Chemicals, physical and sensory properties of cookies produced from wheat (*triticum aestivum*), whole wheat (*triticum aestivum*), and unripe plantain (*musa paradisiaca l.*) flour blends

ABSTRACT

This study evaluated the chemical composition, physical and sensory properties of cookies produced from wheat, whole wheat and unripe plantain flour blends. Five different flour blends of wheat, whole wheat and unripe plantain flours were prepared at 100:0:0, 90:5:5, 80:10:10, 70:15:15, 60:20:20 and 50:25:25. The proximate, phytochemical, minerals, physical and sensory properties of the cookies were analyzed using standard methods. The results were significantly different ($p<0.05$). Moisture, ash, fat, fibre, protein and carbohydrate ranged from 3.31 to 4.15 %, 1.64 to 2.19 %, 24.90 to 29.82%, 7.98 to 12.47%, 8.31 to 18.38% and 39.06 to 51.82 %, respectively. Flavonoid, tannins and alkaloid ranged from 0.74 to 1.14 mg/100g, 0.66 to 1.23 mg/kg and 2.79 to 4.11 mg/kg, respectively. The micro minerals, zinc, iron and copper ranged from 0.51 to 0.67 mg/100g, 0.77 to 1.40 mg/100g and 0.01 to 0.04 mg/100g, respectively. The macro minerals, phosphorous, magnesium and calcium ranged from 3.32 to 4.05 mg/100g, 0.03 to 0.06 mg/100g and 5.05 to 6.54 mg/100g, respectively. The weight, diameter, height and spread ratio increased from 52.50 to 54.20g, 0.72 to 0.91 cm, 7.35 to 8.90 cm and 3.67 to 3.83 %, respectively with increase in the added whole wheat flour and unripe plantain flour. The sensory properties, aroma, colour, taste, texture, and overall acceptability ranged from 7.23, 7.35, 7.18, 6.48 and 6.73 respectively. The sensory property of 60:20:20 (6.73) was preferred. The nutritional composition and sensory properties of cookies was enhanced with the flour blends.

Keywords: Proximate composition, Phytochemical compositions, Mineral compositions, and Sensory properties

1.0 INTRODUCTION

Cookies are a widely enjoyed snack globally, constituting the largest category among snack foods. They are made from traditional dough, typically made from wheat flour, which is heated to create a delicious final product (Adeyeye, 2016; Chauhan *et al*., 2016). Other ingredients like fat, sugar, and water from the base, while additional elements such as milk, salt, flavourings, leavening agents and some additives can be included (Panghal *et al*., 2018). These snacks are consumed by individuals across various age groups and socio-economic backgrounds. In tropical regions like Nigeria where wheat isn't locally grown due to climate limitations, its importation could escalate the prices of baked goods (Ismaila *et al*., 2010). However, there is a need to employ locally available resources for cookie production.[43-45]

“Composite flours have been used extensively in the production of baked goods. In countries where malnutrition poses a serious problem, especially among children, composite flours which have better nutritional quality would be highly desirable” (Okpala, 2013). “Composite flour can be made from legumes and nuts and root and tubers such as yam, cassava, and sweet potatoes” (Abioye *et al*., 2018; Ubbor *et al*., 2022). Production of cookies from blends of whole meal wheat flour and flour from locally produced crops that will meet the needs of people who consume whole meal wheat cookies is highly desirable.

“Wheat flour is the main ingredient used in the manufacturing of bread, cookies and noodles and the characteristics of wheat used for milling are very important” (Adetuyi *et al*., 2022). “The composition of wheat flour can vary depending on the type of wheat used (e.g., hard red, soft red, hard white, soft white), the milling process (e.g., whole wheat or all-purpose flour), and any additives or fortifications made by manufacturers” (Kanojia *et al*., 2018). “Wheat provides protein; calories, phytochemicals and antioxidants which promote better health” (Gupta *et al*., 2021). “Wheat flour is used in varieties of food production which include breads, noodles, biscuits, cakes, cookies, and pasta products, among others” (Kapagavalli, 2015).

“Whole wheat flour contains the bran, germ, and endosperm of the wheat kernel, while all-purpose flour is often made from just the endosperm, resulting in a finer texture and milder flavor” (Pagani *et al*., 2014).

“Whole wheat flour is milled from red wheat berries, sometimes called “hard red wheat.” The dark, reddish colour bran layer of kernels gives whole wheat flour the rich colour, hearty taste, and coarse texture most of us associate with whole grains. It is widely used in the bakery industry to increase product diversity. It is richer than refined wheat flour since it has higher levels of vitamins, minerals, antioxidants, and fibre” (Doblado-Maldonado *et al*., 2012). “As a traditionally recognized product, bread is the main choice of food product for whole wheat flour incorporation. It is a rich source of these functional ingredients such as fibre, phytochemicals, minerals and essential amino acids that are located in the bran and fat-soluble vitamins contained in the germ of the whole wheat grain” (Dewettinck *et al*., 2008).

“Unripe plantain is very low in sugar as compared to ripe or overripe plantain and it makes it a good choice for diabetes especially when added with other protein-rich food. Unripe plantain prevents cancer. Unripe plantain has been used to produce flour that can be blended with common flours (e.g., wheat, maise, rice, etc.) or ingredients (e.g., protein) in bread, cookies, pasta and snacks” (Patiño-Rodríguez *et al*., 2019; Flores-Silva *et al.*, 2017). The effect of heat on the chemical composition of unripe plantain flour can lead to several changes due to the denaturation of proteins, breakdown of carbohydrates, and alteration of other components. Heat can cause the denaturation of proteins, breakdown of complex carbohydrates, such as starch, into simpler sugars and degradation of vitamin C. Heat affects the stability and bioavailability of antioxidants, influences lipid oxidation and affects the flavor and shelf life of flour (Gerardi *et al*., 2022).

2.0 MATERIALS AND METHODS

2.1 MATERIALS

The wheat flour, whole wheat flour and unripe plantain used for this study were purchased at WUKARI new market in WUKARI Local Government Area of TARABA State. All other ingredients used in the production of the bread were also obtained from the same market.

2.2 PREPARATION OF FLOUR

2.2.1 Preparation of Wheat and Whole Wheat Flour

The method described by Ayo *et al.* (2008) was adopted in the preparation of wheat and whole wheat flour. Wheat grains were cleaned manually by handpicking the chaff and dust, and stones were removed by washing in clean water (sedimentation). The washed and stone-free grains were oven-dried at 60^{o}C for 48 hours and then milled using a milling machine. The flour was sieved using a 0.3mn aperture sieve, packaged (polyethene bag) and stored at room temperature. The flowchart for wheat and whole wheat flour production is shown in Figures 1 and 2 respectively.

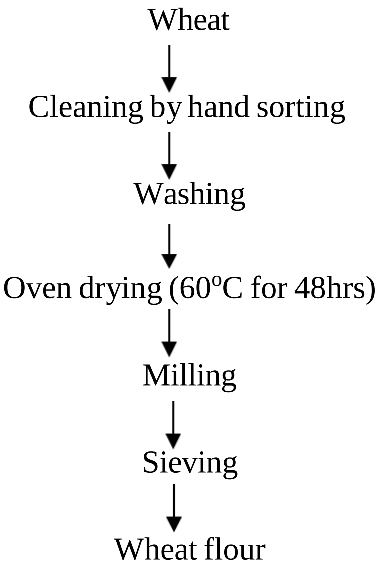
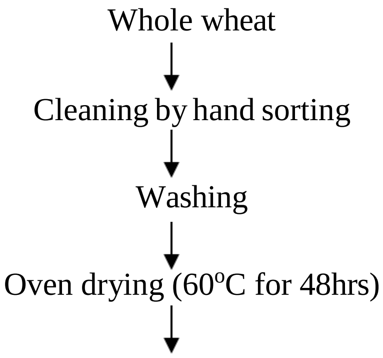


Figure 1: Production of Wheat Flour Source:

(Ayo *et al*., 2008).



