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PRODUCTION AND QUALITY EVALUATION OF FIBRE-RICH BISCUIT FROM BLENDS OF WHOLE TIGERNUT (*CYPERUS ESCULENTUS* L.) AND UNRIPE BANANA (*MUSA SPP*) FLOUR BLENDS

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ABSTRACT
The use of whole wheat flour has been largely utilized for the production of fibre-rich biscuit, a practice that has limited the exploration of indigenous crops for this purpose. The objective of this study was therefore, to utilize local crops for fibre-rich biscuit production, thereby minimizing their postharvest losses, as well as reduce the dependency on wheat flour. Whole tigernut and unripe banana, used for this study, were processed into flour and blended at various ratios. The flours were analysed for functional properties prior to biscuit production. The biscuit samples were analyzed for proximate composition, mineral content, dietary fibre profile, and physical properties using standard methods. Compeletely randomnized designed was used, and the data obtained was subjected to descriptive analysis using one-way ANOVA at a 95% confidence interval. Functional properties varied: bulk density (0.62-0.86 g/ml), water absorption capacity (1.37-1.88 g/ml), oil absorption capacity (1.29-1.53 g/ml), emulsion capacity (16.70-20.85%), foam capacity (15.28-21.51%), swelling index (2.12-2.49%), and gelatinization temperature (59.00-66.00°C). The nutrient content such as ash (1.75% to 4.33%), protein (4.38 to 9.18%), fibre (1.63% to 5.88%) and fat (13.22 to 16.82%) improved significantly. Fibre profile increased in the composite biscuit samples. Insoluble dietary fibre ranged from 1.95 to 11.72% while soluble dietary fibre ranged from 0.57 to 8.65% respectively. Results of mineral content revealed an improved mineral concentration in the composite samples while the physical properties were comparable to those produced from wheat flour. Conclusively, composite biscuit had improved nutrient properties compared to biscuit from wheat flour. Overall, the 90% whole tigernut flour / 10% unripe banana flour blend sample (TF90) yielded biscuits with the best properties.

Keywords: Dietary fibre, Micronutrient, Physical, Tigernut, Banana

INTRODUCTION
Biscuits are baked products made from wheat flour, sugar, milk, fat, flavouring agents and other raising agents (Ayo and Gidado, 2017). They are ready-to-eat, convenient and inexpensive food products with an appreciable quantity of fat and carbohydrate, hence are energy-giving food. They are also a good source of protein and minerals (Adeyanju *et al*., 2021). They represent a fast-growing segment of food because of consumer demands for convenient and nutritious food products with improved taste, safety and good shelf life at ambient temperature (Kwaghsende *et al.,* 2019). This has necessitated renewed interest and attempts to improve the nutritional qualities and functionalities of biscuits by fortifying and supplementing wheat flour with a wide variety of nutrient-rich cereal, pulses, fruit and tubers (Shamaail *et al*., 2020) such as tigernut and unripe banana.
Tigernut (*Cyperus esculentus* L.) has a sweet and nutty taste (Popova and Mihaylova, 2019) and the tubers are edible and can be eaten raw, dried, roasted, and prepared as tiger nut milk or oil, as well as used as a composite in the production of confectioneries (Abiodun *et al.,* 2017). The use of tigernut flour in biscuit making is desirable due to its constituent of dietary fiber (Adedokun *et al.,* 2014), carbohydrate (Ukwuru and Ogbodo, 2011), oil content and antioxidant capacity (Adedokun *et al.,* 2014). The use of wheat-tigernut flour blends in biscuit making has been reported (Pooja *et al.,* 2018; Adie *et al.*, 2020; and Kwaghsende *et al.,* 2019). According to Abiodun *et al.* (2017), tiger nut is non-allergenic and has been reported to be high in dietary fiber and is effective in the prevention and treatment of a lot of diseases, not excluding colon cancer, coronary heart diseases, gastro intestinal disorders, obesity and diabetics.
Banana (*Musa spp*) is native to South East Asia and most diverse in Malaysia and Indonesia (Harith *et al.,* 2018). The fruits are short, stubby and highly angular of 8-13 cm long and 2.5-5.5 cm in diameter (Phacharapiyangkul *et al.,* 2019). In Nigeria, banana is available year round in the Southern part of the country but highly underutilized. Gomes *et al.* (2020) reported unripe banana to be rich in minerals, ash and ascorbic acid. According to Ogbonna *et al*. (2016), unripe banana flour contains 5.69- 6.47% protein, 0.41-0.70% fat, 2.58-3.16% ash and 89.66-91.30% carbohydrate. It is a good source of vitamin A, B_6 and C which helps maintain vision, good skin and builds immunity against diseases. It is also rich in potassium, magnesium and phosphate when cooked green (Bakar *et al.,* 2018). Durgadevi *et al.* (2019) reported that unripe banana contains some vitamins and mineral elements, extremely low in fat and protein, high in fibre and starch.
Nigeria depends on the importation of wheat to sustain its confectionery industry despite the fact that its climactic conditions does not favour the cultivation of wheat. In order to meet the demand for wheat flour, Nigeria relies on importation, which is detrimental to the economic health of the nation. However, cultivation of indigenous crops like tigernut, banana, plantain amongst others are suitable to cultivate under the Nigerian weather, consequently, it is important to adequately consider the replacement of wheat flour, partially or completely, with flour from our local crops. More so, the gluten content in wheat flour causes damages to the immune system for the gluten intolerance patients and would be more beneficial when replaced. Tigernut and banana

are prone to lots of postharvest losses due to their underutilization. Tigernuts are dominantly sold in local market and consumed as a snack while banana is consumed when ripe and has been utilized in mixed fruit juice production and smoothies. Converting them into other forms like flours usable by bakery industry to improve their utilization, industrial value, reduce postharvest losses and make Tigernut and unripe banana products available all year round would be beneficial. The objective of sthis study is therefore, to boost the utilization of tigernut and banana as a major raw matrial in the development of fibre-rich baked products like biscuit.

MATERIALS AND METHODS

The following materials such as unripe banana, wheat flour (Nigeria Flour Mill Ltd), baking powder, eggs, sugar, margarine, salt (Dangote Nigeria Ltd) were purchased from commercial stockers at Ubani main market, Umuahia, Abia state. Fresh tigernut tubers (brown variety) was purchased from Ogbo-Hausa market, Owerri road, Umuahia, Abia state. Production and analysis of biscuit samples was carried out at the Food Science and Technology Laboratory at Michael Okpara University of Agriculture, Umudike (MOUAU). High quality chemicals of analytical grade was used for this work.

Chemicals

The following chemicals were used for the following analysis; Petroleum ether, H_2SO_4 Solution, carbonate free NaOH, copper sulphate and sodium sulphate (catalyst) in the ratio 5:1, 40% sodium hydroxide and 0.02 molar of hydrochloric acid were used to conduct the proximate analysis. Masking agents (hydroxylamine, hydrochloride, sodium cyanide and sodium potassium ferrocyanide) and then NH_3-NH_4Cl aqueous buffer (dissolved 7 g of ammonium chloride in 57 mL of concentrated ammonia), 0.02N EDTA, 50% hydrochloric acid, 1.00 mL hydroxylamine hydrochloride, ammonium acetate buffer, 1.10 phenanthroline, 2.00 mL ammonium solution, ethanol, acetone were used to conduct the mineral content analysis. Alpha-amylase, protease and amyloglucosidase, etnanol, acetone, MES-Tris buffer were used for dietary fibre profile analysis.

