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Production and assessment of crackers produced from the blend of Cassava (*Manihot esculenta*), *Ugba* (*Pentaclethra macrophylia),* and Wheat (*Triticum aestivum*) Flours

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ABSTRACT

This work produced composite flour from newly released Cassava (Baba 70), *Ugba*, and wheat, determined the functional properties of the composite flour, produced crackers using the composite flour, and evaluated the physicochemical and sensory acceptability properties of the crackers. The flour and cracker samples were subjected to functional, physicochemical, and sensory analysis. The water absorption capacity, Oil absorption capacity, bulk density, and foam stability of the flour samples had values from 1.6 – 2.7 g/ml, 0.72 – 1.82 g/ml, 0.63 - 0.72 g/ml, and 30.01 - 87.01 % respectively. The moisture, ash, crude fiber, fat, crude protein, and carbohydrate contents had values from 3.20 – 7.51 %, 2.73 - 3.20 %, 0.60 - 8.50 %, 10.32 - 22.50 %, 3.30 - 20.02 % and 38.50 - 78.12 % respectively. The mineral contents had values from 1.23 - 20.24 mg/100g for calcium, 1.20 - 11.02 mg/100g for Iron, 0.30 - 14.80 mg/100g for Sodium 3.62 - 36.50 mg/100g, and 5.60 - 10.21 mg/100g respectively. The values for weight, diameter, thickness, texture, color, density, and break strength values ranged from 6.71 - 10.04 g, 4.23 - 5.10 cm, 0.23 - 0.62 cm, 4.02 to 27.01 N, 7.00 to 18.50, 0.91 - 1.12 g/cm3 and 200.00 - 350.24 g, while the sensory properties had values which ranged from 4.05 – 9.12 for appearance, 2.90 – 8.65 for taste, 4.80 – 7.90 for texture, 5.54 – 8.60 for aroma and 6.00 – 8.90 for general acceptability. This study has shown that producing crackers using Cassava (*Baba* 70), *Ugba*, and wheat flour blends presents a promising approach to creating a nutritious and functional snack, thereby diversifying raw materials and promoting food security and sustainability, especially in regions with abundant ingredients.

Keywords: Baba 70 cassava, *Ugba*, Wheat, Flour, Cracker

1. INTRODUCTION

The increasing demand for convenient and portable snacks has driven the popularity of crackers (Massodi and Bashir, 2012). Their versatility, whether consumed independently or paired with dips, spreads, and toppings, makes crackers a favored choice for those seeking quick meal solutions or healthier snack alternatives. Consequently, the global market for crackers and similar snack foods is expected to expand. Cassava flour, derived from the starchy roots of *Manihot esculenta* (Baba 70 variety) is well-known for its availability, affordability, and gluten-free properties. While it has a neutral flavor and lower protein content than wheat, cassava flour is widely used in baked goods due to its economic benefits and abundance in tropical regions.

However, its limited gluten formation and low protein content restrict its functionality in baking. *Ugba*, also called *Ukpaka*, refers to fermented African oil bean seed (*Pentaclethra macrophylla*), which is rich in protein and essential nutrients (Ogueke et al., 2010). Besides its culinary uses, it serves purposes such as a salt substitute, edible oil source, and medicinal applications (Ogueke et al., 2010; Okorie and Olasupo, 2013). The seed contains phytonutrients like alkaloids, saponins, and flavonoids, contributing to its reported health benefits, such as treating diarrhea and anemia. *Ugba* flour, processed from these seeds, is valued for its high protein, dietary fiber, and mineral content, making it a complementary ingredient to cassava flour for baking. Research has shown that including 10-20% *Ugba* flour in flour blends enhances baked products like crackers' nutritional and sensory properties.

Wheat is highly important among cereals mainly because of its grains, which comprise protein with exclusive physical and chemical attributes. It also encompasses other useful components, such as minerals (Cu, Mg, Zn, Fe, and P), protein, and vitamins (riboflavin, thiamine, niacin, and alpha-tocopherol), and is also a valuable source of carbohydrates (Garg et al., 2021). However, wheat proteins have been found to lack vital amino acids; for example, lysine and threonine (Urade et al., 2018; Siddiqi et al., 2020). The wheat, as produced by nature, contains several medicinal virtues. Every part of the whole-wheat grain supplies elements needed by the human body. Starch and gluten in wheat provide heat and energy; the inner bran coats, phosphates and others. The whole wheat, which includes the bran and wheat germ, therefore, provides protection against diseases such as constipation, ischaemic, heart disease, disease of the colon called diverticulum, appendicitis, obesity, and diabetes.

There are many reports of the association of wheat, and particularly wheat proteins, with medical conditions, ranging from improbable reports in the popular press to scientific studies in the medical literature. Cracker biscuits, commonly known as crackers, are a type of baked snack food that is usually thin, crispy, and crunchy. They are made from a mixture of flour, water, and other ingredients, such as salt, yeast, sugar, or butter. Crackers come in a variety of shapes and sizes, and they can be plain or flavored with herbs, spices, or cheese (Manley, 2011). Cracker biscuit consumption is influenced by factors such as availability, cost, taste preferences, and cultural norms. However, due to their convenience, long shelf life, and versatility, crackers remain a popular snack food around the world. Flour is the primary ingredient in crackers, typically comprising more than 80% of the final product. The type of flour used in crackers can vary depending on the desired texture and flavor profile (Florence et al., 2014).

Low-protein soft flour, also known as pastry flour, may be used in some recipes to create a softer and more delicate texture. There is a growing demand for convenient and on-the-go snacks, which has contributed to the increasing popularity of crackers (Massodi and Bashir, 2012). The amalgamation of cassava, wheat, and *Ugba* flours presents an exciting opportunity to craft crackers that not only meet taste expectations but also fulfill nutritional needs. By leveraging the strengths of each component – cassava's affordability and neutral taste, *Ugba's* protein and mineral fortification, and wheat's baking properties – this exploration aims to rewrite the melody of the humble cracker, transforming it into a symphony of both flavor and nutrition. Through this project, we embark on a culinary and scientific journey, exploring the untapped potential of a harmonious blend that has the potential to revolutionize cracker production. This study explores the potential of these blends, focusing on the recently developed cassava variety "Baba 70".

2. MATERIALS AND METHOD

Raw Material Sourcing

Fresh cassava roots (Baba 70) were obtained from the National Root Crops Research Institute in Umudike, Nigeria. *Ugba* seeds, wheat flour, and other ingredients were purchased locally in Imo State. Processing was conducted at Michael Okpara University of Agriculture's Food Science and Technology Department.

Sample Preparation

Production of Cassava flour

The method described by Lagnika et al., (2019) was adopted in the processing of cassava flour. Fresh and good quality roots of *Baba 70* were selected from the harvested cassava, then peeled, washed, and soaked in water for about 15 min to reduce the cyanogen. The roots were then sliced to 3 mm thickness using a manual slicer, bagged in a jute bag, and pressed using a manual hydraulic presser to reduce the moisture and allow the leaching out of the cyanogen. Both the settled starch after removing the liquid and the pressed cassava slices were sun-dried for 6 h followed by oven drying at 55 °C for 24 h. The dried cassava slices were milled into flour using a hammer-milling machine. The flour produced was sieved to obtain an 80-mesh powder. The flour sample was packaged in an airtight container before laboratory analysis (Figure 1).

