Functional, Nutritional and Sensory Characteristics of Biscuits Improved with Plantain, Breadfruit and Termite Flour

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ABSTRACT

Background: *High cost of wheat flour in non-wheat producing countries poses an economic problem.*

Objectives: *The potentials of plantain, breadfruit and termite in biscuit making as well as the nutritional and sensory characteristics of the processed biscuits were investigated.*

Methods: *The food crops and termite were processed into flour and the functional properties determined. The flours were combined in different proportions to obtain composite flours; (40% wheat, 30% breadfruit & 30% plantain), (40% wheat, 30% breadfruit & 30% termite), (40% wheat, 30% plantain & 30% termite) and (30% breadfruit, 40% plantain & 30% termite). Commercial wheat flour was used as control. Biscuits were baked using the composite flours and evaluated for nutrient composition and sensory attributes. Data were analyzed using Statistical Package for Social Sciences, version 21. Significance was accepted at* $p < 0.05$.

Results: *The biscuit made with only commercial wheat was significantly (*$p < 0.05$*) low in protein (6.24%) and fat (20.01%) content. Biscuits processed from composite flours had significantly (*$p < 0.05$*) high amount of folate and vitamin* B_6 *compared to the control. Sensory characteristics of biscuits made with blends of wheat, breadfruit and plantain flours were comparable to the control.*

Conclusion: *Highly nutritious and low cost biscuits could be produced by incorporating plantain, breadfruit and termite into wheat flour.*

Keywords: Biscuit, Termite, Insects, Breadfruit, Plantain

INTRODUCTION

Biscuits are nutritive snacks produced from unpalatable dough that is transformed into appetizing product through the application of heat in an oven (1). Biscuits are widely consumed by children among other snacks as they form one of the essential products in their school lunch boxes. This is due to their nature as they are ready-to-eat, convenient and inexpensive. They are rich sources of protein, fat, carbohydrate and minerals (1). The principal ingredients in biscuits are flour, fat, sugar and water; while other ingredients such as milk, salt, flavouring agent are optional. Wheat flour is commonly used in baking than any other cereal because of the quality and quantity of its characteristic protein called gluten. Research has shown that composite flour has advantage of improving the nutrient value of baked products (2-4). However the acceptability of such food products mostly depends on the ratio of flour mixture. Nwanekezi (5) suggested the ratio of 50:50 wheat to non-wheat flour mixture for production of good quality biscuit and other bakery products. Addition of non-wheat flour in baked products not only makes them nutritious but also cheap and affordable to the rural poor hence could be of importance in eradicating hunger and malnutrition.

Breadfruit (*Treculia africana*) is a member of Moraceae family. The geographical distribution of *Treculia africana* extends through West and

Central Africa. Breadfruit is cultivated primarily for its delicious seeds. It is highly nutritious, cheap and readily available in overwhelming abundance during its season however, its application in the food industry is limited. Plantain (*Musa paradisiaca*) is the common name for herbaceous plant of genus Musa. It is an important staple food in Central and West Africa. Plantain is a basic food crop and cheap source of energy. An average plantain finger has about 220 calories and is a good source of potassium and dietary fibre (6). Nigeria produces up to 2.4 million metric tons of plantain annually (7), but inappropriate technologies for food processing and lack of storage facilities result to 35-60% post-harvest losses (8).

Termites (*Macrotermes nigeriensis*) are eaten as delicacy and used as traditional medicine in many African countries. There are many species of termites (*M. nigeriensis, M. notalensis, M. subhylanus*, or *M. bellicosus*) commonly regarded as winged termites, termites or *Macrotermes* species. Edible termites contribute to the nutritional need of the people in time of scarcity (planting season) and are regarded as cheap source of protein. Research findings have revealed that termite contains protein (33.51–39.74 g/100g), fat (44.82– 47.31 g/100g), iron (53.33–115.97mg/100g), and zinc (7.10–12.86 mg/100g) (9). Obviously, termites are particularly important in less developed countries where malnutrition is common, as they could help in improving nutritional health.

High cost of wheat flour in non-wheat producing countries poses an economic problem to the countries, bakery industries and consumers. It is well established that no other crop can achieve the baking properties of wheat however, composite flour is still receiving considerable attention in food industries. The use of composite flour in developing countries have the advantages of saving cost, promoting high-yielding native plant species, supplying nutritious food products and eradicating malnutrition. This presents the need to further study the potentials of indigenous and available food sources in baking to possibly improve nutritional health. There is dearth of information on the biscuit making potentials of composite flour formulated with termite, breadfruit and plantain. Providing such information will increase utilization of these indigenous food crops and termite, at the same time reduce the economic cost of importing wheat for non-wheat producing countries thus, the need for this study.

