71.23 µg/100 g, respectively, with the addition of beetroot flour. The phosphorus, potassium, sodium, and magnesium content of the flour blends increased from 162.54 to 276.47, 398.35 to 426.67, 98.63 to 169.67, and 143.45 to 195.67 mg/100g, respectively, with the addition of beetroot flour. The break strength and spread ratio decreased from 1210.0 to 767 g and increased from 7.10 to 7.60 with the addition of beetroot flour. Generally, all the blend products were accepted (8.42 to 6.63), but the most preferred was that of 100% wheat flour. The study confirmed that acceptable and nutritious biscuits can be produced from acha, Bambara nut and beetroot flour blends

Key Words: Functional property, Nutritional composition, Biscuits, acha (*Digitaria exilis*), Bambara nut (*Vigna subterranean)*, beetroot (*Vulgaris ruba*)

INTRODUCTION

Biscuits may be regarded as a form of confectionery, dried to a very low moisture content, made from unleavened dough (Obi and Nwakalor, 2015). They are ready-to-eat, convenient and inexpensive food products, containing digestive and dietary principles of vital importance. The major ingredients for biscuit production are flour, fat, sugar, salt, and water, which are mixed with other minor ingredients, such as baking powder, skim milk, emulsifier, and sodium metabisulfite, to form a dough containing a gluten network (Oyedele et al., 2017). According to Nwakalor (2014), the dough is rested for a period and passed between rollers to make a sheet. These sheets, however, are transformed into an appetising product through the application of heat in the oven.

Biscuits are a popular product due to their low cost, ease of transportation, long shelf life, and nutritional properties, as biscuit provides significant amounts of carbohydrates, protein, and complex B vitamins (Fradique et al., 2013). It was found that moisture content ranging from 9.44 - 9.79 %, protein from 8.43 – 13 %, fat from 1.97 - 2.5 %, ash from 1.25 - 1.62 %, crude fiber from 7.14 - 11 %, carbohydrate from 62.44 - 71.39 %, magnesium from 86.30 - 136 mg/100g, calcium from 32.90 - 38 mg/100g, iron from 2.92 - 3.86 mg/100g (Olalekan et al., 2017). Biscuit is produced from imported wheat flour which are very expensive and also relatively low in other essential nutrient such as vitamin B, and minerals (like iron and magnesium), so there is need to research into locally cultivated cereal (acha) and other plant food (Bambara groundnut and beetroot) and were underutilized making them relatively cheaper hence reducing cost of producing biscuits.

Acha seeds are nutritious, containing 8.79 % protein and may be up to 11.89 % in some black acha samples (Isah et al., 2017). The grains are rich in amino acids: leucine (9.80 %), methionine (5.60 %), valine (5.80 %) and cysteine, which are vital to human health but deficient in today's major cereals (Jideani and Jideani 2011). According to Ayo et al. (2018), acha grains contain substantial minerals (mainly iron, calcium, and phosphorus) at approximately 5.00% dry matter. Acha seeds are rich in methionine and cystine, amino acids vital to human health that are deficient in most cereals (Omeire et al., 2014). Acha (Digitaria exilis), also known as fonio or hungry rice, is an annual crop indigenous to West Africa that is classified as an underutilised crop (Inyang et al., 2018). In Nigeria, it is widely cultivated and consumed in the Northern Areas. It can be consumed completely, milled into flour, processed into gruel, porridges, alcoholic and non-alcoholic beverages. They are a good source of magnesium, iron, and copper, but low in potassium, sodium, lead, and manganese compared to most cereals. They also contain 7.90% protein, 1.80% fat, 71.00% carbohydrate, and 6.80% fibre (Orisa and Udofia, 2019). The colour and size of the grain also classify Acha. Acha is one of the most nutritious of all grains. Its seed is rich in methionine and cystine, which are vital to human health, and these amino acids are deficient in major cereals such as wheat, rice, maize, sorghum, barley, and rye.