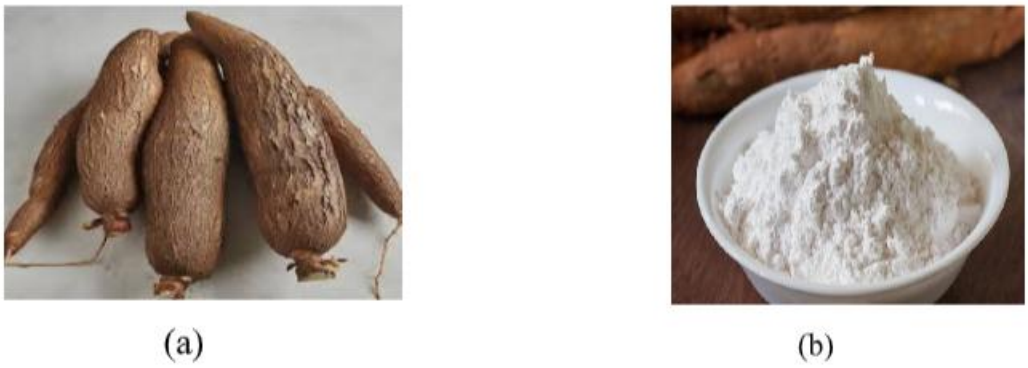

Figure 1 (a) Fresh Cassava roots and (b) Cassava Flour

Production of Ugba flour

The method described was used to produce *Ugba* flour. The beans were first thoroughly washed to remove dirt and debris, and soaked in water for 24 - 48 hours, to soften and initiate natural fermentation. The softened beans are dehulled (outer shell removed) using mortar and pestle. The dehulled beans (cotyledons) were boiled for about 2 h to soften them and enhance the fermentation process. The cotyledons are then thinly sliced (usually 2 mm thick) using a sharp knife.

The sliced cotyledons are wrapped in blanched banana leaves to create a natural fermentation chamber and left to ferment at room temperature for 48 h. The slices were oven-dried at 50 °C for 12 h. After which the dried slices were milled into a finer powder using a hammer milling machine resulting in the production of *Ugba* flour. The flour produced was cooled and sieved through a 200 mm mesh sieve to obtain experimental flour samples (Figure 2). The flour samples were packaged separately in an airtight container for laboratory analysis.

Figure 2 (a) Fresh *Ugba* seeds and (b) *Ugba* Flour

Production of Crackers

The method described by with modification was used to produce crackers. Cassava, *Ugba*, and Wheat flour were mixed with ½-teaspoon salt and other desired dry ingredients like spices, herbs, or grated cheese (Table 1 & 2; Figure 3). Butter was added and thoroughly mixed until it became crumbly gradually. Water was added and the flour mixture was kneaded until the dough came together, then it was allowed to chill for 30 minutes. The dough was wrapped in a plastic wrap and refrigerated for 30 minutes.

This allows the flavors to meld and the dough to rest, making it easier to roll out, while the oven was preheated to 180 °C. Then chilled dough was rolled out to about ¼ -inch thickness on a flat rolling board (sprinkled with flour). The desired shapes were cut using a cookie cutter or a sharp knife. Tiny holes were made into the dough with a fork and docking tool to prevent puffing during baking and ensure even cooking, and then transferred the crackers to a baking sheet lined with parchment paper and baked for 12-15 minutes until golden brown and slightly firm container before further use.

Table 1 Standard Recipe for Production of Crackers

Ingredients	**Proportion (by weight to total flour)**
Ugba Flour	30 %
Cassava Flour	40 %
Wheat flour	15 %
Butter	11 %
Salt	2 %
Baking powder	2 %
Water	Quantity Sufficient

Table 2 Modified Formulation for Production of Crackers for our Research

SAMPLE CODE	**Wheat**	***Ugba***	**Cassava**
CRK 1	100 (control)	0	0
CRK 2	80	10	10
CRK 3	60	25	15
CRK 4	0	100	0
CRK 5	0	0	100

Key: CRK1 = 100 % wheat, 0 % *Ugba*, 0 % Cassava, CRK2 = 80 % wheat: 10 % *Ugba;* 10 % cassava, CRK3 = 60 % wheat: 25 % *Ugba*: 15 % cassava, CRK4 = 0 % Wheat, 100 % *Ugba*, 0 % Cassava, CRK5 = 0 % Wheat, 0 % *Ugba*, 100 % cassava

Methods

Functional Properties of Composite Flour

The functional properties (water and oil absorption capacity, foaming capacity, and bulk density) of the composite flour were determined according to the methods described by (Onwuka, 2018).

Water holding capacity (WHC) and Oil absorption capacity (OAC)

One gram (1 g) of the sample was mixed with 10 ml distilled water, or 10 ml of vegetable oil of known density (0.99 mg/ml) for 5 min on a magnetic stirrer at 1000 rpm. The mixture was centrifuged (Model: SM 800B Uniscope Surgifriends Medicals, England) at 3500 rpm for 30 min and the volume of the supernatant was noted. WAC or OAC was calculated and expressed as g of water or oil absorbed or retained per g of sample.