Materials and methods

Procurement of samples

Commercial wheat flour (all purpose), fresh unripe plantain, mature breadfruit seeds and other ingredients for biscuit making were purchased from *Ogige* Main Market in Nsukka, Enugu State, Nigeria. Winged termites were collected fresh from the field during their nuptial flight at the University of Nigeria, Nsukka (UNN).

Preparation of the samples

The plantain fingers at stage 2 of ripeness (10) were washed, peeled, sliced into round shapes of 5mm thick, blanched (in boiling water for 15min), sun-dried for 96h (during dry season) and milled into flour using Attrition Mill (Globe P 44, China). Breadfruit seeds were washed, sun-dried for 72h (during dry season), sorted and milled into flour using Attrition Mill. Live termites were washed, drained, solar dried with crop solar dryer of 26^{0}C to moisture content below 10%. They were subsequently stripped of their wings using a draft blower, and milled using Corona dry grain manual grinder.

Formulation of composite flours

Wheat-breadfruit-plantain composite (WBP) in the ratio of 40:30:30; wheat-breadfruit-termite flour (WBT) in the ratio of 40:30:30; wheat-plantain-termite flour (WPT) in the ratio of 40:30:30; and breadfruit-plantain-termite flour (BPT) in the ratio of 30:40:30. The control sample was 100% wheat flour (WF). The flours were mixed using a B8 universal spiral mixer at 450 rpm for 20min until uniform blends were obtained.

Recipe for composite biscuit making

The biscuit samples were processed using a standardized recipe from preliminary experiment. The recipe had ingredients as 500g flour, 300g butter, 80g egg, 100g milk, 20g sugar, and 10g baking powder. All ingredients were measured and the right proportions of the flours incorporated to form composite flour. The butter and sugar were creamed together in a large bowel until fluffy before each composite flour, milk, and baking powder were added. The eggs were whisked and added to the flour mixture and the mixture was gradually worked on for about 30min until it forms dough. The dough was rolled on a flat wooden surface and kneaded lightly for 5min to evenly spread the dough. A manual biscuit cutter was used to cut the dough into same sizes and shapes. The cut dough was arranged on greased trays and baked in a pre-heated oven at 140°C for 30min. After baking, the biscuits were allowed to cool to room temperature (25°C) for 15min before being packaged in polythene bags until further analysis.

Chemical analysis

Functional properties of the flour samples

The water and oil absorption capacity were determined by the method described by Okezie and Bello (11). Slightly modified methods of Onwuka (12) and Okaka and Potter (13) were adopted in determination of bulk density and swelling power, respectively. Determination of foaming capacity was as described by Narayana and Narasinga (14). The flour samples were analyzed for viscosity following the procedures described in Onwuka (12). Solubility index of the flour samples was determined according to the method of Leach *et al*. (15).

Proximate Analysis

The proximate composition of the samples was analyzed using AOAC (16) methods. Moisture content was determined by air oven method, protein content was determined using micro-Kjeldahl method while Soxhlet extraction method was used to determine fat. Ash was obtained by weighing 5g of charred sample into a tarred porcelain crucible then incinerated at 600°C for 6h in ash muffle furnace until ash was obtained. Crude fibre was determined by exhaustive extraction of soluble substances in a sample using H_2SO_4 and NaOH solution, after the residue was ashed and the loss in weight recorded as crude fibre. Total carbohydrate content was determined by difference.

Vitamin and mineral analysis

Vitamin A was determined using the method adopted from IVACG (17). Thiamin, pyridoxine and folate were quantitatively determined using AOAC method (16). Sodium was determined using Uranyl zinc acetate method (18), calcium was determined using Differential spectrophotometric method (19), and magnesium was determined using the titan yellow method (20). Zinc analysis was done using dithizonemicellar solution method (21) and iron was determined using atomic absorption spectrophotometer (22).

Sensory Evaluation

Sensory evaluation was conducted in the Diet Therapy Laboratory of the Department of Nutrition and Dietetics, UNN. Thirty panelists consisting of staff and final-year students of the Department of Nutrition and Dietetics, UNN were selected based on their experience through participation in similar works. The biscuit samples were evaluated for colour, taste, texture, flavor and general acceptability using a 9 point hedonic scale (23). The samples were coded and placed in flat plates with plain white background. The samples were presented to the panelists in random position. They were provided with drinking water and instructed to rinse their mouth between evaluations to avoid carryover effect.