Sample Preparation

Processing of Tigernut Tubers into whole Tigernut Flour

Fresh tigernut tubers were sorted to remove extraneous substances like stones, pebbles and spoilt tubers before washing with potable tap water as described by Adedokun *et al*. (2014). The cleaned tubers were dried in a hot air oven (Model no.SX3-4.5-15: made in China) at 60°C for 24 h to a moisture content of about 10-12%. The dried tubers were milled into flour using a commercial hammer mill (Model no. XE-33425-8; made in China). The flour was packaged and sealed in an air-tight transparent polythene bag for further analysis.

Processing of Unripe Banana into Flour

Unripe bananas were sorted to remove bruised and damaged ones. Wholesome ones were washed under running tap water, peeled, washed again, drained and were sliced uniformly to about 3 cm x 3 cm using a clean stainless steel knife. The slices were steam blanched for 3 min at 85°C, dried in a hot air oven (Model OV 160, England) at 60°C for 48 h, cooled, and milled using a table top laboratory milling machine (model HL 3294/C Phillips) to get unripe banana flour, which was packaged in an air-tight transparent plastic container prior to use (Adegunwa *et al.,* 2014).

Formulation of Composite Flour

The formulated composite flours ratios for fibre-rich biscuit production are presented in Table 1, while 100% wheat flour was used in the production of the reference sample.

Table1: Formulation of whole Tigernut and Unripe Banana Composite Flours (%)

Sample Codes	Whole Tigernut Flour (TF)	Unripe Banana Flour (UBF)
TF100	100	0
UBF100	0	100
TF90	90	10
TF80	80	20
TF70	70	30

Functional Properties of Composite Flours

The functional properties which are bulk density, swelling index, water absorption capacity, oil absorption capacity, emulsion capacity, foam capacity, gelatinization temperature was determined according to method described by Onwuka (2018). All functional properties were determined in triplicates.

Production of Biscuit Samples

Tigernut-unripe banana fibre rich biscuits were produced using the rubbing-in method as described by Ahmed and Hussein (2014) with slight modifications in the recipe. All the ingredients contained in the recipe were accurately weighed or measured as the case may be (Table 2). The dry ingredients (flour, sugar, salt and baking powder) were thoroughly mixed in a bowl for about 3 min using an electronic hand mixer set 400 rpm. Vegetable shortening (baking margarine) was added and mixed for 3 min at 300 rpm until uniform. Egg, milk and water was added and the mixture kneaded. The dough was rolled and cut with a 50 mm diameter biscuit cutter. The biscuits dough were placed on greased stainless steel baking trays at room temperature, with spaces (4 mm) in between and baked at 180°C for 10 min in the baking oven (Gallenkamp, Model OV 160, England). Following baking, the biscuits were cooled to ambient temperature (15-25°C), packed in an air-tight plastic transparent containers and stored at room temperature prior to analysis and sensory evaluation.

Table 2: Biscuits Recipe with Different Levels (%) of whole Tigernut- Unripe Banana Flour Blends

Ingredients (%)	WF100	TF100	UBF100	TF90	TF80	TF70
Wheat flour (g)	250	0	0	0	0	0
Whole-tigernut flour (g)	0	250		225	200	175
Unripe banana flour (g)	0	0	250	25	50	75
Margarine (g)	50	50	50	50	50	50
Sugar (g)	100	100	100	100	100	100
Baking powder (g)	4	4	4	4	4	4
Salt (g)	1	1	1	1	1	1
Egg (g)	30	30	30	30	30	30
Milk (ml)	40	40	40	40	40	40
Water (ml)	40	40	40	40	40	40

WF00 = 100% wheat flour. TF10 = 100% whole tigernut flour. UBF100 = 100% unripe banana flour. TF90= 90% whole tigernut flour: 10% unripe banana flour. TF80= 80% whole tigernut flour: 20% unripe banana flour. TF70= 70% whole tigernut flour: 30% unripe banana flour

Methods of Analyses

Proximate Analysis

Moisture content was determined according to the constant weight method of AOAC (2012). Crude fiber was determined using the method described by Onwuka (2018). The micro Kjeldahl method as described by AOAC (2012), was used to determine crude protein. The Soxhlet extraction method described by AOAC (2012), was used in determining the fat content of the samples. Ash content was determined using the incineration method of AOAC, (2012). Carbohydrate content was determined by difference. All proximate parameters were determined in triplicates.

Mineral Content Determination

The EDTA titrimetric method of AOAC, (2012) was used. O-phenanthroline method was used to determine iron in the test sample AOAC (2012). Sodium and potassium were done by flame photometry method as described by AOAC (2012). All mineral contents were determined in triplicates.

Dietary Fibre Determination

Enzymatic-Gravimetric Method measures total dietary fibre using phosphate buffer systems as described by AOAC (2012). Triplicate samples of dried (defatted if necessary) foods was gelatinized and partially digested with alpha-amylase and then enzymatically digested with protease and amyloglucosidase to remove the protein and starch present in the sample, simulating human digestion. Ethanol was added to precipitate the soluble dietary fiber. The residue was filtered and washed with ethanol and acetone, then dried, and weighed. One portion of the sample was analyzed for protein and the other was ashed. Total dietary fibre was calculated as the weight of the residue minus the weight of the protein and ash, reported as a percentage of the original sample weight.

$$TDF = \frac{\mathrm{Wr}-(\mathrm{Wp}+\mathrm{Wa})}{\mathrm{Sw}}\ x\ 100$$

Where:
Wr = weight of residue
Wp = weight of protein
Wa = weight of ash
Sw = sample weight

Soluble (SDF) and insoluble (IDF) dietary fibre was measured using an MES-Tris buffer as described by AOAC (2012). The sample was defatted and dispersed in buffer, the starch gelatinized and partially digested with alpha-amylase, and then further digested with protease and amyloglucosidase enzymes. The undigested IDF mass was removed by filtration, dried, and weighed. Ethanol was added to the filtrate to precipitate the soluble dietary fiber. The undigested SDF mass was isolated, dried, and weighed.

Physical Analysis

The physical characteristics including weight, height, spread ratio, and break strength of the biscuit samples were determined according to the method described by Onwuzuruike *et al*. (2023) in triplicates. Weight was measured as average values of four individual biscuits with the help of an analytical weighing balance (Model number: 12043, Nez Delhi). Average values for weight was reported in grams (g). Height was measured as an average values of four individual biscuit using a manual Vernier calliper. Average values was reported in centimetre (cm). Spread ratio was calculated by dividing diameter by thickness. Thickness of biscuits was determined by measuring the diameter of four biscuit samples placed edge to edge with a digital Vernier caliper. An average of four values was taken for each set of samples. Average value for thickness was reported in millimetre (mm). Break strength was evaluated by placing biscuits of known height between two bars. Known weight that caused the breaking of the biscuit was regarded as the break strength of the biscuits.

Experimental Design

Completely randomnized design (CRD) was used for this study.

Reproducibility Measures

In order to ensure reproducibility of the present study, established and validated protocols for data collection and analysis were deployed. Also, detailed records of research procedures, data and, results were maintained.

Statistical Analysis

The experimental data were expressed as mean ± SD (standard deviation). The data were subjected to one-way analysis of variance (ANOVA) while the Duncan Multiple Range Test (DMRT) method was used to compare the means of experimental data at 95% confidence interval. All statistical analysis were done using the Statistical Product of Service Solution version 20.0 software.