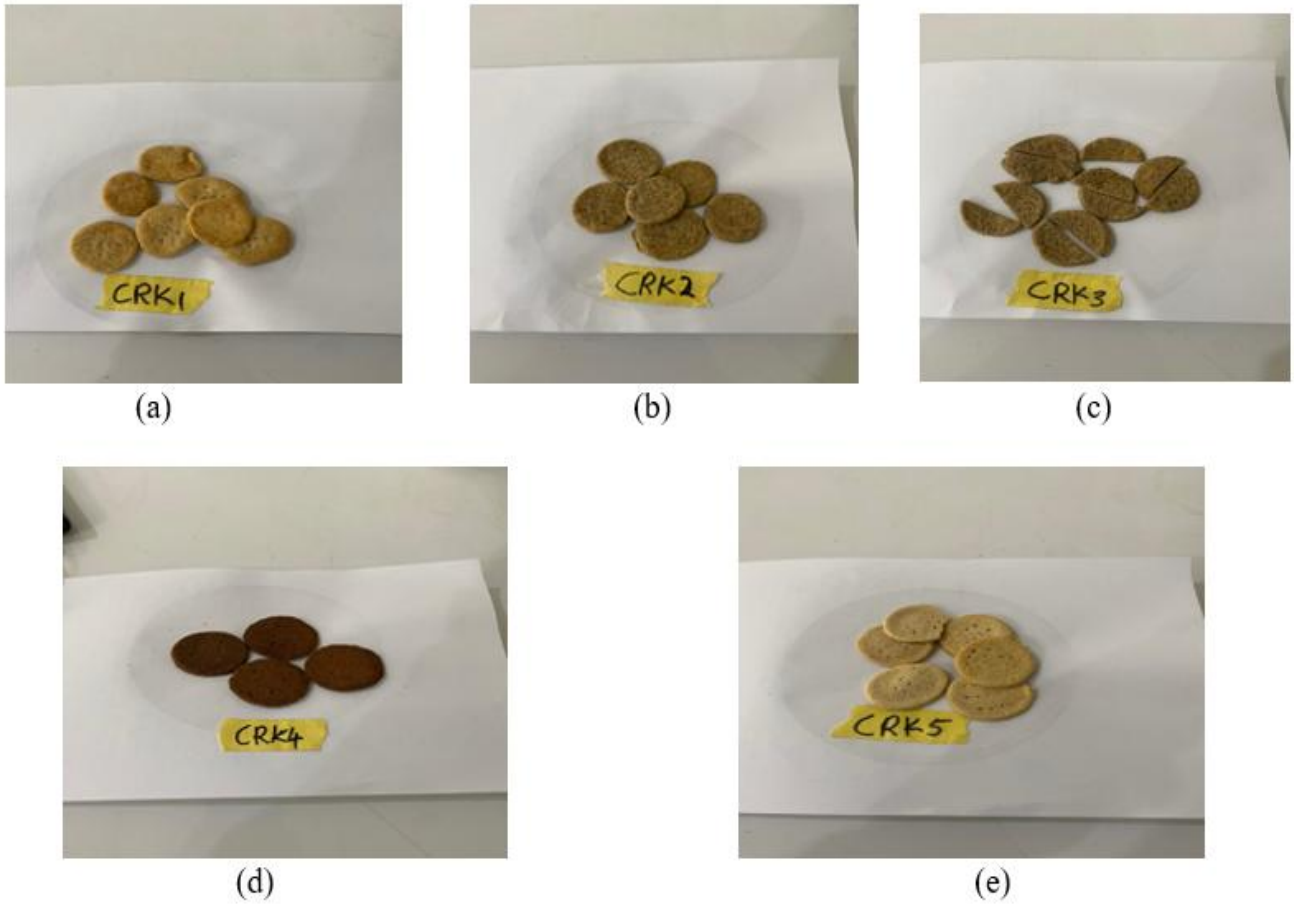

Figure 3 (a) 100 % wheat, 0 % *Ugba*, 0 % Cassava, (b) 80 % wheat: 10 % *Ugba;* 10 % cassava, (c) 60 % wheat: 25 % *Ugba*: 15 % cassava, (d) 0 % Wheat, 100 % *Ugba*, 0 % Cassava, (e) 0 % Wheat, 0 % *Ugba*, 100 % cassava

Water holding capacity %

$$= \frac{\text{Amount of water added} - \text{free water (g)}}{\text{Weight of sample (g)}} \times density\ of\ water \times 100 \quad (1)$$

Oil absorption capacity %

$$= \frac{\text{Amount of oil added} - \text{free oil (g)}}{\text{Weight of sample (g)}} \times density\ of\ oil \times 100 \quad (2)$$

Bulk density

A 10 ml graduated cylinder was weighed dry and gently filled with the flour sample up to the 10 ml mark. The bottom of the cylinder was then tapped gently on a laboratory bench several times. This continued until no further diminution of the test flour sample in the cylinder after filling to mark was observed. The weight of the cylinder plus flour was measured and recorded. Bulk density was expressed as:

$$\text{Bulk density (g / ml)} = \frac{\text{weight of Sample (g)}}{\text{volume of sample (ml)}} \quad (3)$$

Proximate composition of the Crackers

Moisture content

To determine the moisture content of the samples, Onwuka, (2018) methodology was employed. The plates made of aluminum were properly cleaned and weighed. Five grams of the sample was introduced into the dish and the weight of the dish with the sample was taken every 30 minutes. Thereafter, it was dried in the oven at 70°C for 2 h and at 120°C until a constant weight was obtained and then

cooled in the desiccator, after which the dry weight of the sample plus dish was taken. The moisture content of the samples was calculated as follows:

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (4)$$

Where: W1 = Initial weight (g) of empty crucible
W2 = Weight (g) of crucible plus sample before drying
W3 = Final weight (g) of crucible plus sample after drying

Crude protein

The Kjedahl technique, as described by Onwuka, (2018), was used to determine the crude protein content of the samples. Five grams of the samples were introduced into the digestion flask. Kjedahl catalyst (Selenium tablets) was added to the sample. Twenty milliliters of concentrated sulphuric acid were added to the sample and fixed to the digester for eight hours until a clear solution was obtained. The cooled digest was transferred into a 100 ml volumetric flask and made up to the mark with distilled water. The distillation apparatus was set and rinsed for ten minutes after boiling. Twenty milliliters of 4 % boric acid were pipetted into a conical flask.

Five drops of methyl red were added to the flask as an indicator and the sample was diluted with 75 ml distilled water. Ten milliliters of the digest was made from alkaline with 20 ml of sodium hydroxide (NaOH) (20 %) and distilled. The steam exit of the distillatory was closed and the change of color of the boric acid solution to green was timed. The mixture was distilled for 15 minutes. The filtrate was then titrated against 0.1 N Hydrochloric acid (HCl) until a permanent blue color appears. The total percentage of protein was determined in duplicate and calculated as follows:

Protein (%) = % nitrogen x conversion factor (6.25). (5)

Fat content

Using a Soxhlet apparatus, as described by Onwuka, (2018), the fat content of the samples was assessed. The samples (2 g) were wrapped in filter paper and placed in a Soxhlet reflux flask. The Soxhlet reflux flask was connected to a condenser on the upper side and to a weighed oil extraction flask filled with two hundred milliliters of petroleum ether. The ether was brought to its boiling point, and the vapor condensed into the reflux flask immersing the samples completely for extraction to take place by filling up the reflux flask siphons over carrying the oil extract back to the boiling solvent in the flask. The process of boiling, condensation, and reflux was allowed to go on for four (4) hours before the defatted samples were removed. The lipid extract in the flux was dried in the oven at 60 °C for thirty (30) minutes and then weighed. The assessment was done twice, and the following formula was used to determine the fat content of the samples:

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{weight of sample}} \times 100 \quad (6)$$

Ash content

The amount of ash in the samples was ascertained using the technique specified by (Onwuka, 2018). Porcelain crucibles were dried and cooled in desiccators before weighing. Three grams of the samples were weighed into the crucible and the weight was taken. The crucible containing the samples was placed into the muffle furnace and ignited at 550 °C for 3 h. The muffle furnace was allowed to cool before bringing the crucibles out, cooled, and weighed. The ash content of the samples was determined in duplicates and calculated as follows:

$$\text{Ash (\%)} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100 \quad (7)$$

Where: W2 = weight of crucible + ash (g)
W1 = weight of empty crucible (g)

Crude Fiber

The crude fiber of the samples was determined according to the method of (Onwuka, 2018). With 200 ml of solution containing 1.25 g of tetraoxosulphate (vi) acid (H2SO4) per 100 ml of solution, five grams of the sample was boiled under reflux for 30 minutes. The solution was filtered through linen on a flaunted funnel and was washed with water until the washing was no longer acidic. The residue was then transferred to a beaker and boiled for thirty minutes with 100 ml of solution. The final residue was filtered through a

thin but closed pad of washed and ignited asbestos in a Gosh crucible. The residue was then dried in an electric oven at 150°C for 10 minutes. The residue was incinerated, cooled, and weighed. The crude fiber content of the samples was then determined in duplicate and calculated as follows:

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{W_1} \quad (8)$$

Where: W1 = weight of sample used (g)
W2 = weight of crucible plus sample (g)
W3 = weight of sample crucible (g)

Carbohydrate content

Using the formula outlined by Onwuka (2018).

Carbohydrate (%) =100 − % (protein + fat + fibre + ash + moisture content) (9)

The carbohydrate content of the sample items was calculated by difference in duplicate.

Determination of energy value

The energy value was estimated using Atwater factors as described by (Onwuka, 2018). The energy value was calculated by multiplying the proportion of protein, fat, and carbohydrate by their respective physiological fuel value of 4, 9, and 4 kcal/g respectively, and taking the sum of their products.