Bambara nut (Vigna subterranea) is a legume indigenous to Africa; it is cultivated in semi-arid regions of Africa. Bambara nut typically consists of 49–63.5% carbohydrates, 15–25% protein, 4.5–7.4% fat, 5.2–6.4% fibre, 3.2–4.4% ash, and 2% minerals (Murevanhema and Jideani, 2013). It has also been reported that Bambara nut is rich in essential amino acids, including leucine, isoleucine, lysine, methionine, phenylalanine, threonine, and valine. Despite these favourable nutritional properties, Bambara nut consumption is limited because it is regarded as difficult to cook with, and firewood scarcity poses serious problems in many regions (Mubaiwa et al., 2018).

Beetroot (Beta vulgaris ruba) is a crop belonging to the family Chenopodiaceae, and it is an excellent source of red and yellow pigments. It has been reported that red beetroot has a high concentration of betalain, which are used as food colourants and food additives (Kathiravan et al., 2015). Betalains impart attractive colours to food products and have been shown to confer free-radical scavenging and antioxidant activities. They can be eaten raw, boiled, steamed and roasted. Red beetroot is a rich source of minerals (manganese, sodium, potassium, magnesium, iron, copper). Beetroot contains a high amount of antioxidants, vitamins A and E (36 IU and 0.30 mg), fibre, and natural dyes. The macronutrients include: protein contents (13.57-15.83 %), ash content 1.02 - 3.18 %), dietary fibre (0.53 to 2.43%), fat (21.63 - 21.59 %) and energy (410.07 to 394.75 kcal/100 g) (Kohajdova et al., 2018; Singh et al., 2016). Beetroots are rich in other valuable compounds such as carotenoids (Abiodun et al., 2021), glycine betaine, saponins, betacyanins, folates, betanin, polyphenols and flavonoids (Chhikara et al., 2018).

Wheat flour is very expensive and also relatively low in other essential nutrients, such as vitamin B, and minerals (like iron and magnesium), so there is a need to research into locally cultivated cereal (acha) and other plant foods (Bambara groundnut and beetroot), which were underutilised, making them relatively cheaper, hence reducing the cost of producing biscuits. The objective was to determine the functional and nutritional composition of biscuits produced from blends of acha, Bambara nut, and beetroot flour.

MATERIALS AND METHODS

Materials

Acha (Digitaria exilis), Bambara groundnut (Vigna subterranea)(Plate 1), Beetroot (Vulgaris ruba)(Plate 2), sugar, baking powder, and baking fat were purchased from the new market, Wukari, Taraba State, Nigeria

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Plate 1: Pictorial view of Bambara ground nut purchased.

Plate 2: Pictorial view of Beetroot purchased with produced flour

Preparation of acha, Bambara groundnut and beetroot flour

Acha grains were manually cleaned, destoned (sedimentation in portable water), sun dried (for 6 h), milled (Kenwood model), sieved (14 mm), to produce acha flour (Mepba et al., 2021), and stored (32 -34 °C) for further use. Bambara groundnut seeds were dried under the sun (40 - 45 °C), dehulled, milled (Kenwood model), sieved (14 mm mesh sieve) to produce flour (Musah et al., 2021), stored in a Ziplock plastic bag and stored at room temperature (32 – 34 °C). Beetroot was washed, grated, dried (70 °C), milled (Kenwood model) and sieved (14 mm mesh sieve) to produce beetroot flour (Eke-Ejiofor et al., 2022).

Experimental Design

The bulk and principal flour used was a 90:10 mixtures of acha and Bambara groundnut, based on previous research (Ayo et al., 2016). The beetroot flour was substituted for the principal flour (acha) at 0, 5, 10, 15, 20, and 25% to produce respective flour blends used for the production of biscuits. Wheat flour (100%) was used as a control.