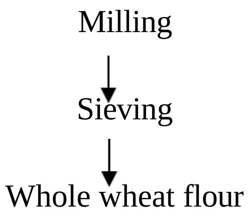


Figure 2: Production of Whole Wheat Flour Source:

(Ayo *et al*., 2008).

2.2.2 Preparation of Unripe Plantain Flour

The method described by Inyang and Asuquo (2016) was used in the preparation of unripe plantain flour. The unripe plantain fruits were first removed from the bunches. They were washed, steam blanched at 100^oC for 15min, sliced with a stainless knife and dried in a conventional oven at 60^oC to constant weight. The dried slices were milled, sieved to pass through a 0.25mm mesh sieve, packaged in a low-density polyethene bag, and sealed and stored at 4^oC for subsequent use. The flowchart for unripe plantain flour production is shown in Figure 3.

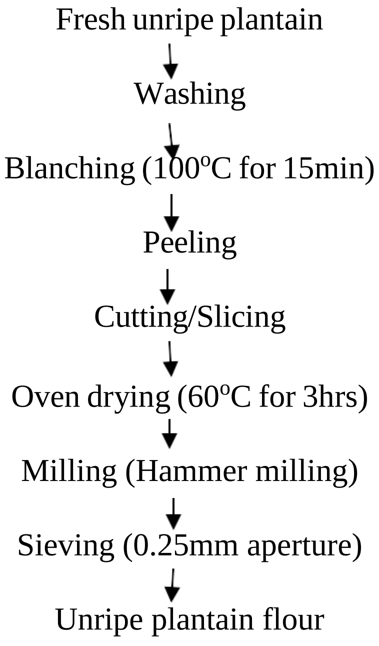


Figure 3: Flowchart for the production of unripe plantain flour Source:

(Inyang and Asuquo, 2016).

3.3 PREPARATION OF WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS

The wheat and whole wheat flour was thoroughly blended with unripe plantain flour in ratios of 90:5:5, 80:10:10, 70:15:15, 60:20:20 and 50:25:25(w/w/w) respectively using a Kenwood food blender. The 100% whole wheat flour was used as the control sample.

2.4 PREPARATION OF COOKIES

Cookies were prepared by the method adopted by Adeyeye (2016) with slight modifications. The cookie dough was prepared from wheat flour (control) and composite flour combinations using flour (100%), sugar (40%), baking powder (1.6%) and salt (1%). Flour from each sample of different flour blends was used for the experiment. Using a Kenwood Chef, the sugar was creamed with margarine until a light and fluffy consistency was achieved. The speed was gradually increased until the chef indicator reached the mark of 6. After adding the whole egg, flour, baking powder, powdered milk, and salt, everything was combined to create a firm paste, or batter.

The batter was rolled on a floured board using a rolling pin to a thickness of 0.2–0.3 cm. The rolled batter was cut into circular shapes with a cutter, arranged on a greased tray and baked at 150°C for 20 min. The cookies were brought out, cooled and packaged in cellophane bags until used for laboratory analysis. The flowchart for the production of cookies is shown in Figure 4.

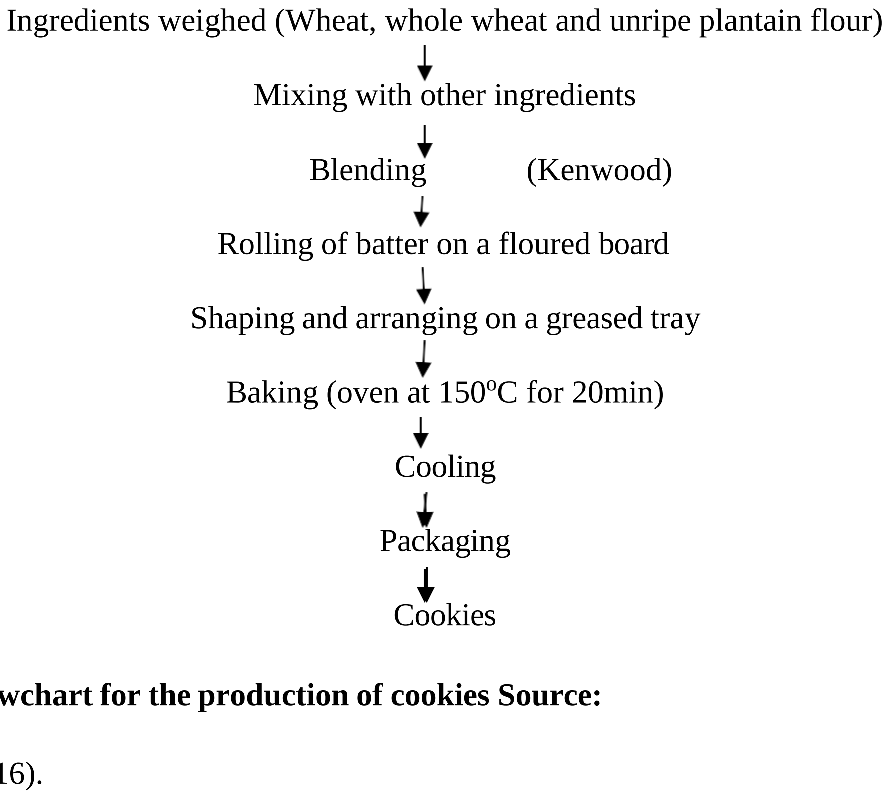


Figure 4: Flowchart for the production of cookies Source:

(Adeyeye, 2016).

TABLE 1: RECIPE FOR PRODUCTION OF WHOLE WHEAT, WHEAT FLOUR AND UNRIPE PLANTAIN FLOUR BLENDS

Samples code (%)	Wheat (%)	Whole wheat (%)	Unripe plantain (%)	Margarine/ fat (%)	Sugar (%)	Baking powder (%)	Salt (%)	Water (ml)
100	100	0	0	50	40	1.6	1	10
90:5:5	90	5	5	50	40	1.6	1	10
80:10:10	80	10	10	50	40	1.6	1	10
70:15:15	70	15	15	50	40	1.6	1	10
60:20:20	60	20	20	50	40	1.6	1	10
50:25:25	50	25	25	50	40	1.6	1	10

2.5 ANALYTICAL METHODS

2.5.1 Proximate Analysis

The proximate analysis of samples for moisture content, crude protein, ash, Crude fat, Carbohydrate and crude fibre will be carried out on the flour:

2.5.1.1 Determination of moisture content

The hot air oven method as outlined by AOAC (2010) was used to determine the moisture content. After weighing two grams of the material into a crucible with a specified weight, it was baked for four hours at 105 degrees Celsius. Before being weighed, the samples were taken out of the oven and allowed to cool in a desiccator. After re-entering the furnace, the crucible was weighed until a consistent weight was noted. The moisture content was computed as the weight loss from the initial sample weight.

$$\%\text{Moisture content} = \frac{\text{Weight loss}}{\text{Weight of sample}} \times \frac{100}{1}$$

2.5.1.2 Determination of ash content

Ash content was determined by the method of AOAC (2010). The ash content was determined after incineration of 2 g of the sample in a muffle furnace at 550^{o}C for 2 hours until a light gray ash was obtained. It will then be cooled in a desiccator, weighed and calculated using the formula:

$$\%\text{Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times \frac{100}{1}$$

2.5.1.3 Determination of crude fat content

AOAC (2010) describes the Soxhlet extraction method that was used to determine the fat content. The 500 ml round bottom flask and the reflux condenser-equipped Soxhlet extractor were fixed. A thimble was filled with two grams of the sample and sealed with cotton wool. After six hours of refluxing the completed soxhlet device, the petroleum ether evaporated into a reusable container. After the flask was free of ether, it was baked for an hour at 105 degrees Celsius to dry it out.