The energy value was calculated thus:

Fe = (% CP x 4) + (% CF x 9) + (% CHO x 4) (10)

Where: Fe = Food energy (in grain calories)
CP= Crude protein
CF= Crude fat
CHO= Carbohydrate

Mineral analysis

Determination of calcium and magnesium

The calcium and magnesium content of the samples were determined with the complexometric titration method of (Onwuka, 2018). Twenty milliliters (20 mL) of the extract were measured into a conical flask and treated with pinches of the masking agents (hydroxylamine hydrochloride, sodium cyanide, and sodium-potassium ferrocyanide). The flask was shaken to dissolve the mixture before adding 20 mL of ammonia buffer to raise the pH to 10.00. The mixture was titrated against 0.02N ethylenediaminetetraacetic acid (EDTA) solution using Eriochrome Black T as an indicator to a permanent blue end point from deep red. A reagent blank was also titrated the same. The titration value represents both Ca2+ and Mg2+ in the test sample. The analysis was repeated to determine Ca2+ alone by titrating with 10 % NaOH instead of ammonia buffer and solo chrome dark blue indicator in place of Eriochrome black T. Total calcium and magnesium contents were calculated separately using:

$$\frac{Ca}{Mg}\left(\frac{mg}{mg}\right) = \frac{100}{W} \times \frac{T - B(N \times Ca/Mg)}{Va} \times \frac{Vf}{1} \quad (11)$$

Where W= Weight of sample
T= Titre value of sample
B= Titre value of blank
Ca= Calcium equivalence
Mg= Magnesium equivalence
Va= Volume of extract titrated
Vf= Total volume of extract
N= Normality of titrant (0.02N EDTA)

Determination of Potassium

Potassium was determined using the procedure described by (Onwuka, 2018). A potassium standard was prepared. The standard solution was used to calibrate the instrument readout. The meter reading was at 100% E (emission) to aspire to 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 and potassium was calculated as follows:

$$\text{Potassium (\%)} = \frac{ppm \times 100 \times DF}{1000} \quad (12)$$

Where DF= Dilution factor

ppm= Part per million

Determination of Sodium

Sodium was determined using the flame photometry method (AOAC, 2010). Jaway digital flame photometry was set up according to the manufacturer's instructions. It was switched on and allowed for 10 min to equilibrate. Standard sodium solutions were prepared separately and diluted in series to contain 10, 8, 6, 4, and 2 g of sodium. After equilibrating the instrument, 1 mL of each standard was aspirated into it and sprayed over the non-luminous flame. The optional density of the emission from each standard solution was recorded. Before filtering, sodium was put in place with standard and measured, the test sample extracts were measured in time and their graphs were plotted into a standard curve which was used to extrapolate the content of sodium. The sodium content of the sample was calculated as shown below:

$$\text{Sodium (mg/100g)} = {}^{X}/_{1000} \times {}^{Vt}/_{Va} \times D \times {}^{100}/_{w} \quad (13)$$

Where X= Concentration of the test element from the curve

Determination of Iron

The iron content of the sample was determined using the spectrophotometric method of (AOAC, 2010). Five grams (5 g) of the sample were first digested with 20 mL of acids mixture (650 mL concentrated HNO3, 80 mL perchloric acid, and 20 mL concentrated H2SO4). The digest was diluted by making up to 100 mL with water. Two grams of the sample solution were pipetted inside a flask before 3 mL buffer solution, 2 mL hydroquinone solution, and 2 mL bipyridyl solution were added. The absorbance reading was taken at a wavelength of 520 nm and the blank was used to zero the instrument.

Also, a standard solution of iron was prepared by dissolving 3.512 g of Fe (NH4)2. (SO4). 6H2O in 10 mL of distilled water and two drops of 0.5 NHCl were added and diluted to 500 mL with distilled water. The iron standard was further prepared at different concentrations (2–10 ppm) by diluting it with distilled water. Three milliliters (3 mL) of buffer solution, 2 mL of hydroquinone solution, and 2 mL of bipyridyl solution were added. Absorbance reading was taken at 520 nm. The reading was used to plot a standard iron curve for extrapolation.

Physical properties of crackers

Thickness

The thickness of the crackers was measured by stacking ten pieces of crackers, following the method explained by (Ahmed and Hussein, 2014). The samples were recorded in triplicates, and the mean values for thickness were reported in mm.

Diameter

The diameter of a single cracker was measured by arranging ten pieces of crackers edge to edge. The samples were collected in triplicates for each sample. The average values were recorded in mm.

Weight

A weighing balance was used to determine the weight of crackers. Mean values for weight were reported in g.

Spread ratio

The spread ratio was determined by dividing diameter by thickness following the method of (Ahmed and Hussein, 2014).

Texture

The TA-XT Plus texture analyzer was used to measure the hardness and tractability of the biscuit samples as described by (Ahmed and Hussein, 2014). The first bite of the cracker was determined by a texture analyzer set to perform single-cycle measurements. A speed of 2 mm/s and 5 mm distance was applied. The plots of force against time were analyzed for tractability and breaking force. Break force is a force required to break down biscuits or food material.

Experimental Design

Completely Randomized Design (CRD) was used in this research work.

Statistical Analysis

One-way analysis of variance of a completely randomized design using the statistical product of service solution version 22.0 was used to compare the mean values while treatment Means were separated using the Duncan multiple range test at a 95 % confidence level ($p<0.05$).

3. RESULTS AND DISCUSSION

Functional Properties of the Composite Flour

Water Absorption Capacity

The results of the functional properties of the flour samples are presented in (Table 3). The water absorption capacity of the flour samples ranged from 1.6 (CRK 1 and 2) to 2.7 g/ml (CRK5). Sample CRK5 had the highest water absorption capacity value (2.7 g/ml) while samples CRK1 and CRK 2 had the lowest water absorption capacity value (1.6 g/ml) respectively. These values are lower than the value of 4.39–5.53 g/ml reported by Anosike et al., (2023) in "Evaluation of baking qualities, functional and physicochemical properties of wheat supplemented with cassava and mung bean flour blends for bread making".

The water absorption capacity values of samples CRK1 and CRK2 were seen to be significantly different ($p>0.05$) from the water absorption capacity values of other samples. WAC is an indication of the amount of water absorbed by the flour blends under conditions where water is limiting and is an important parameter that has implications for viscosity (Harlina et al., 2023). This ability would be useful in food systems and processing such as dough handling as reported by (Nilusha et al., 2021).

Oil Absorption Capacity

Oil absorption capacity represents the ability of the protein matrix to bind to fat by capillary action (Atuna et al., 2022). The Oil absorption capacity values ranged from 0.72 to 1.82 g/ml. Sample CRK4 had the highest oil absorption capacity of 1.82 g/ml while sample CRK 1 had the lowest value of 0.72 g/ml. The high value obtained in sample CRK4 is an indication that the 100 % *Ugba* could be an excellent retainer of taste, flavor, mouth feel, palatability, and extension of shelf life especially in bakery products. There was a significant difference ($p > 0.05$) in the oil absorption capacity of all the samples.

The features of food material other than its nutritional attributes that govern its behavior to various treatments are referred to as the functionality of the food ingredients (Harlina et al., 2023). Oil absorption capacity is reported not to only influence the oil retention in samples, but can also regulate some important sensory attributes such as flavor and mouthfeel (Fasoyiro et al., 2016). Thus, the use of food ingredients in food product formulations is determined by their functional qualities.