RESULTS AND DISCUSSION

Functional Properties of Whole Tigernut and Unripe Banana Composite Flours

The functional properties of the composite flours are shown in Table 3.

Table 3: Functional Properties of Whole Tigernut and Unripe Banana Composite Flour Blends (%)

Samples	Bulk density (g/ml)	Water absorption capacity (g/ml)	Oil absorption capacity (g/ml)	Emulsion capacity (%)	Foam capacity (%)	Swelling index (%)	Gelatinization temperature (°C)
WF00	$0.78^{b}±0.01$	$1.88^{a}±0.02$	$1.29^{d}±0.01$	$20.85^{a}±0.78$	$21.51^{a}±0.13$	$2.12^{f}±0.03$	$64.50^{c}±0.01$
TF100	$0.62^{f}±0.01$	$1.37^{e}±0.01$	$1.53^{a}±0.01$	$18.75^{b}±0.18$	$19.54^{d}±0.08$	$2.18^{e}±0.01$	$66.00^{a}±0.01$
UBF100	$0.86^{a}±0.01$	$1.74^{b}±0.02$	$1.29^{d}±0.01$	$16.70^{f}±0.14$	$15.28^{f}±0.04$	$2.49^{a}±0.03$	$59.00^{f}±0.01$
TF90	$0.64^{e}±0.01$	$1.53^{de}±0.04$	$1.48^{b}±0.01$	$17.60^{c}±0.14$	$20.75^{b}±0.07$	$2.23^{d}±0.02$	$65.50^{b}±0.01$
TF80	$0.67^{d}±0.01$	$1.57^{d}±0.01$	$1.46^{b}±0.01$	$17.16^{d}±0.65$	$19.73^{c}±0.11$	$2.27^{c}±0.01$	$63.00^{d}±0.01$
TF70	$0.68^{c}±0.01$	$1.61^{c}±0.01$	$1.36^{c}±0.01$	$17.06^{e}±0.65$	$19.13^{e}±0.11$	$2.31^{b}±0.01$	$62.48^{e}±0.01$

Values are means ± s.d of triplicate determination. Mean value in the same column but with different superscript (a-f) are significantly different (P<0.05). WF100: 100% wheat flour biscuit. TF100: 100% whole tigernut flour biscuit: UBF100: 100% unripe banana flour biscuit. TF90: 90% whole tigernut flour/10% unripe banana flour biscuit. TF80: 80% whole tigernut flour/20% unripe banana flour biscuit. TF70: 70% whole tigernut flour/30% unripe banana flour biscuit

Bulk Density

Bulk density (BD) is defined as the mass/volume of a substance. It reveals how porous a product is which is an important determinant in the design and requirement of packaging materials, since it reveals the load carrying capacity of a food material when allowed to rest on its weight (Onimawo and Akubor, 2005). It is often expressed as g/ml and is a good index of structural changes (Malomo *et al.,* 2012). The bulk density (BD) obtained in this study ranged from 0.62 to 0.86 g/mL and is in agreement with 0.76 to 0.82 g/mL reported by Suresh *et al.* (2015) for cassava-wheat composite flour, 0.72 to 0.85 g/mL reported by Florence *et al.* (2020) for development and quality characteristics of biscuits from sprouted sorghum, pigeon pea and orange flesh sweet potato flour blends but higher than 0.50 to 0.55 g/mL reported by Olosunde *et al.* (2020) for development and quality evaluation of a typical flour blend from orange –fleshed sweet potato and soy-bean. The highest BD (0.86 g/mL) was recorded in 100% unripe banana flour (UBF100) while 100% tigernut flour (TF100) had the lowest BD (0.62 g/mL). There was significant difference (p<0.05) among the samples. Increasing proportion of unripe banana flour, increased the bulk density of the composite flours from 0.62 g/ml in TF100 to 0.68 g/ml in TF70 (70% tigernut flour: 30% unripe banana flour. Akapata and Akubor (1999) reported that bulk density of composite flour increased with an increase in the incorporation of different flours. Similar observation was observed in this study such that, increasing the proportion of unripe banana flour from 0% in TF100 to 30% unripe banana flour in TF70 increased the bulk density from 0.62 g/ml to 0.68 g/ml. Low BD would be an advantage in the formulation of weaning foods (Ezeocha and Onwuka, 2010). The BD obtained in this study is considerably low and suggest their suitability in food formulation with an extra advantage in the formulation of complimentary foods (Akapata and Akubor, 1999) and may possibly encourage bulk packing of the flour samples using compact packaging material (Ezeocha and Onwuka, 2010).

Water Absorption Capacity

Water absorption capacity (WAC) refers to the ability of the flour or starch to hold water against gravity that can comprise of bound water, hydrodynamic water, capillary water and physically entrapped water (Moure *et al.,* 2006). The water absorption capacity (WAC) (1.37 to 1.88 g/mL) of this study differ significantly (p<0.05) among the samples, which may be due to variation in the concentration of protein content, degree of association and conformational characteristics (Butt and Batool, 2010). TF100 (100% whole tigernut flour) had lower WAC than 100% unripe banana flour (UBF100), which influenced the increase of WAC in the composite flour as the proportion of unripe banana flour increased in the blends. Higher WAC obtained for UBF100 over TF100 may be due to its starch content. However, WF100 (wheat flour; control) had the highest WAC than other flour samples. Butt and Batool (2010) reported that protein possess both heads (hydrophilic and hydrophobic properties) which enables its association with moisture in foods. Ibeogu (2020) reported that carbohydrates also influence water absorption capacity of foods. The values obtained in this study were lower than 2.40 to 2.67 g/mL reported by Olosunde *et al.* (2020) but higher than 1.00 to 1.47 g/mL reported by Florence *et al*. (2020). The values of WAC for the composite flours were considerably high, which might be attributed to the presence of hydrophilic protein that has the capacity to bind water as well as high digestible starch and may be suitable for formulation of food product that requires high imbibition of water.

Oil Absorption Capacity

Oil absorption capacity (OAC) has been attributed to the physical entrapment of oil. This is important since fat acts as flavour retainer and increases the mouth feel of food. It is an indication of the rate at which the protein binds to fat in food formulations. Oil absorption capability required in most food applications, such as in bakery products, wherein required in flavour retention and improvement of palatability (Abu *et al.,* 2005). They are also important because of storage stability in the rancidity development (Siddiq *et al.,* 2010). The oil absorption capacity (OAC) ranged from 1.29 to 1.53 g/mL and was lower than 130.00 to 156.00 g/mL reported by Suresh *et al.* (2015) for cassava-wheat composite flour but corresponds 1.39 to 1.57 g/mL reported by Olosunde *et al.* (2020) but higher 0.69 to 1.22 g/mL reported by Florence *et al.* (2020). The OAC of the flour samples differ significantly (p<0.05) from each other. TF100 (100% whole tigernut flour) had the highest value which may be due to the fact that it is an oil seed. Oil absorption capacity of WF100 (wheat flour) and UBF100 (100% unripe banana flour) did not differ significantly (p<0.05) from each other. OAC decreased in the composite flours as the proportion of UBF100 increased due to the dominantly starchy nature. OAC is an index of flour protein capacity to bind fat (Onimawo and Akubor, 2005). The protein content, liquidity of the oil as well as the type of method used may have affected the oil absorption capacity of the samples leading to variation (Ibeabuchi *et al.,* 2017). The OAC content obtained for the flour blends were considerably low and may affect the retention of flavour, and mouth feel of products. Although, the low OAC of the flour blends might be beneficial with respect to rancidity and its influence in shelf life particularly in bakery products (Adebowale and Lawal, 2004).