It was cooled in a desiccator and weighed. The percentage fat content was calculated as:

$$\%\text{Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times \frac{100}{1}$$

2.5.1.4 Determination of crude fibre content

The crude fibre was determined according to the method of AOAC (2010). Petroleum ether was used to defat 2g of sample. This was put in a beaker containing 200 ml of 1.25 % H_2SO_4, boiled for 30 minutes, filtered through muslin cloth on a fluted funnel and washed with boiling water until it was free of acid. The residue was returned to 200 ml boiling NaOH and allowed to boil for 30 minutes. It was washed with 1 % HCl and then with boiling water to free it of acid. The final residue was drained and transferred to a silica ash crucible (porcelain crucible) dried in the oven to a constant weight and cooled. The crude fibre content was calculated as:

% Crude fiber = loss in weight after ignition x 100.

2.5.1.5 Determination of protein content

The protein content was determined by the micro-Kjeldahl method as described by AOAC (2010). The sample (1 g) was digested in the Kjeldahl digesting system. The digested sample was cooled and then distilled into a flask containing 5 ml of 2 % boric acid solution and a few drops of methyl red indicator. The distillate was diluted with distilled water followed by the addition of about 5 milliliter of 60 % sodium hydroxide solution.

The distilled sample was titrated against 0. l m HCl solution. A blank titration was carried out. The percentage nitrogen content was calculated as:

$$\%\text{Nitrogen} = \frac{\text{Vs} - \text{Vb} \times \text{N} \times 14}{1000 \times \text{Weight of sample}} \times \frac{100}{1}$$

Where:

Vs and Vb = volumes of acid required to titrate the sample and the blank, respectively.

N = Normality of the acid

The protein content was calculated as:

% Protein = % N x 6.25, where 6.25 is a conversion factor.

2.5.1.6 Determination of carbohydrate content

The carbohydrate content of the samples was calculated by difference as described by AOAC (2010)

% Carbohydrate = 100 - % moisture + % protein + % ash + % crude fibre + % crude fat

2.5.2 Phytochemical Analysis

2.5.2.1 Determination of flavonoids

This was determined according to the method adopted by Nwosu *et al*. (2022). 5g of the sample was boiled in 50 ml of 2 M HCl solution for 30 minutes under reflux. It was allowed to cool and subsequently filtered through a filter paper. A measured volume of the extract was recovered by filtration using weighed filter paper. The resulting difference is the weight of the flavonoid in the sample.

2.5.2.2 Determination of tannins

Tannin content would be determined using the Folin-Denis spectrophotometric method described by Parmar *et al*. (2017). 1g of each sample would be dispersed in 10 ml of distilled water, shaken and allowed to stand for 30 min. at 28°C before it would be centrifuged to get the extract. About 2.5 ml of the supernatant (extract) would be dispersed into a 50 ml volumetric flask. Similarly, 2.5 ml of standard tannic acid solution would be dispersed into a separate 50 ml flask. One ml Folin-Denis reagent would be measured into each flask, followed by 2.5 ml of saturated $Na_2CO_{3(aq)}$ solution. The mixture would be diluted to mark in the flask (50 ml), and incubated for 90 min. at 28°C. The absorbance would be measured at 250 nm in a spectrophotometer. Readings would be taken with the reagent blank at zero. The tannin content would be calculated as follows:

$$\% \, Tanin = \frac{An}{As} * C * \frac{100}{W} * \frac{Vf}{Va}$$

Where An is the absorbance of the test sample, As is the absorbance of standard solution, C is the concentration of the standard solution, W is the weight of the sample, Vf is the total volume of extract, and Va is the volume of extract.

2.5.2.3 Determination of alkaloids

The gravimetric method of Harbone (1980) was used. Five gram of sample was dispersed into 50 ml of 10 % acetic acid solution in ethanol. The mixture was shaken well and allowed to stand for 4 hours before filtering. The filtrate obtained was evaporated to one quarter of its original volume. Concentrated ammonium hydroxide was added drop wise to precipitate the alkaloids. The precipitate was filtered with a weighed filter paper and washed with 1 % NH_4OH solution. The precipitate in the filter paper was dried in the oven at 60 °C for 30 minutes and reweighed.

$$\% \, Alkoloid = \frac{W_2 - W}{W} \times \frac{100}{1}$$

Where:

W = Weight of sample

W_1 = Weight of empty filter paper

W_2 = Weight of filter paper plus precipitate

2.5.3 Determination of Micro and Macro Minerals

Determination of Micro Minerals

2.5.3.1 Determination of zinc

Zinc was measured using the Onwuka (2005) technique. Three grams of the sample were put in a crucible and heated to 550 degrees Celsius in a muffle furnace for six hours. The sample was then allowed to cool in the furnace for an hour before being put into the desiccator. The acid combination (650 ml Conc. HNO3, 80 ml PCA, and 20 ml Conc. H2SO4) was introduced to a digestion flask containing one gramme of the ashed sample, which had been weighed beforehand. Heat was applied to the digestion flask until a clear digest was achieved. Distilled water was used to dilute the digest to the 500 milliliter mark.

Ten milliliters of the diluted digest were injected into atomic absorption spectrophotometer and the absorbance was read at the maximum wavelength ($ʎ_{max}$) of absorption of the respective element. Standard curves were plotted, from which the concentration of zinc were extrapolated.

2.5.3.2 Determination of iron

Iron was determined by the method described by Onwuka (2005). Three grammes of sample were placed in a crucible and put in a muffle furnace at 550^{o}C for 6 hours, after which it was allowed to cool for 1 hour in the furnace before being transferred to the dessicator. One gramme of ashed sample was weighed into a digestion flask and 20 ml of the acid mixture (650 ml Conc. HNO_3, 80 ml PCA and 20 ml Conc. H_2SO_4) were added. The digestion flask was heated until a clear digest was obtained. The digest was diluted with distilled water to 500 ml mark. Ten milliliters of the diluted digest were injected into atomic absorption spectrophotometer and the absorbance was read at the maximum wavelength ($ʎ_{max}$) of absorption of the respective element. Standard curves were plotted, from which the concentration of iron were extrapolated.

2.5.3.3 Determination of copper

25mL of copper (II) sulphate solution was pipetted into a 250mL conical flask. Ammonia solution was added drop-wise until the light blur precipitate first formed dissolves to form a clear blue solution and diluted to about 100mL with distilled water. 3 to 4 drops of Murixide indicator was added and titrated with 0.01 M EDTA until the color changes from yellow (green) to purple. The final volume will then be obtained from the calibration scale on the burette and the volume used was recorded (VEDTA). The titration was repeated twice.

Determination of Macro Minerals

2.5.3.4 Determination of phosphorous

Phosphorus in the samples was determined according to Onwuka (2005) by the molybdate method using hydroquinone as a reducing agent. Five milliliters (5 ml) of the test sodium 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 colour development. The absorbance was measured at 660 nm against a blank. A curve relating absorbance to milligram (mg) phosphorus present was constructed. Using the phosphorus standard solution, and following the same procedure for the test sample, a standard curve was plotted to determine the concentration of phophorus in the sample.