Statistical Analysis

Data was analyzed statistically using Statistical Package for Social Sciences, version 23. Data were subjected to a one-way analysis of variance. Means were separated with least significant difference test and significance was accepted at $p < 0.05$.

Results

Breadfruit flour had the highest water absorption capacity (3.50g/g) followed by plantain (2.60g/g) and wheat (2.58g/g) flours (Table 1). Termite flour had the least water absorption capacity (1.63g/g). The solubility index of the flour ranged from 0.06 (termite flour) to 0.11g/g (breadfruit flour). There was statistical difference in the swelling and foaming capacity of the samples with wheat flour having the highest values of 1.79ml and 25%, respectively.

Table 1: Functional properties of wheat, breadfruit, plantain and termite flour

Functional properties	Wheat flour	Breadfruit flour	Plantain flour	Termite flour
Solubility index (g/g)	0.10 ± 0.01^{b}	0.11 ± 0.01^{b}	0.14 ± 0.02^{c}	0.06 ± 0.01^{a}
Viscosity (Pa.s)	1.37 ± 0.26^{b}	1.03 ± 0.02^{a}	1.06 ± 0.01^{a}	0.97 ± 0.02^{a}
Swelling power (ml)	1.79 ± 0.07^{d}	0.05 ± 0.01^{a}	1.37 ± 0.06^{c}	1.07 ± 0.12^{b}
Bulk density (g/ml)	0.80 ± 0.01^{c}	0.64 ± 0.04^{b}	0.60 ± 0.06^{b}	0.54 ± 0.00^{a}
Foam capacity (%)	25.00 ± 0.00^{d}	4.90 ± 0.00^{b}	16.55 ± 0.38^{c}	2.00 ± 0.00^{a}
Water absorption capacity (g/g)	2.58 ± 0.02^{b}	3.50 ± 0.05^{c}	2.60 ± 0.05^{b}	1.63 ± 0.05^{a}
Oil absorption capacity (g/g)	2.86 ± 24.83^{b}	3.50 ± 0.00^{d}	3.20 ± 0.00^{c}	2.53 ± 0.05^{a}

Values are Means ± SD (standard deviation) of triplicate determinations. Means on the same row with different superscripts are significantly different at $p<0.05$

Table 2: Proximate composition (%) of wheat based biscuit improved with breadfruit, plantain and termite

Biscuit samples	Moisture	Ash	Protein	Crude fibre	Crude fat	Carbohydrate
WF	7.07 ± 1.01^{b}	2.00 ± 0.00^{ab}	6.24 ± 0.29^{a}	10.99 ± 1.14^{d}	20.01 ± 1.14^{a}	53.69 ± 2.18^{e}
WBP	7.67 ± 0.31^{b}	2.13 ± 0.31^{bc}	10.05 ± 1.16^{b}	16.23 ± 0.12^{e}	25.96 ± 1.29^{b}	37.96 ± 2.53^{b}
WBT	3.47 ± 0.31^{a}	2.47 ± 0.23^{bc}	38.32 ± 1.08^{d}	7.47 ± 0.12^{c}	22.96 ± 0.68^{ab}	25.31 ± 1.05^{a}
WPT	3.80 ± 0.53^{a}	2.53 ± 0.12^{c}	16.12 ± 0.53^{c}	4.17 ± 0.31^{b}	29.95 ± 1.04^{c}	43.43 ± 0.64^{c}
BPT	7.00 ± 0.80^{b}	1.53 ± 0.12^{a}	17.97 ± 1.06^{c}	2.16 ± 0.20^{a}	22.78 ± 1.78^{ab}	48.56 ± 1.49^{d}

Values are Means ± SD of triplicate determinations. Means on the same column with different superscripts are significantly different at $p<0.05$
WF= Control sample (100% wheat flour)
WBP = 40% wheat, 30% breadfruit & 30% plantain blend
WBT= 40% wheat, 30% breadfruit & 30% termite blend
WPT= 40% wheat, 30% plantain & 30% termite blend
BPT = 30% breadfruit, 40% plantain & 30% termite blend

Protein content of the biscuit samples ranged from 6.24-38.32% with the control (WF) having the least protein content (6.24%) while the carbohydrate content of the samples ranged from 25.31-53.69% (Table 2). The crude fibre content varied significantly among the samples with WBP (16.23%) as the highest followed by WF (10.99%).