Emulsion Capacity

Emulsion capacity of the flour samples ranged from 16.70 to 20.85% with significant differences ($p<0.05$) among the flour samples. 100% wheat flour which is the control sample had the highest emulsion capacity possibly due to the gluten content which is a protein. Protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal *et al.,* 2012). The Emulsion capacity of composite flours were found to be significantly decreased with increasing proportions of unripe banana flour (UBF100) flours up to 30%. This may be due to increasing concentration of starch and protein depreciation as the proportion of unripe banana decreased. Emulsion stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation (Eke-Ejiofor and Kporna, 2019). Increasing emulsion capacity (EA), emulsion stability (ES) and fat binding during processing are primary functional properties of protein in such foods as comminute meat products, salad dressing, frozen desserts and mayonnaise. Decreasing emulsion capacity as the proportion unripe banana flour increased suggest the dilution of rigid globular protein found in whole tigernut flour (TF100) flour. Despite the decreasing emulsion capacity of the flours, all composite flours showed relatively good capacity of emulsion activity.

Foam Capacity (FC)

Foams are used to improve texture, consistency and appearance of foods (Akubor and Badifu, 2014). Foam capacity of protein refers to the amount of interfacial area that can be created by the protein (Onwuzuruike *et al.,* 2023). Foam is a colloidal of many gas bubbles trapped in a liquid or solid. Small air bubbles are surrounded by thin liquid films. The foaming capacity (FC) of the flours samples ranged from 15.28 to 21.51%. Control (WF100) had the highest foam capacity than other flour samples followed by TF90 (90% whole tigernut flour: 10% unripe banana flour) while UBF100 (100% unripe banana flour) had the lowest value. The difference could be attributed to protein quality in the flour samples, since FC is assumed to be dependent on the configuration of protein molecules. Flexible proteins have good foaming capacity, but a highly ordered globular molecule gives low foaming ability (Timothy and Bassey, 2019), hence, whole tigernut2 flour (TF100) and unripe banana flour (UBF100) may have more globular protein than flexible protein which amounts to their lower FC than control (WF100). More so, UBF100 had much lower FC than TF100 which suggest higher amount of highly ordered globular protein. More so, the different proportions of the flours may have affected the flexibility of the protein molecules differently. The values obtained in this study are lower than 60% and 80% reported for wheat flour and African breadfruit kernel flour (Akubor and Badifu, 2014) respectively. Good foam capacity are desirable qualities for flours used for the production of various baked products. Food products such as cakes, sponges, ice creams, marshmallows, whipped creams, and bread require food ingredients with high foaming capacity (Atuonwu and Akobundu, 2010). However, food ingredients with low foaming capacity may suitably be applied in biscuits, crackers, and cookies (Borja *et al.,* 2013).

Swelling Index (SI)

Swelling index show the degree of exposure of the internal structure of starch granules to action of water, that is, a measure of hydration capacity (Awuchi *et al.* 2019). The results of swelling index in the present study indicated that blending of flours in varying proportions caused slight aggregation of starch granules to different degrees and subsequently affect the level of its exposure to water and its swelling index. The swelling index value ranged from 2.12 to 2.49%. UBF100 had the highest swelling index value, probably because its starch composition and presence of hydrophilic proteins. Wheat flour had the lowest swelling index. Swelling index of composite flours was higher than the whole tigernut flour (TF100). The value increased from 2.18% to 2.31% as the proportion of UBF100 increased from 0 to 30% as the starch concentration increased. The swelling capacity (index) of flours are influenced by the particle size, species variety and method of processing or unit operations (Suresh and Samsher, 2013). The high swelling index in UBF100 (100% unripe banana flour) and composite flours suggested that it could be useful in food systems (spaghetti, noodles) where swelling is required. Swelling index provide suitable predictive method for identifying noodle-quality flours. The values obtained in this study are higher than 0.53 to 0.71 g/mL recommended for wheat flour (EAS, 2011) but corresponds with 2.14 to 2.47% for swelling capacity reported by Ukegbu *et al*. (2023) for whole tigernut and wheat flour blends.

Gelatinization Temperature (GT)

Gelatinization temperature (GT) is the critical temperature at which about 90% of the starch granules have swelled irreversibly in hot water and start to lose crystallinity and birefringence (Khush *et al*., 1998). Suresh *et al.* (2015) defined it as the temperature at which gelatinization of starch take place. The lower the GT the better the gelation ability of the protein ingredient (Akintayo *et al.,* 2011). Gelatinization temperature ranged from 59.00 to 66.00°C. UBF100 (unripe banana flour) had the lowest gelatinization temperature while the TF100 (whole tigernut flour) had the highest gelatinization temperature. This may be due to the higher starch content in unripe banana flour (UBF100) and the higher protein and oil content of whole tigernut flour (TF100) which suggest that, UBF100 may gelatinize faster followed by control while TF100 will take longer time to gelatinize. Gelatinization temperature of composite flours decreased as the proportion of unripe banana flour increased, thereby increasing the starch content and shortens the time for gelatinization to take place. Suresh *et al.* (2015) reported that the flour which was higher in starch content took lowest temperature for gelatinization. Notably, the gelatinization temperature and time of composite flours significantly decreased with increase in the incorporation of different flours. Flour with shorter gelling time could be a good thickening agent, hence, UBF100 may exhibit better gelling potential than other samples and may find more use in food applications such as pudding production that require significant thickening since the gel structure of such food systems provides a matrix for retaining moisture, fat and other added ingredients.

Proximate Composition of Whole Tigernut and Unripe Banana Composite Biscuit

The proximate composition of the biscuit samples is presented in Table 4.

Table 4: Proximate Composition of Composite Biscuits (%)

Samples	Moisture content	Ash content	Crude protein content	Crude fibre content	Crude fat content	Carbohydrate content
WF00	$6.64^b\pm0.08$	$1.75^e\pm0.01$	$8.46^d\pm0.03$	$1.63^f\pm0.01$	$13.22^e\pm0.03$	$68.30^a\pm0.14$
TF100	$5.81^e\pm0.01$	$3.85^d\pm0.01$	$8.22^e\pm0.06$	$5.69^d\pm0.01$	$16.82^a\pm0.01$	$59.61^d\pm0.01$
UBF100	$7.11^a\pm0.01$	$4.33^a\pm0.01$	$4.38^f\pm0.04$	$4.77^e\pm0.02$	$13.42^e\pm0.01$	$65.99^b\pm0.07$
TF90	$5.77^f\pm0.05$	$3.89^d\pm0.01$	$9.18^a\pm0.03$	$5.88^a\pm0.02$	$16.37^b\pm0.02$	$58.91^e\pm0.12$
TF80	$5.90^d\pm0.01$	$3.95^c\pm0.01$	$9.15^b\pm0.01$	$5.81^b\pm0.02$	$15.77^c\pm0.04$	$59.42^d\pm0.02$
TF70	$6.47^c\pm0.01$	$4.07^b\pm0.01$	$8.65^c\pm0.01$	$5.73^c\pm0.01$	$14.73^d\pm0.01$	$60.35^c\pm0.03$

Values are means ± s.d of triplicate determination. Mean value in the same column but with different superscript (a-f) are significantly different (P<0.05). WF100: 100% wheat flour biscuit. TF100: 100% whole tigernut flour biscuit: UBF100: 100% unripe banana flour biscuit. TF90: 90% whole tigernut flour/10% unripe banana flour biscuit. TF80: 80% whole tigernut flour/20% unripe banana flour biscuit. TF70: 70% whole tigernut flour/30% unripe banana flour biscuit