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

2.5.3.5 Determination of magnesium

Magnesium was determined using the method described by Bartram and Balance (1996). Ten milliliters of digested sample were pipetted into 250 ml conical flask and a small amount of Eriochrome Black T was added to the solution which, when buffered at pH 10.0. Then the solution was titrated with ethylenediaminetetraacetic acid (EDTA), the magnesium was complexed; at the end-point the solution changed from wine-red to blue

2.5.3.6 Determination of calcium

Calcium was determined using the method described by Kirk and Sawyer (1998). Twenty-five milliliters of digested sample were pipetted into 250 ml conical flask and a pinch of Eriochrome Black-T-Indicator (EBT) was added. Thereafter, 2 ml of 0.1 N NaOH solution was added and the mixture titrated with standard EDTA (0.01M EDTA) solution.

$$\text{Ca} \left({}^{\text{mg}}/_{\text{l}}\right) = \frac{\text{T} \times \text{M} \times \text{E} \times 1000}{\text{Volume of sample used}}$$

Where,

T = Titre value

M = Morality of EDTA

E = Equivalent weight of calcium

2.5.4 Physical Properties of Cookies

2.5.4.1 Weight

The weight was measured as average values of the individual samples with the help of an analytical weighing balance. The average value for weight was reported in grams (Jemziya, 2017).

2.5.4.2 Diameter

The diameter was determined by placing the edge of the sample on edge and measuring it with a digital vernier caliper (Bala *et al*., 2015). An average of six values was taken for each set of samples. The average value for diameter was reported in millimeters.

2.5.4.3 Thickness and height

The thickness was determined by measuring the diameter of the samples placed edge to edge with a digital vernier calliper (Bala *et al*., 2015). An average of six values was taken for each set of samples. The average value for thickness was reported in millimeters.

2.5.4.4 Spread ratio

The spread ratio was determined using the method of Jemziya and Mahendran (2017). Three rows of five well-formed cookies were made and the height was measured. Also the same was arranged horizontally from edge to edge and the sum diameter was measured. The spread ratio is calculated as diameter/ height.

2.5.4.5 Break strength

"Cookies of known thickness were placed between two parallel wooden bars. Weights were added to the sample until it snapped. The least weight that caused the breaking of the biscuit was regarded as the break strength of the cookie" (Bala *et al*., 2015).

2.6 SENSORY EVALUATION

The sensory evaluation of the prepared cookies after baking and storage at room temperature was assessed in the Department of Food Science and Technology, Federal University WUKARI. This was carried out using 20 semi-trained panels drawn from the university community. All panel members were regular consumers of cookies. Water at room temperature was provided to rinse the mouth between evaluations. The cookies were evaluated for taste, aroma, crispiness, colour, and overall acceptability using a 9-point hedonic scale (1= Dislike extremely, 2= Dislike very much, 3= Dislike moderately, 4= Dislike slightly, 5= neither like or dislike, 6= like slightly, 7= like moderately, 8= like very much, 9= like extremely).

2.7 STATISTICAL ANALYSIS

All determinations were done in triplicate and subjected to statistical Analysis of Variance (ANOVA) using the SPSS statistical package to determine variation between means. Duncan Multiple Range Test (DMRT) was used to separate means. Significant variation was accepted at $p<0.05$.

3.0 RESULTS AND DISCUSSION

3.1 PROXIMATE COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

“The proximate composition of cookies produced from wheat, whole wheat and unripe plantain flour blends are shown in Table 1. The moisture contents of the cookies ranged from 3.31 to 4.15 % and were significantly different ($p<0.05$). The cookie produced from wheat flour had moisture content of 3.96% and decreased, with increase in whole wheat flour and unripe plantain flour. Cookies with 25% whole wheat flour and 25% unripe plantain flour (50:25:25) had the lowest moisture content (3.31%). All the cookies had generally had relatively low moisture content, which implied that the biscuits could have an extended shelf life. These values were lower than 27.76 to 32.14 % for bread prepared from whole meal wheat and unripe plantain composite flour” (Inyang and Asuquo, 2016).

The ash content of the cookies ranged from 1.64 to 2.19 % and were significantly different ($p<0.05$) among each other. Highest ash (2.19 %) was observed in cookies formulated with 10% whole wheat flour and 10% unripe plantain flour (80:10:10). The high ash content reported in cookies formulated with 10% whole wheat flour and 10% unripe plantain flour shows that it has higher concentration of mineral elements than the other formulated cookies. The values reported in this work were similar to those reported (1.4 to 2.4%) by Udomkun *et al*. (2022) for bread made with plantain and soy flours. The ash content gives an overall estimate of the total mineral elements present in the food. Ash content is the residue remaining after destroying combustible organic matter of a food or product. Minerals like calcium, phosphorus, and magnesium helps in maintaining the strength of bones and teeth and are involved in muscle contraction, relaxation and proper immune function.

The fat content of the cookies ranged from 24.90 to 29.82% and were significantly different ($p<0.05$) from each other and increased as a result of increase in substitution of whole wheat flour and unripe plantain flour. The highest fat content (29.82%) was observed in cookies formulated with 20% whole wheat flour and 20% unripe plantain flour (60:20:20). Fat values of 2.24 to 3.45 % were reported by Inyang and Asuquo (2016) for bread prepared from whole meal wheat and unripe plantain composite flour. Low fat contents in cookies helps to enhance their storage stability as they are less likely to develop rancid flavour.

TABLE 2: PROXIMATE COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF:WWF :UPF	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	CHO (%)
100:0:0	3.96^{b} ± 0.00	1.69^{d} ± 0.00	24.90^{e} ± 0.00	8.89^{d} ± 0.00	8.75^{e} ± 0.00	51.82^{a} ± 0.00
90:5:5	4.15^{a} ± 0.00	1.64^{d} ± 0.00	28.79^{b} ± 0.00	7.98^{f} ± 0.00	18.38^{a} ± 0.00	39.06^{f} ± 0.00
80:10:10	3.74^{c} ± 0.00	2.19^{a} ± 0.00	24.85^{e} ± 0.00	11.90^{b} ± 0.00	15.75^{c} ± 0.00	41.56^{d} ± 0.00
70:15:15	3.60^{d} ± 0.00	1.73^{c} ± 0.00	25.59^{d} ± 0.00	11.35^{c} ± 0.00	16.19^{b} ± 0.00	41.55^{e} ± 0.00
60:20:20	3.55^{e} ± 0.00	1.56^{e} ± 0.00	29.82^{a} ± 0.00	12.47^{a} ± 0.00	8.31^{e} ± 0.00	44.28^{c} ± 0.00
50:25:25	3.31^{f} ± 0.00	1.97^{b} ± 0.00	27.94^{c} ± 0.00	8.27^{e} ± 0.00	13.42^{d} ± 0.00	45.40^{b} ± 0.01

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at $p<0.05$.

WF = Wheat flour; WWF = Whole wheat flour ; UPF = Unripe Plantain Flour.

The fibre content of the cookies ranged from 7.98 to 12.47%. The highest fibre content (12.47%) was observed in cookies formulated with 20% whole wheat flour and 20% unripe plantain flour (60:20:20). The fibre content increased with increasing amount of whole wheat flour and unripe plantain flour in the cookies, and were significantly different ($p<0.05$) from each other. Fibre contents ranging from 0.89 to 3.51% was reported for wheat grain, soy cake, rice-bran and oat-bran flour blends (Ijarotimi *et al*., 2019). “Dietary fiber plays a crucial role in reducing cholesterol levels, lowering the risk of coronary heart disease, colon and breast cancers, and hypertension. Additionally, it improves glucose tolerance and boosts insulin sensitivity” (Galisteo *et al*., 2008).

“The protein content of the cookies ranged from 8.31 to 18.38% and were significantly different ($p<0.05$) in all the blend formulations. The highest protein content (18.38%) was observed in cookies formulated with 5% whole wheat flour and 5% unripe plantain flour (90:5:5). Protein content of 6.53-12.88% was reported in bread prepared from whole meal wheat and unripe plantain composite flours (Inyang and Asuquo, 2016). Proteins play an important role in the organoleptic properties of food products and acts as a source of amino acids in the food” (Tahergorabi, 2017).