Biscuit Preparation

The method, as described by Ayo et al. (2018) with slight modifications, was used. The sugar (50 %) was beaten into fat (50 %) (Kenwood mixer). Mixed with acha-Bambara groundnut flour blends, baking powder (1.5%) and salt (1.5%) were slowly added to the fluffy sugar-fat mixture and blended until a uniform, smooth paste was obtained. The paste was rolled on a flat, oiled rolling board to form a uniform thickness of 0.4 cm using a wooden rolling pin. Circular biscuits of 4.0 cm diameter were cut (using a biscuit-cutter), placed on a greased baking tray and baked at 160ºC for 15 min (BCH- Rotary oven, Great Britain). The biscuit was allowed to cool down (to about 32º C) and hermetically sealed in a polyethene bag.

ANALYTICAL METHODS

Determination of functional properties of flour

Determination of bulk density: The loose bulk density was determined using the method outlined by Eltayeb et al. (2011). Five grams of the sample were placed into a 25 ml graduated cylinder, and its bottom was tapped on the laboratory bench until no further decrease in the sample's volume was observed. The observed volume of the sample was then recorded as the bulk density

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$$Bulk\ Density = \frac{weight\ of\ sample\ (g)}{\text{Volume of sample after tapping(ml)}} \qquad Eqn\ (i)$$

Determination of swelling capacity, foaming capacity, and oil and water absorption capacity: The swelling capacity, foaming capacity, and oil and water absorption capacity were determined as described by Coffman et al. (2012)

Chemical analysis of flour blend biscuit

Proximate composition: The proximate (moisture, crude protein, crude fibre, crude fat, ash, carbohydrate) composition of the flour blend biscuits was determined using the AOAC (2020) method.

Mineral and vitamin composition of flour blend biscuits

The Mineral (sodium and magnesium) and vitamin (Vit A and Vit B) composition of biscuits produced from acha, Bambara nut, and beetroot flour blends was determined using the AOAC (2020) method.

Sensory evaluation of the biscuit

The biscuit samples were assessed by the method described by Akubor et al. (2023). Twenty (20) panelists were randomly selected amongst the students of the Department of Food Science and Technology, Federal University Wukari, Nigeria, who were familiar with the quality attributes of biscuits. The samples were evaluated for appearance, flavour, taste, mouthfeel, and overall acceptability on a 9-point Hedonic scale (1 = dislike extremely and 9 = like extremely). The samples were presented to the panelists in clean glass tumblers. The order of presentation of the samples to the panelists was randomised. The evaluation was carried out in a sensory evaluation laboratory under controlled conditions of lighting and illumination.

Statistical analysis

Data were analysed using Analysis of Variance (ANOVA) in a completely randomised design with replicates, as implemented in the Statistical Package for the Social Sciences (SPSS) Version 16.00. Significant differences were separated using Duncan's Multiple Range Test (DMRT). Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Functional properties Acha, Bambara nut, and beetroot flour blends (g/ml)

The functional properties of flour blends are shown in Table 1. The water absorption and the forming capacity increased from 1.75 - 3.40 g/cm3 and 46.00 - 57.00 %, while the bulk density, swelling capacity and the oil absorption capacity decreased from 6.35 - 5.05, 4.15 - 3.75 and 2.75 – 1.40 cm3/100mg, respectively, with an increase in the percentage added beetroot powder (0 -25 %).

The results indicate significant ($p \leq 0.05$) variations among the samples, suggesting that the incorporation of Acha, Bambara nut, and beetroot flours influences these functional properties differently. The decrease in the bulk density could be due to a relative decrease in the particle size of the added beetroot flour. Bulk density reflects the particle packing efficiency, which in turn affects dough handling and the texture of the final product (Ayo et al., 2016). The decrease in swelling capacity with a sample containing 95% Acha-Bambara nut flour blend and 5% beetroot flour (4.35 g/ml), showing the highest value, suggests superior starch gelatinisation, which enhances dough expansion during baking (Singh et al., 2007). The findings align with those of Oladele and Aina (2007), who observed that higher swelling capacity in composite flours improves biscuit texture by promoting better dough rise and a more desirable crumb structure.