Bulk Density

The bulk densities reported in this work ranged from 0.63 to 0.72 g/ml. Sample CRK4 had the highest bulk density (0.72 g/ml) while sample CRK1 and CRK2 had the lowest bulk densities of 0.63 g/ml each. The bulk density obtained in sample CRK4 was significantly different ($p > 0.05$) from that obtained in other samples. Bulk density measures the heaviness of flour samples, and is generally affected by particle size. Thus, bulk density is essential in determining packaging requirements, handling, and application in the food

industries. The low bulk density of the samples observed in this study will aid the transportation and cost efficiency of bakery products (Christiana and Nkemakonam, 2018). The values obtained in this work agree with Anosike et al., (2023) who reported bulk density values of 0.62 – 0.83 g/ml, but different from the findings of Iwe, (2014) in high-quality cassava and wheat flour blends (0.58–0.70 g/ml) and Olakunle and Adebayo, (2012) in wheat, cassava, maize, and cowpea flour blends for bread making (0.32–0.49 g/ml).

Foaming Stability

The foaming stability of the flour samples ranged from 30.01 (CRK1) to 87.01 % (CRK4). Sample CRK4 had the highest foaming stability value (87.01 %) while sample CRK1 had the lowest (30.01 %). There was a significant difference ($p<0.05$) in the foaming stability of the different flours. According to Robert, (2019) in his paper "Proximate, Starch, Sugar Compositions and Functional Properties of Cassava Flour", the values found in this study fall between 48.03 to 80.19 percent. The ability of the protein to be stable against mechanical and gravitational stresses is known as foam stability (Kalra et al., 2023). Surface tension, viscosity, processing techniques, pH, and protein type all affect the production and stability of foam. Protein surface activity has an impact on foaming capacity. The distinct nature and content of the protein fractions in the flours may be the cause of the variations in their foaming stabilities.

Table 3 Functional properties of the composite flour samples

Samples	WAC (g/ml)	OAC (g/ml)	BD (g/ml)	F.S (%)
CRK1	1.57d±0.42	0.73e±0.41	0.63b±0.42	30.01e±0.44
CRK2	1.32d±0.44	0.87d±0.37	0.63b±0.42	41.12d±0.37
CRK3	1.97c±0.37	1.05c±0.59	0.68ab±0.42	52.33c±0.37
CRK4	2.52b±0.40	1.82a±0.60	0.73a±0.37	87.01a±0.37
CRK5	2.66a±0.40	1.23b±0.40	0.67ab±0.37	84.02b±0.60
CV	1.1	1.9	3.1	0.0

Note: values are means of duplicate determinations. Means with different superscripts along a column are significantly different at ($p < 0.05$). Key: WAC = Water absorption capacity, OAC = Oil absorption capacity, BD = Bulk density, F.S = Foam stability, CRK1 = 100 % wheat, 0 % *Ugba*, 0 % Cassava, CRK2 = 80 % wheat: 10 % *Ugba;* 10 % Cassava, CRK3 = 60 % Wheat: 25 % *Ugba*: 15 % Cassava, CRK4 = 0 % Wheat, 100 % *Ugba*, 0 % Cassava, CRK5 = 0 % Wheat, 0 % *Ugba*, 100 % cassava

Physical properties of Cracker samples

Figure 4 is the clustered chart, which shows the distribution pattern of the physical properties of the cracker samples.

Weight and Diameter

The maximum physical dimensions are shown by the highest weight and diameter figures for CRK 4 (0 % Wheat, 100 % *Ugba*, and 0 % Cassava). Its higher density and break strength are in line with this. While CRK 5 (0 % Wheat, 0 % *Ugba*, 100 % Cassava) also has a slightly higher diameter but moderate weight, CRK 1 (100 % Wheat, 0% *Ugba*, 0% Cassava), CRK 2 (80% Wheat: 10% *Ugba*; 10% Cassava), and CRK 3 (60 % Wheat: 25% *Ugba*: 15% Cassava) have relatively similar, lower weight and diameter values compared to CRK 4. The increased weight of the crackers may be explained by the composite flours' higher bulk densities (Table 3), which were similarly correlated with their higher fiber contents.

In their work "Formulation of fiber-enriched crackers biscuit: Effect on nutritional composition, physical and sensory properties", Ujong et al., (2023) reported values ranging from 3.77 to 9.83 g. Additionally, in their article "Physical characteristics, nutritional composition and acceptability of gluten-free crackers produced from germinated pearl millet (*Pennisetum glaucum*), defatted sesame seed (*Sesamum indicum*), and defatted tiger nut (*Cyperus esculentus*) composite", Akeem et al., (2023) reported values ranging from 8.52 to 10.83 g.

Thickness

Once more, CRK 4 was the thickest sample, which might have contributed to its higher break strength. The lowest thickness, CRK 3, indicates a thinner structure that may have an impact on its mechanical characteristics, especially texture and break strength. The

thickness of crackers made with wheat and defatted coconut flour often decreased, according to a 2009 study by (Montagnac et al., 2009). The poor thickness of the crackers in this investigation may be due to the composite flours' limited water absorption capabilities (Table 3). Therefore, it might be argued that the low thickness of the generated crackers is most likely caused by the high fiber composition of the composite flours.

Texture

CRK 4 may be the most resistant to pressure or deformation due to its significantly higher texture measurement (27 N). CRK 1, CRK 2, and CRK 5 have intermediate texture values for thickness, however, CRK 3 has extremely high values. In their work "Chemical composition and functional characteristics of wheat/African oil bean flour blends and sensory attributes of their cookies", Gyedu-Akoto and Laryea, (2013) reported 1.33 to 4.27 N, while Ujong et al., (2023) reported 3.10 to 3.70 N in their work "Formulation of fiber-enriched crackers biscuit: Effect on nutritional composition, physical and sensory properties". The values found in this work are lower than these values.

Color

In comparison to other samples, particularly CRK 4, which has the lowest color reading, CRK 5 has the greatest color value, indicating a possibly more dramatic appearance. This can be the result of differences in the processing or composition of the materials. According to the crackers' color measurement, CRK 5 had a greater value than the produced crackers CRK2 and CRK3, as well as the control CRK 1 in that order. The values found in this study are less than the 41.46 to 48.40 values that Akeem et al., (2023) reported. Variations in the flour composition may be the cause of the lower values observed for the created composite crackers. Given that a significant portion of the composite flours is composed of crops high in protein and carbohydrates, this is conceivable.

Density

Following its greater weight and thickness, CRK 4 has the highest density, which may add to its robustness. The slightly lower densities of CRK 2 and CRK 5 may have an impact on their break strength. The results obtained in this study are consistent with those reported by Djouadi et al., (2022) in their work "Nutritional and Storage Stability of wheat-based crackers incorporated with brown rice flour and carboxymethyl cellulose (CMC)" and "Development of Healthy Protein-Rich Crackers Using Tenebrio molitor Flour", which ranged from 0.77 to 0.97 g/cm3 and 0.65 to 0.72 g/cm3, respectively. One crucial cracker quality factor is density. Customers want crackers that are lighter and less dense (Nammakuna et al., 2015). This is a relevant quality parameter, as consumers generally want less heaviness and more density crackers.