The carbohydrate content of the cookies ranged from 39.06 to 51.82 %. Highest carbohydrate (51.82%) was observed in 100% wheat flour and decreased with addition of whole wheat flour and unripe plantain flour. The values were significantly different ($p<0.05$) at all levels of formulation. The carbohydrate content in this study showed similar values to those reported by Inyang and Asuquo (2016) in bread prepared from whole meal wheat and unripe plantain composite flours (51.24-54.76%). “Carbohydrate provides the body with energy for daily tasks and is the primary fuel source for the brain’s high energy demands” (Gibson, 2007).

3.2 PHYTOCHEMICAL COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

The phytochemical composition of cookies produced from wheat, whole wheat and unripe plantain flour blends is shown in Table 2.

TABLE 3 PHYTOCHEMICAL COMPOSITIONS OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF:WWF:UPF	Flavonoid (mg/100g)	Tannin (mg/100g)	Alkaloid (mg/100g)
100:0:0	$0.81^{d} \pm 0.01$	$0.95^{c} \pm 0.01$	$2.97^{cd} \pm 0.04$
90:5:5	$1.14^{a} \pm 0.02$	$0.73^{d} \pm 0.03$	$3.36^{b} \pm 0.21$
80:10:10	$0.74^{e} \pm 0.03$	$1.10^{b} \pm 0.00$	$4.11^{a} \pm 0.13$
70:15:15	$1.01^{c} \pm 0.01$	$1.23^{a} \pm 0.03$	$3.05^{bcd} \pm 0.01$
60:20:20	$1.07^{b} \pm 0.02$	$0.66^{d} \pm 0.01$	$2.79^{d} \pm 0.16$
50:25:25	$1.00^{c} \pm 0.00$	$1.04^{b} \pm 0.06$	$3.13^{bc} \pm 0.35$

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at $p<0.05$.

WF = Wheat flour; WWF = Whole wheat flour ; UPF = Unripe Plantain Flour.

The flavonoid content of the cookies ranged from 0.74 to 1.14 mg/100g and showed significantly different ($p<0.05$) among the cookie samples. The highest flavonoid content (1.14 mg/100g) was observed in cookies formulated with 5% whole wheat flour and 5% unripe plantain flour (90:5:5). Flavonoids are believed to offer numerous health benefits, including reducing the risk of chronic diseases such as heart disease, cancer, and neurodegenerative disorders (Kozlowska, 2014). They also help improve vascular health, support immune function, and promote overall well-being.

The tannins content of the cookies ranged from 0.66 to 1.23 mg/100g and were significantly ($p<0.05$) different among the samples. Tannin was highest (1.23 mg/100g) in cookies formulated with 15% whole wheat flour and 15% unripe plantain flour (70:15:15). The increase was observed with increase in whole wheat flour and unripe plantain flour. The low tannin content reported in this study showed that the flour blends are good for consumption. Bello *et al*. (2020) reported higher tannins in cookies produced from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends (0.31 to 14.21 mg/kg). Tannins in food help to reduce bioavailability of minerals decrease the digestibility and palatability of proteins and carbohydrates by forming insoluble complexes with them.

The alkaloid content of the cookies ranged from 2.79 to 4.11 mg/100g. The alkaloid content was highest (4.11 mg/100g) in cookies formulated with 10% whole wheat flour and 10% unripe plantain flour (80:10:10). They were significantly ($p<0.05$) different. Alkaloid of 1.37 mg/100g was reported to unripe plantain flour (Eleazu *et al.*, 2011). “Alkaloids interact with various receptors and neurotransmitter systems, influencing physiological processes such as pain perception, mood regulation, and muscle contraction” (Hanapi *et al*., 2021).

3.3 MINERAL COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

3.3.1 Micro Minerals in Cookies Produced From Wheat, Whole Wheat And Unripe Plantain Flour Blends.

The micro minerals composition of cookies produced from wheat, whole wheat and unripe plantain flour blends is shown in Table 3.

TABLE 4 MICRO MINERAL COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF:WWF:UPF	Zn (mg/100g)	Fe (mg/100g)	Cu (mg/100g)
100:0:0	$0.67^{a} \pm 0.04$	$1.40^{ab} \pm 0.14$	$0.03^{b} \pm 0.00$
90:5:5	$0.65^{a} \pm 0.07$	$0.88^{ab} \pm 0.04$	$0.01^{c} \pm 0.00$
80:10:10	$0.57^{ab} \pm 0.04$	$1.10^{ab} \pm 0.14$	$0.04^{a} \pm 0.01$
70:15:15	$0.49^{b} \pm 0.01$	$1.55^{a} \pm 0.64$	$0.02^{c} \pm 0.00$
60:20:20	$0.62^{a} \pm 0.02$	$0.85^{ab} \pm 0.07$	$0.04^{a} \pm 0.00$
50:25:25	$0.51^{b} \pm 0.01$	$0.77^{b} \pm 0.04$	$0.04^{a} \pm 0.00$

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at $p<0.05$.

WF = Wheat flour; WWF = Whole wheat flour; UPF = Unripe Plantain Flour.

The zinc content of the cookies decreased from 0.67 to 0.51 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) among the treatment groups. Highest zinc (0.67 mg/100g) was observed in the 100% wheat flour (100:0:0). Inyang and Asuquo (2016) reported that the zinc of bread prepared from whole meal wheat and unripe plantain composite flours decreased from 1.98 to 1.61 mg/100g. “Zinc is needed for growth and for maintenance of immune function and enhances both the prevention of recovery from infectious diseases” (Sobukola *et al*., 2010).

The iron content of the cookies decreased from 1.40 to 0.77 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) between the samples. Iron was highest zinc (1.40 mg/100g) in cookies formulated with 100% wheat flour (100:0:0). The iron of gluten-free sorghum cookies increased 1.28 to 1.74 mg/100g (Ayo-Omogie, 2023). “Iron plays a crucial role in the formation of hemoglobin and is needed for maintenance of physical activity and work capacity and resistance to infection” (Parrow *et al*., 2013).

The copper content of the cookies ranged from 0.01 to 0.04 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) between the samples. Copper was highest zinc (0.04 mg/100g) in cookies formulated with 10% whole wheat flour and 10% unripe plantain flour (80:10:10), 20% whole wheat flour and 20% unripe plantain flour (60:20:20) and 25% whole wheat flour and 25% unripe plantain flour (50:25:25). Nemukondeni *et al*. (2022) reported copper content of 4.99 mg/kg in sorghum landrases obtained in South Africa. "Copper plays a vital role in various biological processes, including the formation of red blood cells, the maintenance of healthy bones and connective tissues, and the function of the nervous and immune systems" (Jomova *et al*., 2022).

3.3.2 Macro Minerals in Cookies Produced From Wheat, Whole Wheat And Unripe Plantain Flour Blends.

The macro minerals composition of cookies produced from wheat, whole wheat and unripe plantain flour blends is shown in Table 4

TABLE 5 MACRO MINERAL COMPOSITION OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF:WWF:UPF	P (mg/100g)	Mg (mg/100g)	Ca (mg/100g)
100:0:0	$4.04^{b} \pm 0.00$	$0.03^{c} \pm 0.00$	$5.05^{e} \pm 0.01$
90:5:5	$4.05^{a} \pm 0.01$	$0.04^{b} \pm 0.00$	$6.20^{b} \pm 0.03$
80:10:10	$3.99^{c} \pm 0.01$	$0.06^{a} \pm 0.00$	$5.69^{d} \pm 0.01$
70:15:15	$4.00^{c} \pm 0.01$	$0.04^{b} \pm 0.00$	$6.54^{a} \pm 0.04$
60:20:20	$3.32^{e} \pm 0.00$	$0.06^{a} \pm 0.00$	$6.07^{c} \pm 0.04$
50:25:25	$3.78^{d} \pm 0.00$	$0.03^{c} \pm 0.00$	$6.03^{c} \pm 0.01$

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at ($p<0.05$).