The increase in the water absorption capacity could be attributed to the higher fibre or protein content from Bambara nut or beetroot flour (Kaur et al., 2011). Increased WAC enhances dough cohesiveness and moisture retention, extending product freshness. Kaur et al. (2011) reported similar trends, noting that WAC increases with elevated protein and fibre content due to their hydrophilic nature.

The effects on the oil absorption capacity indicate better fat-binding ability, which could enhance the richness and palatability of biscuits (Adebowale et al., 2005). Variations in OAC may be due to differences in protein hydrophobicity and fibre content, as hydrophobic protein regions bind lipids more effectively (Adebowale et al., 2005). The increase in the foaming capacity, a good potential for dairy and confectionery foods, could likely be due to protein-polysaccharide interactions enhancing foam stability (Mune Mune et al., 2018).

Table.1 Functional properties Biscuits from Acha, Bambara nut, and beetroot flour blends (g/ml)

Sample Code	Bulk density (g/cm^3	Swelling capacity g/ml)	Water absorption Capacity cm^3/100mg	Oil absorption capacity cm^3/100mg	Foaming capacity (%)
A	6.35^{ab}±0.21	4.15^{bc}±0.01	1.75^{e}±0.01	2.75^{a}±0.35	46.00^{d}±1.41
B	6.05^{b}±0.07	4.05^{c}±0.01	2.15^{d}±0.21	2.10^{b}±0.14	51.50^{cd}±0.71
C	6.35^{ab}±0.21	3.85^{d}±0.01	2.45^{cd}±0.01	2.45^{ab}±0.01	50.50^{c}±0.70
D	6.50^{a}±0.14	4.35^{a}±0.01	2.35^{cd}±0.01	2.10^{bc}±0.14	51.00^{cd}±1.41
E	6.15^{ab}±0.01	4.25^{ab}±0.01	2.60^{bc}±0.14	2.05^{bc}±0.07	52.00^{cd}±1.41
F	6.05^{b}±0.01	4.05^{c}±0.01	2.80^{b}±0.14	1.80^{cd}±0.14	53.50^{bc}±0.71
G	5.40^{a}±0.14	3.85^{d}±0.01	2.90^{b}±0.14	1.55^{de}±0.07	55.50^{ab}±0.71
H	5.05^{b}±0.21	3.75^{d}±0.02	3.40^{a}±0.14	1.40^{e}±0.14	57.50^{a}±0.71

Means within each column not followed by the same superscript are significantly different ($P \leq 0.05$) from each other using Duncan's multiple range test.
Note: The bulk and principal flour (Sample C) used was 90:10 of acha and Bambara groundnut, based upon former research (Ayo *et al*., 2016)
Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha - Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

Chemical Composition of Flour Blend Biscuits

Proximate Composition of flour blend biscuits: The proximate composition of the flour blends showed significant nutritional variations as influenced by the blending ratios and inherent properties of the individual components. The results highlight key trends in macronutrient distribution, which have important implications for food fortification and dietary applications. The fibre, ash and moisture content of the products increased from 2.60 to 2.95, 5.70 to 6.16 and 7.50 to 13.03 %, respectively, while the protein, fat and carbohydrate decreased from 14.20 to 13.05, 4.30 to 2.51 and 65.70 to 59.74 %, respectively, with an increase (0 -25 %) in added beetroot flour. The relative decrease in protein and fat content of the blend biscuit could be due to the low content of these ingredients in the added beetroot flour. The decrease in fat content, which could be attributed to the relatively low natural fat content of Bambara nuts (6–8%) (Hillocks *et al.,* 2012), may lower the energy content but reduce the tendency for oxidative rancidity, thereby improving the storage stability of the product. Lower-fat blends may be preferable for weight management and cardiovascular health (Mozaffarian *et al*., 2011). The increase in fibre content could be attributed to the high fibre content in beetroot flour (Chawla *et al.,* 2016). The relatively high fibre content of the blend product could be an advantage in fortification and enhancing dietary fibre, which may aid in improving gut health and reducing the risks of obesity and diabetes. The increase