Break Strength

The thickness, density, and texture of CRK 4 probably contribute to its highest break strength, which means it can bear more force before breaking. CRK 5 has the lowest break strength, suggesting it may be less durable compared to the other samples. These values were lower compared to 1827 – 2164 g reported by Okpala and Ofoedu, (2018), but higher when compared to 176.7.8 - 206.3 reported by. The varied results could be due to differences in raw materials used as well as the formulation recipe used.

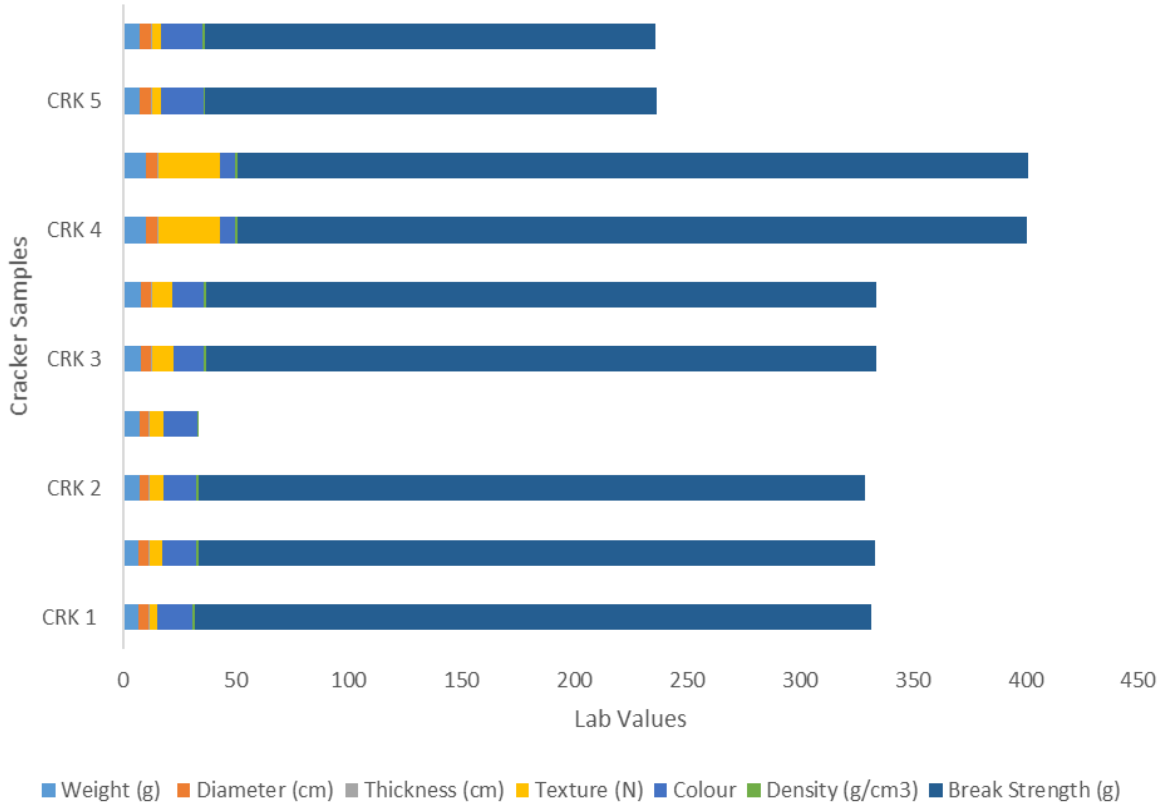

Figure 4 A clustered chart that displays how the physical characteristics of the cracker samples are distributed.

Proximate Composition of Cracker Samples

Figure 5 displays the biplot representing the nutritional data's principal component analysis (PCA) across five samples (CRK1 to CRK5). This visualization combines the sample scores and the variable loadings, giving insight into how each sample compares to others and the influence of each variable. The biplot explains the samples' association with the chemical composition variables (MC, CP, Fat, CF, ASH, and CHO). As can be seen from the chart, CRK4 stands out in the top right quadrant, indicating that it has a unique composition compared to other samples, particularly with higher values in Fat (%), CF (%), and CP (%). CRK5 is positioned far to the left, highlighting its distinct composition, characterized by high CHO (%) and low protein and fat content. CRK1 and CRK2 are closer to each other at the bottom, indicating similar compositions, with moderate levels of all variables. CRK3 is near the origin, showing it has a balanced composition, with no extreme values in any variable.

Variables

CHO (%) has a long arrow pointing to the left, suggesting that this variable contributes to the variation along the PC1 axis and is negatively associated with other variables, especially CP (%), Fat (%), and CF (%). Fat (%), CP (%), and CF (%) have arrows pointing in similar directions, suggesting they are positively correlated with each other. These variables are closely associated with CRK4, which has higher fat and protein content. ASH (%) and CF (%) have shorter arrows, indicating a lower contribution to the overall variance compared to other variables.

Principal Components

PC1 primarily distinguishes samples with high CHO (%) (e.g., CRK5) from those with high Fat (%), CP (%), and CF (%) (e.g., CRK4). PC2 captures more subtle differences in ash and fat contents across the samples.