WF = Wheat flour; WWF = Whole wheat flour; UPF = Unripe Plantain Flour.

The phosphorous content of the cookies ranged from 3.32 to 4.05 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) between the samples. Phosphorous was highest zinc (4.05 mg/100g) in cookies formulated with 5% whole wheat flour and 5% unripe plantain flour (90:5:5). Studies by Ani and Okoye (2021) reported higher phosphorus (157.87 to 170.71 mg/100g) for cookies produced from millet, African walnut and unripe plantain composite flours. "Phosphorus is an essential nutrient for all living organisms and is involved in energy production, DNA and RNA synthesis, cell signaling, and bone formation" (Michigami *et al*., 2018).

The magnesium content of the cookies ranged from 0.03 to 0.06 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) between the samples. Highest magnesium zinc (0.06 mg/100g) was reported for bread made with plantain and soy flours (115.4 to 128.9 mg/100g) by Udomkun *et al*. (2022).

Magnesium is important for the proper functioning of the cardiovascular system, as it helps regulate the contraction and relaxation of muscles, including the heart muscle (Faryadi, 2012).

The calcium content of the cookies ranged from 5.05 to 6.54 mg/100g with increase in whole wheat flour and unripe plantain flour substitution. The values were significantly different ($p<0.05$) between the samples. Calcium was highest zinc (6.54 mg/100g) in cookies formulated with 15% whole wheat flour and 15% unripe plantain flour (70:15:15). Higher calcium were reported (98.40 to 129.92 mg/100g) for bread prepared from whole meal wheat and unripe plantain composite flours (Inyang and Asuquo, 2016). Calcium is important in building and maintaining strong bones and teeth, where it provides structural support and strength (Ross *et al.*, 2011).

3.4 PHYSICAL PROPERTIES OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

The physical property of cookies produced from wheat, whole wheat and unripe plantain flour blends is shown in Table 6.

TABLE 6 PHYSICAL PROPERTIES OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF: WWF:UPF	Weight (g)	Diameter (cm)	Thickness (cm)	Height (cm)	Break Strength (g)	Spread Ratio (%)
100:0:0	$52.50^{d} \pm 0.79$	$0.79^{b} \pm 0.01$	$0.77^{b} \pm 0.01$	$7.35^{d} \pm 0.01$	$3435.00^{a} \pm 7.07$	$3.80^{ab} \pm 0.00$
90:5:5	$52.70^{c} \pm 0.82$	$0.91^{a} \pm 0.01$	$0.91^{a} \pm 0.02$	$8.39^{b} \pm 0.01$	$2852.50^{c} \pm 10.61$	$3.67^{b} \pm 0.01$
80:10:10	$52.93^{c} \pm 1.24$	$0.72^{c} \pm 0.00$	$0.74^{b} \pm 0.03$	$7.56^{c} \pm 0.06$	$1837.50^{e} \pm 3.54$	$3.67^{b} \pm 0.04$
70:15:15	$53.20^{b} \pm 1.47$	$0.79^{b} \pm 0.01$	$0.80^{b} \pm 0.03$	$7.69^{c} \pm 0.13$	$2507.50^{d} \pm 3.54$	$3.76^{ab} \pm 0.06$
60:20:20	$53.57^{b} \pm 1.18$	$0.78^{b} \pm 0.00$	$0.82^{ab} \pm 0.06$	$8.90^{a} \pm 0.03$	$1777.50^{f} \pm 10.61$	$3.76^{ab} \pm 0.06$
50:25:25	$54.20^{a} \pm 1.73$	$0.78^{b} \pm 0.03$	$0.82^{ab} \pm 0.06$	$8.34^{b} \pm 0.08$	$15257.50^{a} \pm 3.54$	$3.83^{a} \pm 0.10$

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at $p<0.05$.

WF = Wheat flour; WWF = Whole wheat flour; UPF = Unripe Plantain Flour.

The weight of the cookies increased from 52.50 to 54.20g with increase in the added whole wheat flour and unripe plantain flour. The weight increased with the level of flour substitution. The cookie formulated with 25% whole wheat flour and 25% unripe plantain flour (50:25:25) was the heaviest (54.20g) among the samples and was significantly ($p<0.05$) different from the other samples. Lower weight (13.17 to 14.48g) was observed for wheat–amaranth flour blend cookies (Chauhan *et al.*, 2016).

The diameter of the cookies ranged from 0.72 to 0.91 cm and was significantly ($p<0.05$) different from the other samples. The highest diameter (0.91 cm) was observed in cookies produced from 5% whole wheat flour and 5% unripe plantain flour (90:5:5). Lowest diameter was observed in cookies from 10% whole wheat flour and 10% unripe plantain flour (80:10:10). Chauhan *et al*. (2016) reported diameter of 51.14 to 52.20 mm (5.11 to 5.22 cm) was observed for wheat–amaranth flour blend cookies.

The thickness of the cookies ranged from 0.74 to 0.91 cm. The highest thickness (0.91 cm) was observed in cookies produced from 5% whole wheat flour and 5% unripe plantain flour (90:5:5) and was significantly ($p<0.05$) different from the other samples. Cookies from 10% whole wheat flour and 10% unripe plantain flour (80:10:10) had the lowest thickness. Chauhan *et al*. (2016) reported a decrease in thickness of wheat–amaranth flour blends cookies (0.88 to 0.81 cm) with increase in amaranth flour.

The height of the cookies ranged from 7.35 to 8.90 cm. The highest height (8.90 cm) was observed in cookies produced from 20% whole wheat flour and 20% unripe plantain flour (60:20:20) and was significantly ($p<0.05$) different from the other samples. The lowest cookie height was observed in cookies from 10% whole wheat flour and 10% unripe plantain flour (80:10:10) had the lowest thickness. Lower height (0.20 to 0.38 cm) was reported by Adeyeye (2016) for cookies from wheat flour and composite flour at different sorghum flour blends.

The break strength ranged from 1777.50 to 15257.50 g and was significantly different ($p<0.05$). Cookies produced from 25% whole wheat flour and 25% unripe plantain flour (50:25:25) had the highest break strength (15257.50 g). Lowest break strength was recorded for cookies from 20% whole wheat flour and 20% unripe plantain flour (60:20:20). Cookies from wheat flour and composite flour at different sorghum flour blends recorded break strength of 1.49 to 2.54 kg (1490 to 2540 g) (Adeyeye, 2016).

The spread ratio of the cookies ranged from 3.67 to 3.83 % with increase in the level of whole wheat flour and unripe plantain flour substitution. Cookies produced from 25% whole wheat flour and 25% unripe plantain flour (50:25:25) had the highest spread ratio (3.83 %) and was significantly ($p<0.05$) different from the other samples. The spread ratio of 5.82 to 6.46 % was observed with increase in wheat–amaranth flour blends in produced cookies (Chauhan *et al*., 2016). The increase in spread ration could be as a result of relative low fat content and high starch content.

3.5 SENSORY PROPERTIES OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

The sensory properties of cookies produced from wheat, whole wheat and unripe plantain flour blends is shown in Table 5. The mean hedonic scores for all sensory attributes of the cookies varied with increasing addition of whole wheat flour and unripe plantain flour and were significantly different ($p<0.05$).

Colour score of the cookies ranged from 6.63 to 7.35 and was highest (7.35) in cookies from 20% whole wheat flour and 20% unripe plantain flour (60:20:20). The colour score was significantly ($p<0.05$) different among the cookie samples. Lowest colour score (6.63) was observed in cookies from 10% whole wheat flour and 10% unripe plantain flour (80:10:10). Chauhan *et al*. (2016) reported colour score of 7.00 to 8.00 for cookies from wheat flour and amaranth flour.