in ash content with the addition of beetroot suggests it to be a valuable, mineral-rich food source, addressing micronutrient deficiencies in populations at risk of mineral deficiencies (e.g., iron-deficiency anaemia) (Bailey *et al*., 2015). The increase in the moisture content could be attributed to beetroot's **hygroscopic nature,** which absorbs and retains water (Adeleke and Babalola, 2020). While moisture impacts could negatively affect shelf stability, proper drying and storage techniques could mitigate microbial spoilage, ensuring product longevity (Labuza and Hyman, 1998).

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Mineral composition of flour blend biscuits: The phosphorus, potassium, sodium, and magnesium content of the flour blends increased from 162.54 to 276.47, 398.35 to 426.67, 98.63 to 169.67 and 143.45 to 195.67 mg/100g, respectively, with an increase in the added beetroot flour shown in Table 3. The relative increase in these minerals could be attributed to the addition of beetroot, which has been confirmed to be rich in these minerals (Jideani and Akingbala, 2011; Mazahib *et al.,* 2013; Wruss *et al.,* 2015).

Sodium is critical for maintaining fluid balance and nerve function, but its intake must be moderated to prevent hypertension (Strazzullo and Leclercq, 2014). The observed values of sodium are lower than those in processed foods but comparable to those in whole-food-based blends, indicating that these formulations could be beneficial for individuals monitoring their sodium intake. Magnesium plays a key role in muscle relaxation, oxidative stress reduction, and enzymatic reactions (Nielsen, 2018).

Proximate composition from Acha, Bambara nut, and beetroot flour blends

Table 2 Proximate composition from Acha, Bambara nut, and beetroot flour blends (%)

Sample Code	Crude Protein (%)	Crude Fiber (%)	Fat (%)	Ash (%)	Moisture content (%)	Carbohydrate (%)
A	10.02^{h}±0.01	0.16^{h}±0.01	2.69^{e}±0.04	0.76^{h}±0.05	3.54^{h}±0.01	82.81^{a}±0.08
B	13.95^{c}±0.00	2.20^{g}±0.00	3.61^{b}±0.01	4.95^{g}±0.00	7.00^{g}±0.00	68.29^{b}±0.01
C	14.20^{a}±0.00	2.60^{e}±0.00	4.30^{a}±0.00	5.70^{f}±0.00	7.50^{f}±0.00	65.70^{c}±0.00
D	14.00^{b}±0.00	2.51^{f}±0.01	3.01^{c}±0.01	5.81^{e}±0.01	14.03^{a}±0.00	65.47^{c}±0.66
E	13.91^{d}±0.01	2.73^{d}±0.01	2.90^{d}±0.01	5.98^{d}±0.01	13.92^{b}±0.00	62.60^{d}±0.33
F	13.05^{e}±0.01	2.95^{c}±0.00	2.51^{f}±0.01	6.16^{c}±0.01	13.07^{c}±0.00	59.74^{e}±0.02
G	12.25^{f}±0.01	2.97^{b}±0.00	2.01^{g}±0.01	7.14^{b}±0.00	12.27^{d}±0.00	59.34^{ef}±0.01
H	12.01^{g}±0.01	3.00^{a}±0.00	1.93^{h}±0.01	8.13^{a}±0.00	12.01^{e}±0.00	58.95^{f}±0.01

*Means within each column not followed by the same superscript are significantly different ($P \leq 0.05$) from each other using Duncan multiple range test.