Moisture Content

The moisture content of the biscuit samples ranged from 5.81 to 7.11% with significant differences (p<0.05) existing among the samples. Moisture content in food is very important because it enhances the storage stability. Low moisture inhibits the survival and growth of microorganisms in food products (Onimawo and Akubor, 2012). The values obtained in this study corresponds with 4.67 to 7.51% reported by Ukegbu *et al.* (2023) for whole tigernut and wheat flour composite biscuit containing margarine as the shortening agent and were higher than 4.92 to 5.13% reported by Florence *et al.* (2020) but lower than 7.85 to 8.45% reported by Kayode *et al.* (2015) for nutritional attributes of baked products from composite flour of wheat and pigeon pea, 9.70% reported by Akubor (2017) for quality of biscuit produced from wheat flour and fermented pigeon pea flour blends, 9.05 to 10.70% reported by Arukwe (2020) for proximate composition, physical properties and sensory evaluation of wheat-cocoyam-pigeon pea biscuits and 10.47 to 11.90% reported by Ukegbu *et al.* (2023) for whole tigernut and wheat flour composite biscuit containing avocado paste as the shortening agent. Biscuit samples produced from 100% unripe banana flour (UBF100) had the highest moisture content while biscuit containing 10% unripe banana flour (TF90) inclusion had the lowest moisture content. Addition of unripe banana flours from 10% to 30% increased the moisture content of the biscuit samples which increases the chances for microbial growth. However, the moisture contents of the biscuits were below 10% which suggest reduced chances of spoilage by microorganisms and consequently increased shelf life (Ariahu *et al.,* 1999) at ambient temperature (Offor, 2015). Food products with high moisture content are susceptible to microbial attack leading to spoilage and therefore have limited shelf life (Hassan and Umar, 2014).

Ash Content

Ash content ranged from 1.75% to 4.33%. There were significant differences (p<0.05) among the samples. UBF100 (100% unripe banana flour) had the highest value while WF100 (100% wheat flour) had the lowest amount. TF100 also had higher ash content of 3.85% than WF100. Ash content of the composite biscuit samples increased steadily from 3.85% in TF100 (100% whole tigernut biscuit) to 4.07% TF70 (70% whole tigernut: 30% unripe banana flour biscuit) with increasing proportion of unripe banana flour from 0% to 30%. The values obtained in this study were higher than 1.33 to 3.65% reported by Florence *et al.* (2020), 1.50 to 1.95% obtained by Inyang *et al.* (2018) for rice, unripe banana and sprouted soybean flour blends cookies, 1.26 to 2.01% reported by Kayode *et al.* (2015), 1.40 to 2.09% reported by Jelili *et al.* (2020), 1.37 to 1.78% reported by Nurul *et al.* (2018), and 2.67 to 3.01% reported by Pooja *et al.* (2018) respectively but lower than 4.00 to 8.00% reported by Amal (2015) and 4.00% reported by Akubor (2017). The values (2.45 to 4.05%) obtained by Arukwe (2020) corresponds with the findings of this study. Ash content is the fraction in biomass that is composed of incombustible mineral material, which is a representation of mineral availability in food (Mamiro *et al.,* 2011). Unripe banana is a good source of minerals such as phosphorus, magnesium, iron, calcium, sulphur and potassium but low in sodium (Kunyanga *et al.,* 2013). Tigernut has been reported to be high in some important minerals such as iron, sodium and calcium (Adedokun *et al.,* 2014), which may have contributed to the ash content of TF100. Therefore, production of biscuit from composite flour of whole tigernut and unripe banana flour may boost the mineral content in biscuit production.

Protein Content

Protein content ranged from 4.38 to 9.18%. UBF100 (100% unripe banana flour) had the lowest content while TF90 (90% whole tigernut flour: 10% unripe banana flour) had the highest content. TF100 (100% whole tigernut flour) had higher protein content than UBF100 which consequently affected the composite biscuits protein contents. That is, protein content of composite biscuits decreased from 9.18% to 8.65% as the amount of UBF100 increased from 10% to 30%. However, protein content of composite biscuits were higher than non-composite biscuits. Other studies also reported increase in protein content of composite products (Mashayekh *et al.,* 2008). The protein content in the present study corresponds with 4.38 to 11.61% reported by Florence *et al*. (2020) but lower than 12.50 to 16.19% reported by Kayode *et al.* (2015), 27.5% reported by Akubor (2017) for quality of biscuit produced from wheat flour and fermented pigeon pea flour blends and 11.02 to 13.15% reported by Arukwe (2020). Protein play vital role in enzymatic catalysis, transport and storage of molecules, immune protection, generation and transmission of nerve impulse, control of growth and differentiation (Anuma, 2008). It helps to build and maintain healthy muscle mass, while also supporting tendon, ligaments and other body-tissue. It also helps to prevent spikes in blood glucose, which is especially important for preventing type 2 diabetes and balancing energy (Ajani *et al.,* 2012). About 23-56 g protein was recommended by FAO/WHO/UNU (1994) to meet the protein needs of the human body and combat protein deficiency. The protein content of the biscuit samples suggested that the biscuit might be valuable in combating protein energy malnutrition, especially to low income earners.

Crude Fibre Content

A significant difference in crude fibre content (p<0.05) was observed among the biscuit samples. Crude fibre content of the biscuits are quite high except for biscuit produced from 100% wheat flour (WF100) and ranged from 1.63% to 5.88%. These values were higher than 1.33% to 2.51% reported by Florence *et al.* (2020), 1.84% to 2.83% reported by Kayode *et al.* (2015), 0.20% to 4.40% reported by Obinna-Echem *et al.* (2007), 2.40% reported by Akubor (2017) and 1.05% to 3.20% reported by Arukwe (2020). Fibre content of biscuits produced from 100% whole tigernut flour (TF100) was higher than that of UBF100 (100% unripe banana flour). Blending both flours decreased slightly the fibre content from 5.88% to 5.73% as the amount of unripe banana flours increased from 10 to 30%. Decrease in certain diseases such as diverticulosis and colonic has been associated with increased fibre consumption (Enwere, 1998). Dietary fibre acts as bulking agent and thus, increases intestinal motility and wet faecal mass of faeces (Enwere, 1998). These effects help in reducing diseases of the colon (Enwere, 1998). Some reports showed that some plant fibres can lower serum cholesterol (Wardlaw and Hampin, 2007). The higher fibre contents of experimental biscuit samples than control may imply that, the biscuit samples may contribute significantly to the dietary fibre needs of the human body.

Crude Fat Content

The crude fat content of the biscuit samples ranged from 13.22 to 16.82%. Florence *et al.* (2020) (16.21 to 18.13%) reported higher crude fat values than the values obtained in this study, Akubor (2017) (15.00%) reported corresponding values while Kayode *et al.* (2015) (6.36 to 8.15%) and Arukwe (2020) (3.10 to 4.60%) reported a lower value. Fat content in the samples differ significantly ($p<0.05$) from each other. The fat content was highest in TF100 (100% whole tigernut flour) biscuit formulation and was lowest in WF100 (wheat flour biscuit). More so, UBF100 (unripe banana flour) biscuit had lower fat than TF100. Evidently, increasing the proportion of unripe banana flour from 10% to 30% resulted to decreased fat content of the biscuit samples from 16.37% to 14.73% which might be attributed to the decreased fat content in unripe banana flour. This observation contradicts the findings of Florence *et al.* (2020) who reported that increase in the levels of crude lipid with increasing level of unfermented pigeon pea flour addition. Generally, the lower lipid content of samples containing unripe banana flour might result to increased keeping quality as a result of decreased susceptibility to rancidity (Ikujenlola *et al.,* 2013). However, the biscuit samples contain appreciable fat level arising also from the added baking margarine and may have the capability of serving as a viable vehicle for fat soluble vitamins, improving mouth-feel and palatability (Coppin and Pike, 2011), impart tenderness, moistness, mealy, flavour, colour and anti-bread staling qualities to the biscuit samples (Ayele *et al.,* 2017).