The WBT and BPT had high vitamin A content (Table 3). The thiamin content of the composite biscuit showed no significant difference when compared to the WF except for BPT which had the highest value of 7.00mg.

Table 3: Vitamin composition (per 100 g) of wheat based biscuit improved with breadfruit, plantain and termite

Samples	Thiamin (mg)	Vit. A (µg)	Folate (mg)	Vitamin B_6 (mg)
WF	2.27±0.95[a]	5.65±0.50[a]	3.93±0.23[a]	0.40±0.00[a]
WBP	1.42±0.50[a]	4.26±0.11[a]	5.33±0.51[b]	0.73±0.12[b]
WBT	2.40±0.53[a]	66.89±5.91[c]	5.27±0.31[b]	0.67±0.12[ab]
WPT	2.40±0.53[a]	40.57±0.36[b]	6.40±0.40[b]	0.73±0.12[b]
BPT	7.00±2.18[b]	47.21±1.60[c]	2.27±0.76[c]	0.87±0.12[b]

Values are Means ± SD of triplicate determinations. Means on the same column with different superscripts are significantly different at $p<0.05$
WF = Control sample (100% wheat flour)
WBP = 40% wheat, 30% breadfruit & 30% plantain blend
WBT= 40% wheat, 30% breadfruit & 30% termite blend
WPT= 40% wheat, 30% plantain & 30% termite blend
BPT= 30% breadfruit, 40% plantain & 30% termite blend

Table 4: Mineral composition (per 100 g) of wheat based biscuit improved with breadfruit, plantain and termite

Samples	Iron (mg)	Calcium(mg)	Magnesium(mg)	Zinc (mg)	Sodium (mg)
WF	3.83±0.41[b]	61.17±5.80[a]	19.36±0.42[b]	32.12±0.34[c]	19.73±1.16[a]
WBP	4.32±0.11[b]	59.37±2.37[a]	20.40±1.18[b]	8.67±0.66[a]	26.51±2.13[b]
WBT	5.12±0.14[c]	61.71±6.17[a]	19.47±0.3b[b]	18.36±2.64[b]	25.68±0.48[b]
WPT	5.43±0.36[c]	59.57±2.87[a]	17.52±0.21[b]	16.44±0.76[b]	24.48±2.12[b]
BPT	2.61±0.21[a]	66.52±2.17[a]	15.60±0.26[a]	15.77±2.13[a]	23.79±0.80[b]

Values are Means ± SD of triplicate determinations. Means on the same column with different superscripts are significantly different at $p<0.05$
WF = Control sample (100% wheat flour)
WBP = 40% wheat, 30% breadfruit & 30% plantain blend
WBT = 40% wheat, 30% breadfruit & 30% termite blend
WPT = 40% wheat, 30% plantain & 30% termite blend
BPT = 30% breadfruit, 40% plantain & 30% termite blend

The WBT and BPT had high vitamin A content (Table 3). The thiamin content of the composite biscuit showed no significant difference when compared to the WF except for BPT which had the highest value of 7.00mg.

The sodium contents of the samples were similar except for the control which had the least value, 19.73mg/100g (Table 4). No significant difference was recorded in the calcium content of the biscuit samples. The lowest value of iron and magnesium was observed in BPT sample.

Table 5: Hedonic score for sensory evaluation of wheat based biscuit improved with breadfruit, plantain and termite

Samples	Colour	Flavor	Texture	Taste	General acceptability
WF	8.57 ± 0.77^{b}	7.66 ± 1.77^{c}	7.79 ± 1.29^{c}	7.67 ± 1.26^{d}	8.45 ± 1.06^{d}
WBP	7.63 ± 1.45^{b}	6.27 ± 1.53^{ab}	6.77 ± 1.19^{bc}	6.63 ± 1.65^{c}	7.09 ± 2.13^{c}
WBT	6.13 ± 1.70^{a}	5.0 ± 1.97^{a}	5.67 ± 1.77^{b}	5.70 ± 2.29^{bc}	6.79 ± 1.89^{c}
WPT	5.83 ± 1.95^{a}	4.53 ± 2.15^{a}	5.70 ± 1.91^{b}	5.23 ± 2.10^{b}	5.16 ± 2.05^{b}
BPT	5.20 ± 2.02^{a}	4.03 ± 2.09^{a}	5.01 ± 1.97^{a}	3.33 ± 1.99^{a}	3.61 ± 1.52^{a}

Values are Mean (± standard deviation) score of 30 panelists.
Means on the same column with different superscripts are significantly different at $p<0.05$
WF= Control sample (100% wheat flour)
WBP= 40% wheat, 30% breadfruit & 30% plantain blend
WBT= 40% wheat, 30% breadfruit & 30% termite blend
WPT= 40% wheat, 30% plantain & 30% termite blend
BPT= 30% breadfruit, 40% plantain & 30% termite blend

The Hedonic score for sensory evaluation of the biscuit samples revealed that all the evaluated sensory attributes had the same pattern of score; WF > WBP > WBT > WPT > BPT (Table 5). No statistical difference was observed in the colour, texture and general acceptability of WF and WBP.