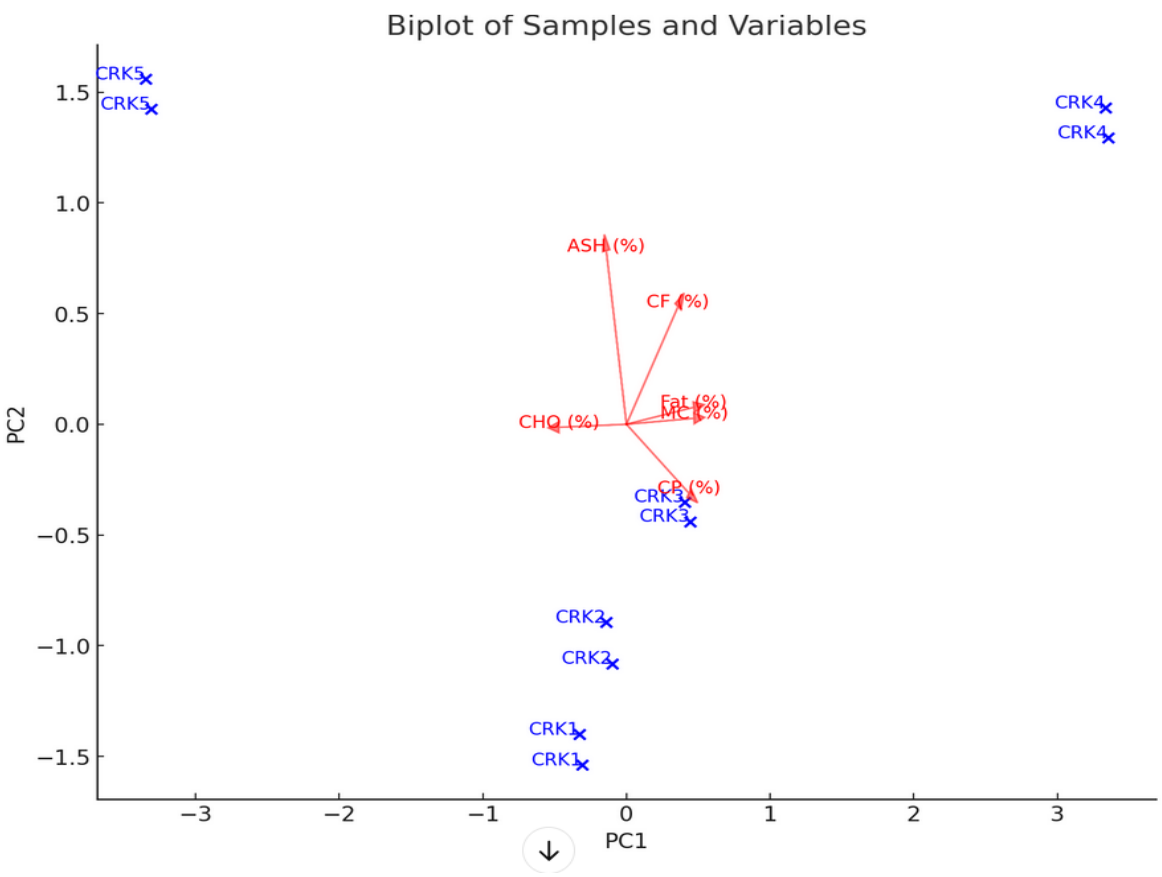

Figure 5 Biplot representing the nutritional data's principal component analysis (PCA) across five samples (CRK1 to CRK5).

Mineral composition of the Crackers

Figure 6 displays the box plot of the mineral composition of the crackers.

Calcium (Ca)

The calcium concentration shows a high variability across samples. The median value is closer to the upper quartile, indicating that higher calcium values are more common among the samples, while the lower range extends significantly. This spread may suggest variability in calcium content across different sample types (CRK1 to CRK5).

Iron (Fe)

The iron levels display a relatively small range, with the majority of the data clustered near the median, though there is one lower outlier around 1.15 mg/100g. This outlier might belong to CRK5, which has a much lower iron content than the other samples.

Sodium (Na)

Sodium has a wide range of values, with the median in the middle of the box. This indicates a balanced spread of sodium content among the samples. The range extends from near zero to high values, reflecting variability between samples (likely CRK4 having the highest sodium).

Potassium (K)

Potassium shows a large interquartile range, with the highest levels among all measured minerals. The wide range from about 3 mg/100g to over 35 mg/100g suggests substantial variation, which could be due to differing potassium content across sample types.

Magnesium (Mg)

Magnesium levels are generally lower than calcium, iron, sodium, and potassium. There is a smaller range, with a slight outlier on the lower end, which could belong to one of the samples with low magnesium content.

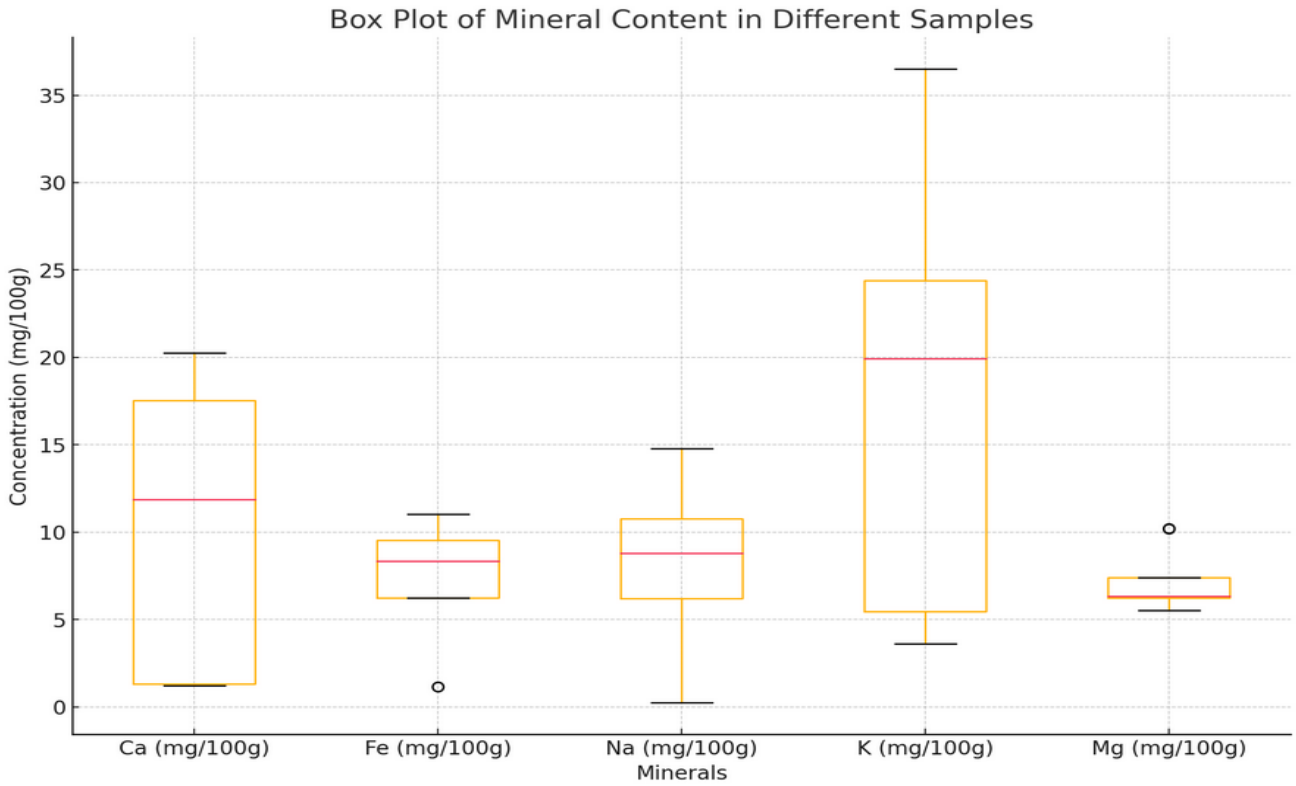

Figure 6 Box plot of the mineral composition of the Crackers.

4. CONCLUSION

This study highlights the potential of creating nutritious and functional crackers using a blend of wheat, *Ugba*, and cassava flour. This formulation leverages underutilized, locally available ingredients, enriching the crackers with added protein and fiber from *Ugba* and cassava flours while enhancing their texture, aroma, and sensory appeal. The product not only offers health benefits but also promotes the diversification of raw materials, contributing to food security and sustainability, particularly in regions where these resources are plentiful.

Recommendations

Biscuit producers are encouraged to incorporate locally sourced ingredients to lower production costs and support sustainable practices. Fortifying crackers with *Ugba* flour presents an excellent opportunity to boost their protein content, enhancing their nutritional value. Ensuring consumer acceptability through sensory evaluations and focusing on improving the product's shelf life and packaging will be critical for achieving market success

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Author's Contributions

Conceptualization: Ogbete CE, Diala DC

Methodology: Ogbete CE, Diala DC
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Data curation: Ogbete CE, Diala DC
Writing-original draft preparation: Ogbete CE, Diala DC
Project administration: Nwanagba NL
All authors have read and agreed to the published version of the manuscript.

Informed consent
Not applicable.

Conflicts of interests
The authors declare that there are no conflicts of interests.

Ethical approval & declaration
In this article, as per the plant regulations followed in the Biotechnology and Product Development Programme, National Root Crops Research Institute Umudike, P.M.B 7006 Umuahia, Abia State Nigeria, the authors assessed the crackers produced from the blend of Cassava (*Manihot esculenta*), *Ugba* (*Pentaclethra macrophylia),* and Wheat (*Triticum aestivum*) flours. The ethical guidelines for plants & plant materials are followed in the study for collection, identification & experimentation.