Carbohydrate Content

Carbohydrate content ranged from 58.91% to 68.30% and differ significantly ($p<0.05$) from each other. Higher carbohydrate content was reported by Florence *et al.* (2020) (58.97 to 69.32%), kayode *et al.* (2015) (63.75 to 68.67%), Akubor (2017) (68.80%) and Arukwe (2020) (65.95 to 71.68%) which were close to the findings of the present study. Increased proportion of unripe banana flour increased the carbohydrate content from 58.91% to 60.35% in the composite flours, although lower than biscuit samples produced from 100% wheat flour (68.30%) which may be due to the increased fat, protein and fiber content. However, the values obtained in this study are appreciably high which suggested that the sample formulations contributed positively to the carbohydrate content of the end product (biscuit samples). Carbohydrates in the biscuits would provide readily available glucose for energy production to meet the high activity level of children and adolescents. As many children go to school most times without breakfast, biscuits prepared from whole tigernut and unripe banana flour blends would be of immense help in furnishing these children with glucose and other nutrients to enhance brain work and sustenance for academic activities.

Dietary Fibre Profile of Composite Biscuit Samples

Table 5 presents dietary fibre profile of biscuit samples baked with different levels of whole tigernut flours and unripe banana flour. Insoluble dietary fibre ranged from 1.95 to 11.72%, soluble dietary fibre ranged from 0.57 to 8.65% and total dietary fibre ranged from 2.52 to 19.47% respectively. Dietary fibre of control sample was significantly ($p<0.05$) lower than the composite samples. TF100 (100% whole tigernut biscuit) had higher dietary fibre profile (insoluble, soluble and total dietary fibre) than UBF100 (unripe banana flour biscuit) and WF100 (100% wheat flour biscuit). Consequently, in each of the biscuit samples, insoluble fibre content was higher than the soluble fibre content. More so, dietary fibre profile decreased significantly ($p<0.05$) with increasing addition of unripe banana flour and increased in biscuit samples containing higher amount of whole tigernut flour. Insoluble, soluble and total dietary fibre content decreased respectively from 11.72 to 10.61%, 7.75 to 7.56% and 19.47 to 18.17% when the level of unripe banana flour substitution increased from 10 to 30% and whole tigernut flour decreased from 100% to 70%. The values obtained in this study were close to 13.26 to 36.74%, 8.43 to 26.87% and 4.83 to 9.87% reported by (Arun *et al.,* 2015) for total, insoluble and soluble dietary fibres, respectively of functional cookies developed from plantain peel flour as a potential source of antioxidant dietary fibre. The total dietary fibre of the samples were within the recommended limit (0.53–2.50%) per day per person and may be beneficial towards enhancing the dietary fibre of other foods or by aiding in the formulation of diets for people with diabetes and other health-conscious individuals. Insoluble dietary fibers are unable to digest and are poorly metabolized in the small intestine (Englyst *et al.,* 2007). They have passive holding characteristics that can reduce the risk of constipation, diverticular disease and haemorrhoids (Anderson and Clydesdale, 1980). Soluble dietary fibre develops gel forming characteristics during digestion which slows down the food as digestion takes place and this contributes to many health benefits such as postprandial blood glucose, serum cholesterol and insulin levels (Jenkins *et al.,* 2000). Thus, substitution of wheat flour with whole tigernut flour and banana flour improved the dietary fibre profile of biscuit samples for healthier nutrition.

Table 5: Dietary Fibre Composition (%) of Composite Biscuits Samples

Samples	Insoluble Dietary Fibre	Soluble Dietary Fibre	Total Dietary Fibre
WF100	1.95^{f}±0.01	0.57^{f}±0.01	2.52^{f}±0.01
TF100	11.17^{c}±0.01	8.65^{a}±0.01	19.82^{a}±0.01
UBF100	9.41^{e}±0.01	6.69^{e}±0.01	16.10^{e}±0.02
TF90	11.72^{a}±0.04	7.75^{b}±0.01	19.47^{b}±0.05
TF80	11.49^{b}±0.01	7.72^{c}±0.01	19.21^{c}±0.01
TF70	10.61^{d}±0.01	7.56^{d}±0.02	18.17^{d}±0.04

Values are means ± s.d of triplicate determination. Mean value in the same column but with different superscript (a-f) are significantly different (P<0.05). WF100: 100% wheat flour biscuit. TF100: 100% whole tigernut flour biscuit: UBF100: 100% unripe banana flour biscuit. TF90: 90% whole tigernut flour/10% unripe banana flour biscuit. TF80: 80% whole tigernut flour/20% unripe banana flour biscuit. TF70: 70% whole tigernut flour/30% unripe banana flour biscuit

Mineral Contents of Composite Biscuit Samples

Effect of blending whole tigernut flour and unripe banana flour on the mineral content of biscuit samples is presented in Table 6. Production of biscuit from whole tigernut flour and unripe banana flour significantly (p<0.05) improved the mineral (potassium, iron, calcium, magnesium and sodium) content of the samples. Control sample (WF100) had lower mineral content compared to composite samples. Mohammed et al. (2018) reported that tigernut tubers contain magnesium (Mg) (118.14 mg/100 g), potassium (K) (267.18 mg/100 g), phosphorus (P) (158.86 mg/100 g), calcium (Ca) (43.36 mg/100 g), sodium (Na) (17.02 mg/100 g), copper (Cu) (0.54 mg/100 g), Iron (Fe) (2.82 mg/100 g) and zinc (Zn) (1.39 mg/100 g). Ani *et al.* (2021) reported a value of 1.776 mg/kg, 13.985 mg/kg, 8.151 mg/kg, 956.38 mg/kg, 4478.76 mg/kg and 33.97 mg/kg for calcium, magnesium, manganese, sodium, potassium and phosphorous, respectively. The inclusion of micronutrients-rich tigernut tubers seemed to contribute to the improvement in the mineral contents of the biscuits.