The taste score ranged from 6.33 to 7.18 and was significantly ($p<0.05$) different among the cookie samples. Cookies from 100% whole wheat flour (100:0:0) had the highest taste score (7.18) and was lowest (6.33) in cookies from 10% whole wheat flour and 10% unripe plantain flour (80:10:10). Adeyeye (2016) reported taste score of 4.89 to 7.90 for cookies from wheat flour and sorghum flour.

The aroma score of the cookies ranged from 6.08 to 7.23 and was significantly ($p<0.05$) different. Highest aroma score (7.23) was observed in cookies from 100% whole wheat flour (100:0:0). Aroma score was lowest (6.08) in cookies from 20% whole wheat flour and 20% unripe plantain flour (60:20:20). Aroma score of 5.25 to 6.25 was reported by Badejo *et al*. (2017) for cookies from plantain and *Moringa oleifera* composite flour blends

TABLE 7 SENSORY PROPERTIES OF COOKIES PRODUCED FROM WHEAT, WHOLE WHEAT AND UNRIPE PLANTAIN FLOUR BLENDS.

WF:WWF: UPF	Colour	Taste	Aroma	Texture	General Acceptability
100:0:0	$6.98^{b} \pm 0.04$	$7.18^{a} \pm 0.04$	$7.23^{a} \pm 0.03$	$6.23^{b} \pm 0.04$	$6.60^{b} \pm 0.02$
90:5:5	$6.73^{bc} \pm 0.04$	$6.45^{c} \pm 0.07$	$6.25^{cd} \pm 0.07$	$6.15^{b} \pm 0.14$	$6.40^{c} \pm 0.14$
80:10:10	$6.63^{c} \pm 0.04$	$6.35^{d} \pm 0.00$	$6.33^{c} \pm 0.04$	$6.43^{a} \pm 0.04$	$6.44^{c} \pm 0.07$
70:15:15	$6.95^{b} \pm 0.04$	$6.33^{d} \pm 0.04$	$6.58^{b} \pm 0.11$	$6.08^{b} \pm 0.04$	$6.48^{c} \pm 0.01$
60:20:20	$7.35^{a} \pm 0.21$	$7.00^{b} \pm 0.00$	$6.08^{d} \pm 0.11$	$6.48^{a} \pm 0.04$	$6.73^{a} \pm 0.04$
50:25:25	$6.90^{b} \pm 0.14$	$6.93^{b} \pm 0.04$	$6.23^{cd} \pm 0.04$	$6.48^{a} \pm 0.04$	$6.64^{b} \pm 0.21$

Values are Means ± standard deviation of duplicate determinations. Means within the same column with different letters are significantly different at $p<0.05$.

WF = Wheat flour; WWF = Whole wheat flour; UPF = Unripe Plantain Flour.

The texture score of the cookies ranged from 6.08 to 6.48. The cookies from 20% whole wheat flour and 20% unripe plantain flour (60:20:20) and 25% whole wheat flour and 25% unripe plantain flour (50:25:25) had the highest texture score (6.48) and was significantly ($p<0.05$) different. The lowest texture score (6.08) was observed in cookies from 15% whole wheat flour and 15% unripe plantain flour (70:15:15). Ijarotimi *et al*. (2022) observed texture score ranging from 6.89 to 8.88 for dough meal from gluten free and high protein-fiber wheat flour blends.

The overall acceptability score of the cookies ranged from 6.40 to 6.73 and was significantly ($p<0.05$) different. Highest overall acceptability score (6.73) was observed in cookies from 20% whole wheat flour and 20% unripe plantain flour (60:20:20) and was lowest (6.40) in cookies from 5% whole wheat flour and 5% unripe plantain flour (90:5:5). Overall acceptability ranging from 6.91 to 8.63 was reported for dough meal from gluten free and high protein-fiber wheat flour blends (Ijarotimi *et al*., 2022). This indicates that the cookies produced with 20% whole wheat flour and 20% unripe plantain flour (60:20:20) had the highest acceptability and was therefore the most preferred.

4.0 CONCLUSION

The study has shown that incorporating whole wheat flour and unripe plantain flour into cookie formulations can help to enhance their nutritional composition and sensory properties. The proximate compositions (moisture content ash, fat, fiber, protein, and carbohydrate content) varied among different formulations. The cookies exhibited differences in mineral content, physical characteristics with different formulations, with cookies containing 50% wheat flour and 25% whole wheat flour and 25% unripe plantain flour (50:25:25) having better mineral content and ability to be stored for longer duration. From the sensory evaluation, the cookie formulated with 20% whole wheat flour and 20% unripe plantain flour (60:20:20) received the highest acceptability scores indicating that it was the most preferred by the panelists.

Authors' contribution

Both authors carried out the research in a collaborative manner. Author OOO designed the study, wrote the protocol, performed the statistical analysis and proofread the draft of the manuscript. Author MNH carried out the literature reviews managed the analyses of the study and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

REFERENCES

1. Abioye, V. F., Olatunde, S. J. and Elias, G. (2018). Quality attributes of cookies produced from composite flours of wheat, germinated finger millet flour and African yam bean. *International Journal of Research-Granthaalayah*, *6*(11), 172-183.

2. Adetuyi, B. O., Odine, G. O., Olajide, P. A., Adetuyi, O. A., Atanda, O. O. and Oloke, J. K. (2022). Nutraceuticals: Role in metabolic disease, prevention and treatment. *World News of Natural Sciences, 42* (1), 1–27.

3. Adeyeye, S. A. O. (2016). Assessment of quality and sensory properties of sorghum–wheat flour cookies. *Cogent Food and Agriculture*, *2*(1), 1245059.
4. AOAC, (2010). *Official Methods of Analysis. 18th Edn*., Association of Official Analytical Chemists (AOAC), Washington, DC., USA

5. Ani, E. C. and Okoye, J. I. (2021). Nutrient composition, physical and sensory properties of cookies produced from millet, African walnut and unripe plantain composite flours. *Journal of Food Science and Nutrition*, *7*, 108.

6. Ayo. J.A., Nkama. I., Haruna, U.S., Bitrus, Y. and Onajaife, F. (2008) Effect of dough improvers on the physical and sensory quality of acha (Digitaria exilis) flour bread. *Nigeria Food Journal*, 26 102-110

7. Ayo-Omogie, H. N. (2023). Unripe banana and defatted sesame seed flours improve nutritional profile, dietary fibre and functional properties of gluten-free sorghum cookies. *Food Production, Processing and Nutrition*, *5*(1), 41.

8. Bala, A., Gul, K. and Riar, C. S. (2015). Functional and sensory properties of cookies prepared from wheat flour supplemented with cassava and water chestnut flours. *Cogent Food and Agriculture*, *1*(1), 1019815.

9. Badejo A. and Enujiugha, V.N. (2017). Probiotic potentials of cereal-based beverages. National Institutes of Medicine 57(4):790-804.

10. Bartram, J. and Balance, R. (1996) Water Quality Monitoring: A Practical Guide to the Design and Implementation of Fresh Water Quality Studies and Monitoring Programmes. Chapman & Hall, London, 400.

11. Bello, F. A., Akpan, E. O. E. and Ntukidem, V. E. (2020). Development and quality characteristics of cookies from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends. *European Journal of Nutrition and Food Safety*, *12*(2), 11-21.

12. Chauhan, A., Saxena, D. C. and Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent Food and Agriculture*, 2(1), 1125773.

13. Dewettinck, K., Filip V., B., Bianka K., Davy V., W., Tine C. and Xavier G. (2008). Nutritional value of bread: influence of processing, food interaction and consumer perception. *Journal of cereal science*, 48(2). p.243-257.