Note: Note: The bulk and principal flour (Sample C) used was 90:10 of acha and Bambara groundnut based upon former research (Ayo *et al*., 2016)

** Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha - Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

Table 3 Mineral composition from Acha, Bambara nut, and beetroot flour blends (mg/100g)

Sample Code	Phosphorus (P)	Potassium (K)	Sodium (Na)	Magnesium (Mg)
A	$123.53^{h}\pm0.01$	$360.50^{h}\pm0.01$	$312.22^{a}\pm0.01$	$137.52^{g}\pm0.02$
B	$126.66^{g}\pm0.01$	$376.27^{g}\pm0.02$	$60.18^{h}\pm0.01$	$86.26^{h}\pm0.01$
C	$162.54^{f}\pm0.01$	$398.35^{f}\pm0.02$	$98.63^{g}\pm0.02$	$143.45^{f}\pm0.00$
D	$212.36^{e}\pm0.02$	$401.45^{e}\pm0.00$	$126.67^{f}\pm0.01$	$166.25^{e}\pm0.00$
E	$218.96^{d}\pm0.02$	$410.86^{d}\pm0.01$	$129.57^{e}\pm0.02$	$169.30^{d}\pm0.01$
F	$225.56^{c}\pm0.01$	$415.26^{c}\pm0.01$	$132.47^{d}\pm0.02$	$172.35^{c}\pm0.02$
G	$251.01^{b}\pm0.01$	$420.96^{b}\pm0.01$	$151.07^{c}\pm0.02$	$184.01^{b}\pm0.02$
H	$276.47^{a}\pm0.02$	$426.67^{a}\pm0.02$	$169.67^{b}\pm0.03$	$195.67^{a}\pm0.02$

The data values are mean ± standard deviation of the mineral composition. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test.

Note: Note: The bulk and principal flour (Sample C) used was 90:10 of acha and Bambara groundnut based upon former research (Ayo *et al*., 2016)

Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha -Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

Vitamin composition of flour blend biscuits:

The vitamin A and B6 content of biscuits made from different blends increased from 5.42 to 6.12 and from 48.84 to 71.23 μg/100 g (Table 4) with the addition of beetroot flour. Beetroot contains significant amounts of provitamin A carotenoids, which could be converted into retinol (active vitamin A) in the body (Jones and Abu, 2019). The higher vitamin B levels in flour blend biscuits proved the potential of beetroot in food (Adebowale et al., 2016; Oyeyinka et al., 2018).

Table 4: Vitamin composition of the Biscuits from Acha, Bambara nut, and beedroot flour blends (ug/100g)

Sample Code	Vitamin A	Vitamin B_6
A	$1.63^{g}\pm0.28$	$0.61^{h}\pm0.04$
B	$4.59^{cd}\pm0.03$	$65.49^{d}\pm0.01$
C	$5.42^{b}\pm0.01$	$48.84^{b}\pm0.01$
D	$3.28^{f}\pm0.02$	$51.70^{g}\pm0.00$
E	$4.17^{f}\pm0.02$	$59.67^{f}\pm0.02$
F	$4.45^{e}\pm0.02$	$64.55^{e}\pm0.01$
G	$4.75^{c}\pm0.04$	$66.44^{c}\pm0.01$
H	$6.12^{a}\pm0.01$	$71.25^{a}\pm0.02$

Means within each column not followed by the same superscript are significantly ($P \leq 0.05$) different from each other using Duncan multiple range test. Note: The bulk and principal flour (Sample C) used was 90:10 of acha and Bambara groundnut based upon former research (Ayo *et al.*, 2016)

Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha - Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

Physical quality of flour blend biscuits:

The break strength and spread ratio decreased from 1210.0 to 767 g and increased from 7.10 to 7.60 with an increase in the added beetroot flour (Table 5). Biscuit weight is primarily determined by moisture retention, dough density, and ingredient composition (Manley, 2011). The differences observed here suggest variations in dough hydration or baking conditions, with heavier biscuits likely retaining more moisture or containing denser flour matrices (Pareyt and Delcour, 2008).