Table 6: Mineral Contents (mg/100 g) of Composite Biscuits

Samples	Potassium	Iron	Calcium	Magnesium	Sodium
WF100	139.16^{f}±0.01	1.32^{e}±0.01	18.94^{f}±0.11	13.11^{f}±0.11	67.18^{a}±0.07
TF100	218.75^{a}±4.17	0.64^{f}±0.02	159.56^{a}±0.08	53.73^{e}±0.11	19.35^{e}±0.07
UBF100	150.82^{e}±0.03	12.68^{a}±0.01	120.64^{e}±0.06	125.79^{a}±0.01	22.60^{c}±0.28
TF90	206.72^{b}±0.03	9.74^{c}±0.01	142.70^{b}±0.14	116.80^{d}±0.01	20.80^{d}±0.04
TF80	193.75^{c}±0.01	9.65^{d}±0.01	130.44^{c}±0.02	119.43^{c}±0.04	22.60^{c}±0.08
TF70	185.81^{d}±0.01	10.71^{b}±0.01	124.20^{d}±0.84	121.41^{b}±0.01	23.55^{b}±0.07

Values are means ± s.d of triplicate determination. Mean value in the same column but with different superscript (a-f) are significantly different (P<0.05). WF100: 100% wheat flour biscuit. TF100: 100% whole tigernut flour biscuit: UBF100: 100% unripe banana flour biscuit. TF90: 90% whole tigernut flour/10% unripe banana flour biscuit. TF80: 80% whole tigernut flour/20% unripe banana flour biscuit. TF70: 70% whole tigernut flour/30% unripe banana flour biscuit

Potassium Content

Potassium is necessary for the normal functioning of all cells. It regulates the heartbeat, ensures proper function of the muscles and nerves. However excessive intake of potassium may upset homeostatic balance and cause toxic side effects (Parr *et al.,* 2012). Shaista *et al.* (2017) reported that potassium plays a key role in skeletal and smooth muscle contraction. The potassium content of the samples ranged from 139.16 to 218.75 mg/100 g. TF100 (whole tigernut biscuit) had the highest potassium content than UBF100 (unripe banana biscuit) and decreased in composite biscuit containing higher amount of unripe banana flour. However, potassium contents of composite biscuits exceeded the value of wheat flour biscuit (control). Hence, production of biscuit from whole tigernut and unripe banana flour improves the potassium content of the end product. The values obtained in this study were higher than 114 to 126.50 mg/100 g reported by Kwaghsende *et al.* (2019) for biscuits produced from wheat-tiger nut composite flour. These results were also higher than the 61.90 to 92.84 mg/100 g reported by Florence *et al*. (2018) for biscuits produced from yellow yam, unripe plantain and pumpkin seed flour blends, and 61.90 – 92.84 mg/100 g for cookies from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends. Potassium content was higher than sodium content in the biscuits, and might be indicative of low hypertension risks following the consumption of such biscuits (Charles *et al.,* 2015).

Iron Content

The iron content of biscuit samples ranged from 1.32 to 12.68 mg/100 g. The reference sample (100% wheat flour biscuit) had the lowest iron value (1.32 mg/100 g) which implied that the development of composite biscuits from whole tigernut flour and unripe banana flour significantly improved the iron content of the final product. However, the iron content obtained in this study satisfied the recommended daily intake for infants and children (5.90 to 6.20 mg/day), adolescent male (9.70 to 12.50 mg/day) and adult male (9.10 mg/day) suggesting that the biscuits may contribute significantly to the dietary iron needs of the body but was below the limit for adolescent female (9.30 to 20.70 mg/day) and adult female (19.60 mg/day) respectively (FAO/WHO, 1998). With reference to previous studies, iron content of biscuit samples in this study was higher than 1.05 to 1.44 mg/100 g reported by Kwaghsende *et al.* (2019) for biscuit produced from wheat-tiger nut composite flour, 0.88 to 1.16 mg/100 g reported by Akujobi (2018) for biscuits produced from cocoyam and tigernut flour blends, 1.57 – 2.52 mg/100 g reported by Florence *et al.* (2020) for cookies from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends and 0.67-4.78 mg/100 g reported by Chinma *et al. (*2012) for biscuits produced from unripe plantain and sesame flour blends.

Calcium Content

Calcium content ranged from 18.94 to 159.56 mg/100 g. TF100 (100% tigernut flour biscuit) had the highest value but WF100 had the lowest value. Whole tigernut biscuit and unripe banana biscuit had high calcium content which account for the high calcium content of composite biscuits, although TF100 had higher calcium content than UBF100. Calcium content decreased with increased proportion of unripe banana flour in the biscuit samples. Calcium is necessary for growth and helps in calcification of strong bones for optimal growth and development (Parr *et al.,* 2012). The values obtained are below the FAO/WHO recommended daily intake for calcium of different target consumers such as infants and children of 0 to 9 years (300 to 700 mg/day), adolescents of 10 to 18 years (1300 mg/day), adults of 19+ years (1000 to 1300 mg/day), pregnant women (1200 mg/day) and lactating women (1000 mg/day) (FAO/WHO, 1998). Calcium promotes contraction of the muscles and assists in blood clotting. Its increase in composite biscuits, although, below the FAO/WHO recommended daily intake might possibly contribute to the calcium needs of the body. Kwaghsende *et al.* (2019) reported corresponding calcium of 117.50 to 130.50 mg/100 g for biscuit from wheat-tiger nut composite flour, while Florence *et al.* (2020) reported lower values of 3.28 to 8.25 mg/100 g compared to the values obtained in the present study.

Magnesium content

Magnesium content ranged from 13.11 to 125.79 mg/100 g with significant ($p<0.05$) existing among the samples. UBF100 had the highest content which influenced positively the magnesium content of composite biscuit samples. Magnesium is an essential component of all cells and is necessary for the functioning of enzymes involved in energy utilization and it is present in the bone (Ayuk *et al.,* 2019). The magnesium content of the composite biscuits increased progressively with increased amount of unripe banana flour. The values obtained are within the recommended intake for infants and children (26 to 100 mg/day) but lower than recommended limit for adolescents (230 mg/day for females and 220 mg/day for males) and adults (220 mg/day for females and 260 mg/day for males) (FAO/WHO, 1998). Consequently, magnesium content of the samples may not be adequate to meet the needs of magnesium in the body except for infants and children. Florence *et al.* (2020) and Akujobi (2018) reported lower values of 1.98 – 4.56 mg/100 g for biscuits from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends and 7.22-9.56 mg/100 g for biscuits produced from cocoyam and tigernut flour blends respectively compared to this study.

Sodium Content

Sodium is an important electrolyte in every living cell, essential in balancing of fluid and muscle contraction in the body. However, excess sodium in the cell induces hypertensive condition in the cells (Charles *et al*., 2015). Sodium content ranged from 19.35 to 67.18 mg/100 g. Composite samples had lower sodium contents than the control sample. Florence *et al.* (2020) reported higher values for sodium 123.90-184.86 mg/100 g than the values obtained in this study.

Physical Properties of Composite Biscuit Samples

Physical properties of whole tigernut-unripe banana composite biscuit samples are shown in Table 7.

Table 7: Physical Properties of Composite Biscuit Samples

Samples	Spread ratio	Weight (g)	Diameter (mm)	Height (cm)	Break strength (g)
WF100	$6.55^{f}\pm0.34$	$17.41^{a}\pm0.04$	$20.81^{e}\pm0.06$	$1.65^{a}\pm0.02$	$185.76^{b}\pm0.78$
TF100	$7.69^{a}\pm0.01$	$14.24^{e}\pm0.02$	$21.03^{c}\pm0.81$	$1.00^{b}\pm0.01$	$172.70^{c}\pm0.14$
UBF100	$6.95^{e}\pm0.01$	$15.53^{c}\pm0.01$	$20.59^{f}\pm0.01$	$0.95^{b}\pm0.01$	$175.50^{c}\pm0.14$
TF90	$7.41^{b}\pm0.01$	$14.98^{e}\pm0.01$	$20.88^{d}\pm0.01$	$0.94^{b}\pm0.02$	$177.81^{c}\pm0.01$
TF80	$7.18^{c}\pm0.04$	$15.19^{d}\pm0.02$	$21.23^{b}\pm0.31$	$0.97^{b}\pm0.01$	$185.70^{b}\pm0.14$
TF70	$7.10^{d}\pm0.01$	$15.94^{b}\pm0.02$	$21.85^{a}\pm0.42$	$0.99^{b}\pm0.02$	$191.60^{a}\pm0.14$