14. Doblado-M. A., Oscar A. P., Jess C. S., and Devin R. (2012). Key issues and challenges in whole wheat flour milling and storage. *Journal of Cereal Science* 56(2):119–126.

15. Faryadi, Q. (2012). The magnificent effect of magnesium to human health: a critical review. *International Journal of Applied*, *2*(3), 118-126.

16. Flores-Silva, C. P., César A. R., Gerardo C., Eduardo J. V., Luis A. B. and Jose A. (2017). In vitro digestibility of ultrasound-treated corn starch. onlinelibrary.wiley.com

17. Galisteo, M., Duarte, J. and Zarzuelo, A. (2008). Effects of dietary fibers on disturbances clustered in the metabolic syndrome. *The Journal of Nutritional Biochemistry, 19*(2), 71- 84.

18. Gerardi, C., Durante, M., Tufariello, M., Grieco, F. and Giovinazzo, G. (2022). Effects of time and temperature on stability of bioactive molecules, color and volatile compounds during storage of grape pomace flour. *Applied Sciences*, *12*(8), 3956.

19. Hanapi, N. A., Chear, N. J. Y., Azizi, J. and Yusof, S. R. (2021). Kratom alkaloids: Interactions with enzymes, receptors, and cellular barriers. *Frontiers in Pharmacology*, *12*, 751656.

20. Harborne, J., B. (1980). General Procedures and Measurement of Total Phenolics. Methods in Plant Biochemistry Volume 1, , Pages 1-28.

21. Ijarotimi, O. S., Ogunjobi, O. G. and Oluwajuyitan, T. D. (2022). Gluten free and high protein- fiber wheat flour blends: Macro-micronutrient, dietary fiber, functional properties, and sensory attributes. *Food Chemistry Advances*, *1*, 100134.

22. Ijarotimi, O. S., Oyinloye, A. C., Adenugba, M. O., Ikhazabor, S. O and Oluwajuyitan, T. D (2019). Comparative study on amino acids, fatty acids, functional properties and blood cholesterol status of rats fed on raw, germinated and fermented white melon seed (Cucumeropsis mannii Naudin) flour. *Annals. Food Science and Technology, 20* (1), 402–414.

23. Inyang, U. E. and Asuquo, I. E. (2016). Physico-chemical and sensory qualities of functional bread produced from whole-meal wheat and unripe plantain composite flours. *MOJ Food Processing and Technology*, *2*(2), 48-53.

24. Ismaila, U. G. A. S., Gana, A. S., Tswanya, N. M. and Dogara, D. (2010). Cereals production in Nigeria: Problems, constraints and opportunities for betterment. *African Journal of Agricultural Research*, *5*(12), 1341-1350.

25. Jomova, K., Makova, M., Alomar, S. Y., Alwasel, S. H., Nepovimova, E., Kuca, K. and Valko,
    i. M. (2022). Essential metals in health and disease. *Chemico-biological Interactions*, *367*, 110173.

26. Jemziya, M. B. F. and Mehendran, T. (2017). Physical quality characters of cookies are produced from composite blends of wheat and sweet potato flour. *Ruhuna Journal of Science*, 8: 12-23

27. Kanojia, V., Kushwaha, N., Reshi, M., Rouf, A. and Muzaffar, H. (2018). Products and byproducts of the wheat milling process. *International Journal of Chemical Studies*, *6*, 990-993.

28. Kirk J. (1998). Lay Summaries of Papers. Volume 4, Issue 5.

29. Kozlowska, A. and Szostak-Wegierek, D. (2014). Flavonoids-food sources and health benefits.
    i. Roczniki Państwowego Zakładu Higieny, 65(2).

30. Michigami, T., Kawai, M., Yamazaki, M. and Ozono, K. (2018). Phosphate as a signaling molecule and its sensing mechanism. *Physiological Reviews*, *98*(4), 2317-2348.

31. Nemukondeni, N., Mbajiorgu, C.A., Hassan, Z.M., Sebola, N.A., Manyelo, T.G., Bodede, O. and Mabelebele, M. (2022). Physical characteristics, nutritional composition and phenolic compounds of some of the sorghum landraces obtained in South Africa. *Food Research*, 6(4),12-28

32. Nwosu, A. N., Nweze, B. C. and Onwuchekwa, A. I. (2022). Chemical composition of biscuits supplemented with orange peel and pulp flours. *Agro-Science*, *21*(2), 24-32.

33. Okpala, L. C. and Okoli, E. C. (2013). Development of cookies made with cocoyam, fermented sorghum and germinated pigeon pea flour blends using response surface methodology, *Journal of Food Science and Technology*, 3(1), 38–49.

34. Onwuka, G. I. (2005). Food analysis and instrumentation: theory and practice. Naphathali prints, Nigeria, 95-96.

35. Pagani, M. A., Marti, A. and Bottega, G. (2014). Wheat milling and flour quality evaluation.
    i. *Bakery Products Science and Technology*, 17-53.

36. Panghal, A., Chhikara, N and Khatkar, B. S. (2018). Effect of processing parameters and principal ingredients on quality of sugar snap cookies: a response surface approach. *Journal of Food Science and Technology*, *55*, 3127-3134.

37. Parmar, N., Singh, N., Kaur, A. and Thakur, S. (2017). Comparison of color, anti-nutritional factors, minerals, phenolic profile and protein digestibility between hard-to-cook and easy-to-cook grains from different kidney bean (*Phaseolus vulgaris*) accessions. *Journal of Food Science and Technology*, 54, 1023-1034.

38. Parrow, N. L., Fleming, R. E. and Minnick, M. F. (2013). Sequestration and scavenging of iron in infection. *Infection and Immunity*, *81*(10), 3503-3514.

39. Patiño-Rodríguez O., Agama A., Glenda P., Jose A., Luis A., R., and Bello P. (2019). Physicochemical, microstructural and digestibility analysis of gluten-free spaghetti of whole unripe plantain flour. Food Chemistry Volume 298.

40. Tahergorabi, R. and Hosseini, S. V. (2017). Proteins, peptides, and amino acids. In *Nutraceutical and Functional Food Components, Academic Press*, 15-38.

41. Ubbor, S. C., Arukwe, D. C., Ejechi, M. E. and Ekeh, J. I. (2022). Physiochemical and Sensory Evaluation of Cookies Produced from Composite Flours of Wheat, Bambara Nut and Orange Fleshed Sweet Potato. *Journal of Agriculture and Food Sciences*, *20*(1), 60-77.

42. Udomkun, P., Masso, C., Swennen, R., Romuli, S., Innawong, B., Fotso Kuate, A. and Vanlauwe, B. (2022). Comparative study of physicochemical, nutritional, phytochemical, and sensory properties of bread with plantain and soy flours partly replacing wheat flour. *Food Science and Nutrition*, *10*(9), 3085-3097.

43. Oladebeye, Abraham Olasupo, and Aderonke Adenike Oladebeye. 2023. "Physicochemical and Nutritional Properties of Baby-Led Cookies Produced from Rice, Banana and Cashew-Nut Flour Blends". European Journal of Nutrition & Food Safety 15 (7):14-25. https://doi.org/10.9734/ejnfs/2023/v15i71318.

44. Antarkar, Surbhi, Anurag Sharma, Anushka Bhargava, Honey Gupta, Ritu Tomar, and Sakshi Srivastava. 2019. "Physico-Chemical and Nutritional Evaluation of Cookies With Different Levels of Rosehip and Hibiscus Powder Substitution". Archives of Current Research International 17 (3):1-10. https://doi.org/10.9734/acri/2019/v17i330109.

45. Handa C, Goomer S, Siddhu A. Physicochemical properties and sensory evaluation of fructoligosaccharide enriched cookies. Journal of food science and technology. 2012 Apr;49:192-9.