a.Wheat(100%) b. Acha(100%) c. Acha/Bnut (90/10) d.Acha-bnut/bert(95/5)

e.Acha-Bnut/Bert (90/10) f. Acha-Bnut/Bert(85/15) g. Acha-Bnut/Bert(80/20)h.Acha-Bnut/Bert(75/25)

Bnut= Bambara nut

Plate 3: Pictorial view of the biscuit samples produced

Break strength, a measure of resistance to fracture, was highest in 100 % Wheat flour (3250.50 N) and lowest in 80 % Acha-Bambara nut flour blend and 20% Beet root flour (776.50 N) and 75 %Acha-Bambara nut flour and 20 % Beet root flour (767.50 N). This parameter reflects textural hardness, influenced by gluten development, fat/sugar ratios, and baking time/temperature (Sahin and Sumnu, 2006). The results suggest that Sample A had a more rigid structure, possibly due to the use of high-protein flour or lower fat content, while G and H were more tender, likely because of their higher fat or sugar content.

The spread ratio, which measures dough expansion, was highest in 100% Wheat flour (7.70), 100 % Acha flour (7.60), and 80 % Acha-Bambara nut flour blend and 20% Beet root flour (7.60) and lowest in 95 % Acha-Bambara nut flour and 5 % Beet root flour (6.80). Spread is governed by sugar dissolution, fat lubrication, and leavening efficiency (Jacob and Leelavathi, 2007). Greater spread is linked to enhanced sugar melting (which increases dough fluidity) and optimal fat distribution (Baltsavias *et al.,* 1999)

Table 5: Physical properties of the flour blend biscuits

Sample Code	Weight (g)	Break strength (N)	Spread ratio (%)
A	$9.89^{a}\pm0.01$	$3250.50^{a}\pm0.71$	$7.70^{a}\pm0.14$
B	$9.51^{c}\pm0.07$	$2070.50^{b}\pm0.71$	$7.60^{a}\pm0.14$
C	$9.50^{c}\pm0.08$	$1260.00^{c}\pm7.07$	$7.10^{bc}\pm0.14$
D	$9.83^{a}\pm0.01$	$1710.00^{d}\pm0.00$	$6.80^{c}\pm0.14$
E	$9.83^{a}\pm0.01$	$955.00^{e}\pm7.07$	$7.10^{bc}\pm0.14$
F	$9.63^{b}\pm0.01$	$917.50^{f}\pm3.54$	$7.25^{b}\pm0.07$
G	$8.74^{d}\pm0.01$	$776.50^{g}\pm4.95$	$7.25^{b}\pm0.07$
H	$8.21^{e}\pm0.01$	$767.50^{g}\pm3.54$	$7.60^{a}\pm0.14$

Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test.

Note: The bulk and principal flour(Sample C) used was 90:10 of acha and Bambara groundnut based upon former research (Ayo *et al*., 2016)

Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha - Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

Sensory quality of flour blend biscuits

The average means of appearance, aroma, taste, texture, and overall acceptability decreased from 8.37 to 6.21, 8.21 to 6.31, 7.95 to 5.85, 7.89 to 6.37, and 8.42 to 6.63, respectively, with an increase in the added beetroot flour (Table 6). The low standard deviation (0.37–0.63) suggests high consistency in the panellists' ratings, reinforcing their preference. This can be attributed to an optimal flour blend ratio, which enhances palatability. Similar findings were reported by Oluwajuyitan *et al.* (2021), who noted that balanced composite flour blends enhance the sensory properties of baked goods.