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Data and materials availability
All data associated with this study are present in the paper.

REFERENCES

1. Ahmed ZS, Hussein AMS. Exploring the suitability of incorporating tiger nut flour as a novel ingredient in gluten-free biscuits. Pol J Food Nutr Sci 2014; 64(1):27-33.
2. Akeem SA, Mustapha BO, Ayinla RO, Ajibola O, Johnson WO, Akintayo OA. Physical characteristics, nutritional composition, and acceptability of gluten-free crackers produced from germinated pearl millet (*Pennisetum glaucum*), defatted-sesame seed (*Sesamum indicum),* and defatted-tiger nut (*Cyperus esculentus*) composite flours. Discov Food 2023; 3: 22. doi: 10.1007/s44187-023-00063-7
3. Anosike FC, Okwuowulu RC, Nwigboji AN, Mofunanya GN, Inyang P, Chinaka I, Onye-Chinedu CB, Onyeji GN, Prince-Osuji, CE. Evaluation of baking qualities, functional and physicochemical properties of wheat supplemented with cassava and mung bean flour blends for bread making. Food Bioeng 2023; 2(3):264-272.
4. AOAC. Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC, 2010.
5. Atuna AR, Jemima D, Matthew A, Achaglinkame SB, Linda D, Osei-Kwarteng M, Gustav K, Mahunu IK, Amagloh FK. Types of indigenous vegetables consumed, preparation, preferences and perceived benefits in Ghana. J Ethn Foods 2022; 9 Article No: 38. doi: 10.1186/s42779-022-00154-3
6. Christiana OE, Nkemakonam OC. Production and Quality Evaluation of Enriched Cookies from Wheat, African Yam Bean, and Carrot Composite Flours. Ann Food Sci Technol 2018; 4(3):1-8.
7. Djouadi A, Sales JR, Carvalho MO, Raymundo A. Development of Healthy Protein-Rich Crackers Using Tenebrio molitor Flour. Foods 2022; 11(5):702. doi: 10.3390/foods11050702
8. Fasoyiro S, Hovingh R, Hassan G, Catherine C. Change in water activity and fungal counts of maize-pigeon pea flour during storage utilizing various packaging materials. Procedia Eng 2016; 159:72–76.
9. Florence SP, Asna U, Asha MR, Jyotona R. Sensory, Physical and nutritional qualities of cookies prepared from pearl millet (Pennisetum typhoideum). Food Process Technol 2014; 5(10): 377.

10. Garg M, Sharma A, Vats S, Tiwari V, Kumari A, Mishra V, Krishania M. Vitamins in Cereals: A Critical Review of Content, Health Effects, Processing Losses, Bioaccessibility, Fortification, and Biofortification Strategies for Their Improvement. Front Nutr 2021; 8:586815. doi: 10.3389/fnut.2021.586815
11. Gyedu-Akoto E, Laryea D. Evaluation of cassava flour in the production of cocoa powder-based biscuits. Nutr Food Sci 2013; 43(1):55–59.
12. Harlina PW, Fitriansyah FA, Shahzad R. The challenging concept of diversifying non-rice products from cassava by changing Indonesian people's behavior and perception: a review. Food Res 2023; 7(5):251-259.
13. Iwe MO. Current Trends in Sensory Evaluation of Foods. Revised Edition. Rojoint Communication Service Limited, Uwani Enugu, Nigeria, 2014; 144-145.
14. Kalra S, Kapoor N, Verma M, Shaikh S, Das S, Jacob J, Sahay R. Defining and Diagnosing Obesity in India: A Call for Advocacy and Action. J Obes 2023; 2023:4178121. doi: 10.1155/2023/4178121
15. Lagnika C, Houssou PAF, Dansou V, Hotegni AB, Amoussa AMO, Kpotouchedo FY, Doko SA, Lagnika L. Physico-functional and sensory properties of flour and bread from composite wheat-cassava. Pak J Nutr 2019; 18(6):538-547.
16. Manley D. Manley's Technology of Biscuits Crackers and Cookies. Wood Head Publishing Series in Food Science, Technology and Nutrition, Elsevier Science 2011; 54.
17. Massodi LK, Bashir VAK. Fortification of biscuit with flax seed: biscuit production and quality evaluation. J Environ Sci Toxicol Food Technol 2012; 1:6–9.
18. Montagnac JA, Davis CR, Tanumihardjo SA. Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. Compr Rev Food Sci Food Saf 2009; 8(3):181-194. doi: 10.1111/j.1541-4337.2009.00077.x
19. Nammakuna N, Barringer SA, Ratanatriwong P. The effects of protein isolates and hydrocolloids complexes on dough rheology, physicochemical properties and qualities of gluten-free crackers. Food Sci Nutr 2015; 4(2):143-55. doi: 10.1002/fsn3.266
20. Nilusha RAT, Jayasinghe JMJK, Perera ODAN, Perera PIP, Jayasinghe CVL. Proximate Composition, Physicochemical, Functional, and Antioxidant Properties of Flours from Selected Cassava (Manihot esculenta Crantz) Varieties. Int J Food Sci 2021; 2021:6064545. doi: 10.1155/2021/6064545
21. Ogueke CC, Nwosu JN, Owuamanam CI, Iwouno J. Ugba fermented African oil bean seeds, their production, chemical composition, preservation, safety, and health benefits. Pak J Biol Sci 2010; 13(10):489–496.
22. Okorie PC, Olasupo NA. Growth and extracellular enzyme production by microorganisms isolated from *Ugba*: An indigenous Nigerian fermented food. Afri J Biotechnol 2013; 12:4158–4167.
23. Okpala LC, Ofoedu PI. Quality Characteristics of Cookies Produced from Sweet Potato and Wheat Flour Blend Fortified with Brewer's Spent Grain Flour. Curr Res Nutr Food Sci 2018; 6(1). doi: 10.12944/CRNFSJ.6.1.12
24. Olakunle MM, Adebayo A. Effect of natural fermentation on the nutritive value and mineral composition of African locust beans. Pak J Nutr 2012; 11(1):11–13. doi: 10.3923/pjn.2012.11.13
25. Onwuka GI. Food Analysis and Instrumentation-Theory and Practice. Second Edition. Lagos Nigeria. Naphtali Prints, 2018; 299-314.
26. Robert A. Proximate, Starch, Sugar Compositions and Functional Properties of Cassava Flour. J Food Secur 2019; 7(2):40-46. doi: 10.12691/jfs-7-2-3
27. Siddiqi RA, Singh TP, Rani M, Sogi DS, Bhat MA. Diversity in Grain, Flour, Amino Acid Composition, Protein Profiling, and Proportion of Total Flour Proteins of Different Wheat Cultivars of North India. Front Nutr 2020; 7:141. doi: 10.3389/fnut.2020.00141
28. Ujong AE, Emelike NJT, Woka FI, Otekeiwebia Jnr F. Formulation of fiber enriched crackers biscuit: Effect on nutritional composition, physical and sensory properties. Heliyon 2023; 9(5):e15941. doi: 10.1016/j.heliyon.2023.e15941
29. Urade R, Sato N, Sugiyama M. Gliadins from wheat grain: an overview, from primary structure to nanostructures of aggregates. Biophys Rev 2018; 10(2):435-443. doi: 10.1007/s12551-017-0367-2