Values are means ± s.d of triplicate determination. Mean value in the same column but with different superscript (a-f) are significantly different ($P<0.05$). WF100: 100% wheat flour biscuit. TF100: 100% whole tigernut flour biscuit: UBF100: 100% unripe banana flour biscuit. TF90: 90% whole tigernut flour/10% unripe banana flour biscuit. TF80: 80% whole tigernut flour/20% unripe banana flour biscuit. TF70: 70% whole tigernut flour/30% unripe banana flour biscuit

Spread Ratio

Experimental biscuit samples had significantly higher spread ratio compared to the control sample (WF100). Spread ratio ranged from 6.55 to 7.69 with significant ($p<0.05$) different among the samples. Biscuits produced from whole tigernut flour (TF100) had higher spread ration than those produced from unripe banana flour (UBF100), which in turn reduced the spread ratio of composite biscuits as the amount of unripe banana flour reduced in the composite formulation. The values obtained in this study were higher than 1.95 to 7.70 reported by (Pooja *et al.,* 2018) for cookies made using avocado as a fat (Butter) substitute, 4.75 to 7.50 reported by (Adedeji *et al.,* 2014) for biscuit produced from wheat-tiger nut composite flour, 5.20 to 5.93 reported by (Ayo *et al.,* 2018) for Acha-tigernut composite biscuits as well as 5.42 to 6.55 reported by (Arun *et al.,* 2015) for functional cookies developed from plantain peel flour as a potential source of antioxidant dietary fibre, while (Florence *et al.,* 2018) reported higher value of 9.40 to 11.00 for biscuits produced from mixture of tiger nut flour, milk permeate and soft wheat flour. Spread ratio is an indicator of binding properties and texture. Higher spread ratios are desirable in biscuits. Reduction in spread ratio has been attributed to hydrophilic nature of flours used in the production of biscuits (Ayo *et al.,* 2007). Decreased spread ratio as unripe banana flour increased and whole tigernut flour substitution increased could be due to decreased fibre content of unripe banana flour, which could increase the viscosity of the dough prior to baking. Hoseney and Rogers (1994) reported that spread ratio increases with increase fibre content in biscuits but in the present study, unripe banana flour with reduced fibre content (Table 4) decreased the fibre content of the composite biscuit and increased the viscosity hence, decreased spread ratio. Dough with lower viscosity cause biscuits to spread at faster rate and vice versa (Hoseney and Rogers, 1994)

Weight
The weight of the biscuit samples ranged from 14.24 to 17.41 g. Biscuit produced from wheat flour (WF100) had higher weight than biscuits produced from whole tigernut flour (TF100) and unripe banana flour (UBF100) which may be due to structural density arising from gluten structural network compactness. Also, UBF100 had higher weight than TF100 which may be due to the higher fiber content of TF100 that results to higher porosity and subsequently, lesser weight. Increasing the quantity of unripe banana flour in the formulation from 10% to 30%, increased the weight of the final product (composite biscuits) progressively. The values for weight obtained in this study corresponds with 13.73 to 19.03 g reported by Kwaghsende *et al.* (2019) for biscuits produced from wheat-tigernut composite flour, and 16.25 to 20.37 g reported by (Pooja *et al.,* 2018) for cookies made using avocado as a fat (Butter) substitute. Moustaf *et al*. (2020) and Florence *et al*. (2018) reported lower weight of 8.40 to 9.12 g and 6.42 to 8.33 g for biscuits produced from mixture of tiger nut flour, milk permeate and soft wheat flour and biscuits produced from yellow yam, unripe plantain and pumpkin seed flour blends, respectively.

Diameter
Diameter ranged from 20.59 to 21.85 mm, and was significantly ($p<0.05$) different from each other. TF100 (100% tigernut biscuit) had higher diameter than UBF100 (100% unripe banana biscuit) and WF100 (100% wheat flour biscuit). Notably, composite biscuits had larger diameter than biscuits produced from individual flours. This may be due to lack of strong structural network influenced by gluten in the composite flour, leading to weak cohesion of ingredients and subsequently wider spread. These results are below 37.27 to 39.33 mm reported by Florence *et al.* (2018) for biscuits produced from wheat flour, yellow yam flour and blends of yellow yam, plantain and pumpkin seed flours, but higher than 5.67 to 8.50 mm for biscuits produced from wheat-tiger nut composite flour. Again, the values obtained in this study are lower than 41.86 to 65.76 mm reported by Pooja *et al.* (2018) for cookies made using avocado as a fat (Butter) substitute. Similarly, Moustaf *et al.* (2020) reported higher diameter of 53.00 to 55.60 mm for biscuits produced from a mixture of tiger nut flour, milk permeate and soft wheat flour compared to results of this study. The variations in diameter of the biscuit samples may be attributed to differences in raw material, recipe as well as the methods used in processing the composites and producing biscuits.

Height
The height differed significantly ($p<0.05$) among the samples. Height ranged from 0.94 to 1.65 cm. Control sample (WF00) had higher height (1.65 cm) than composite samples which may be attributed to the gluten present in wheat and its effect in rising the dough prior and during baking, resulting to higher height. Height of composite samples were not significantly ($p>0.05$) from each other because of absence of any significant rising of the dough, hence, the similar height in all experimental samples. The values obtained in this study for height was similar to height of 9.01 to 16.02 mm (0.91cm to 1.60 cm) reported by Pooja *et al*. (2018).

Break Strength
The break strength of control sample was 185.15 g, break strength of biscuits baked with 100% whole tigernut flour (TF100) was 172.70 g, while biscuit baked with unripe banana flour (UBF100) had a break strength of 175.50 g. This indicates that the break strength of control sample was higher than biscuit samples baked whole tigernut and unripe banana flour, but lower than composite biscuits with a range of 177.81 to 191.60 g. In the composite biscuits, break strength increased progressively as the level of unripe banana flour substitution increased. TF100 (whole tigernut flour) had the lowest break strength. This could be caused by the increase in the fibre content resulting in weakening of the bond between the carbohydrate-carbohydrate and carbohydrate-protein molecules (Dhingra and Jood, 2002). However, composite biscuits had higher break strength which may be attributed to the increased starch content of unripe banana flour that increased progressively in the blends, resulting to improve rigidity. Arun *et al.* (2015) reported lower break strength of 53.67 to 68.11 g for functional cookies developed from plantain peel flour as a potential source of antioxidant dietary fibre than the values obtained in this study, while Ayo *et al*. (2018) reported higher break strength of 320 to 570 g for Acha-tigernut composite biscuits.

CONCLUSION
In the present study, fibre-rich biscuit was successfully produced fron blends of whole tigernut flour and unripe banana flour. In comparison to biscuit produced from 100% whole wheat flour, the experimental biscuit samples had better proximate composition, highly rich dietary fibre profile and improved mineral content which indicated superior nutritional quality. The improved dietary profile of the composite biscuit satisfies the aim of this research. This product will therefore be beneficial by helping in bowel movement, lowering blood cholesterol, and reducing the risk of colon cancer. Generally, fibre-rich biscuit produced from 90% whole tigernut flour / 10% unripe banana flour had the best properties. However, advanced study should be carried out on the amino acid profile, storage stability, glycemic index profile, and quality optimization with the intent of improving quality and indigenous crop utilization.

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