The decline in texture scores (7.89–8.11) may be related to the increased fibrous content from Bambara nut or beetroot, as noted by Adeleke and Babalola (2020) in their studies on legume-enriched bakery products. The lower scores in Samples E (90 % Acha-Bambara nut flour blend and 10 % Beet root flour)–H (75 % Acha and Bambara nut flour and 20% Beet root flour) align with findings by Obadina *et al*. (2017), who reported that legume flours can introduce beany or bitter notes, while beetroot may impart an earthy taste that not all consumer's favor. The relatively softer texture, with higher average scores in the control sample (100% Wheat flour and 100% acha flour), may result from acha's fine particle size, as highlighted by Oyeyinka *et al.* (2019). Generally, all the blend products were accepted (8.42 to 6.63), but the most preferred was that of 100% wheat flour.

Table 6: Sensory evaluation of the Biscuits from Acha, Bambara nut, and beetroot flour blends

Sample Code	Appearance	Aroma	Taste	Texture	Overall acceptability
A	$8.84^{a}±0.37$	$8.79^{a}±0.54$	$8.79^{a}±0.63$	$8.68^{a}±0.58$	$8.79^{a}±0.54$
B	$8.32^{ab}±1.44$	$8.11^{ab}±0.57$	$7.95^{b}±0.91$	$8.11^{ab}±0.57$	$8.26^{ab}±0.65$
C	$8.37^{ab}±0.60$	$8.21^{ab}±0.71$	$7.95^{b}±0.85$	$7.89^{bc}±0.65$	$8.42^{a}±0.69$
D	$7.53^{bc}±0.96$	$7.95^{b}±0.78$	$7.58^{bc}±1.12$	$7.47^{bcd}±1.07$	$7.68^{bc}±0.82$
E	$7.26^{cd}±0.99$	$7.21^{c}±1.03$	$7.21^{bcd}±1.13$	$7.42^{bcd}±0.84$	$7.47^{c}±1.07$
F	$7.10^{cde}±1.56$	$7.00^{cd}±1.10$	$6.84^{cd}±1.11$	$7.11^{cde}±1.15$	$7.42^{c}±1.07$
G	$6.47^{de}±1.84$	$6.58^{cd}±1.50$	$6.68^{de}±1.38$	$6.68^{de}±1.57$	$6.68^{d}±1.37$
H	$6.21^{e}±2.29$	$6.31^{d}±1.78$	$5.95^{e}±1.87$	$6.37^{e}±1.95$	$6.63^{d}±1.57$

The data values are mean ± standard deviation of the sensory evaluation. Means within a column not followed by the same superscript are significantly different (P ≤ 0.05).

Note: The bulk and principal flour (Sample C) used was 90:10 of acha and Bambara groundnut based upon former research (Ayo *et al*., 2016)

Key: Sample A= 100 % Wheat flour; Sample B= 100 % Acha flour; Sample C= 100 % Acha - Bambara nut flour blend; Sample D= 9 5 % Acha-Bambara nut flour blend and 5 % Beet root flour; Sample E= 90 % Acha-Bambara nut flour blend and 10 % Beet root flour, Sample F= 85 % Acha-Bambara nut flour blend and 15 % Beet root flour, Sample G= 80 % Acha-Bambara nut flour blend and 20 % Beet root flour, Sample H= 75 % Acha-Bambara nut flour blend and 25 % Beet root flour

CONCLUSION

This study has shown that nutritious and acceptable biscuits can be produced from blends of acha, Bambara nut, and Beetroot flour. The addition of beetroot flour significantly improved the ash, fibre, and mineral content (phosphorus, sodium, and magnesium), as well as the sensory quality of the product. Although all the flour blend products were accepted, the most preferred is that of 100% wheat, which compares favourably with blend samples containing 5-10% beetroot flour. However, the sample containing 100% Acha-Bambara nut has the highest crude protein content (14.20%), indicating that Bambara nut fortification could improve the protein content more effectively. Acha and Bambara nut and beetroot flour blends can present a viable and sustainable alternative to wheat flour, offering enhanced nutrition and functional benefits.

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