Discussion

The performance of flour in baking depends on the functionality properties which vary considerably among botanical species. The high water absorption capacity of the flour is an indication that the flour could be used in formulation of dough and bakery products, it also proves that the flour would be useful where good viscosity is required. Highest value of bulk density was recorded in wheat flour followed by breadfruit flour whose value was comparable to plantain flour. Bulk density is generally affected by the particle size and density of flour blends. The lesser the bulk density, the more the packaging space (24) hence, the low bulk density of the samples depicts that they require more packaging space. The low bulk density of the flours also showed that they could be used in formulating foods with less fear of retrogradation. Viscosity is associated with dough and hence affects the spread ratio of the final product. It is the state of being thick, sticky and semi-fluid in consistency. The viscosities of breadfruit, plantain and termite flour were not comparable with that of wheat flour. However plantain flour had value closer to wheat flour depicting that plantain flour could be a better substitute for wheat flour than termite and breadfruit flours in biscuit making.

Moisture contents of the biscuit samples made with breadfruit and plantain flours were high (Table 2). The high moisture content could be due to the combine effect of high water absorbing capacity of both flours. Samples WBT and WPT had low values for moisture content which implies that they have high keeping quality. Low moisture content decreases water activity and thus increases shelf life of baked products. According to Elleuch *et al*. (25), the relatively low moisture contents is an added advantage as it could improve keeping quality and reduce cost of post handling. Generally, the moisture contents of the biscuit samples were comparable with that reported by Agu *et al*. (26) on the quality characteristics of biscuits made from wheat and African breadfruit (*Treculia africana*).

The amount and type of protein in flour affect the properties of the final product. Low protein content allows for production of good quality products in biscuit making. Wheat flours are typically low in protein content and wheat storage protein has the unique ability to form gluten (27). The high protein content of WBT, WPT and BPT could be attributed to presence of termite. The protein value of termite ranges from 20.94% (28) to 39.74% (9). Higher protein intake is beneficial for various health outcomes, such as weight management, maintaining muscle mass, preventing osteoporosis, and reducing the risk of cardiovascular disease (29, 30). The protein content of the biscuit samples differs from that reported earlier (26, 31, 4) which ranged from 7.2-9.64%. Fat is an essential component of tissues and a veritable source of fat-soluble vitamins. The fat contents of the biscuits were observed to be generally high. In addition to the butter used, the high fat content could be attributed to the fat content (34.23%) of termite (28). The fat contents of the biscuit samples were comparable with that (21.51%) reported by Niaba *et al*. (31).

Ash is an indication of mineral contents of foods and has been shown to be high in composite flour-based food products such as biscuit (31). A food is said to be high in ash when it contains > 1% of ash (32). The biscuit samples had high ash content (1.53-2.53%), this was higher than biscuits made from wheat and African breadfruit and that made from wheat flour and malted barley brand blends as reported by Agu *et al*. (26) and Ikuomola *et al*. (33), respectively. The crude fibre content of the biscuits ranged from 2.16-16.23%. This was higher than crude fibre reported by other researchers; Agu *et al*. (34) reported crude fibre range of 2.08 - 3.56% from the blends of acha, unripe plantain and bambara nut. Nwosu (35) also reported low fibre content of 0.18-1.53% in biscuits made of wheat and bambara nut. Studies have shown the importance of fibre in glycemic control. The increased fibre content of the biscuits provides several health benefits, as it aids digestion in the colon and reduces constipation often associated with products from refined grain flours. The carbohydrate content of the biscuit samples was generally low compared to 67.36-71.47% obtained from biscuits made with acha, unripe plantain and bambara nut (34). The low carbohydrate content of composite biscuits (25.31–48.56%) compared to the control (53.69%) may be due to the added protein sources (breadfruit and termite).

The high vitamin A content of WBT and BPT may be due to incorporation of termite which contains about 7.67μg/100g of vitamin A (36). Vitamin A is important for normal vision and also helps the heart, lungs, kidney and other organs to function properly. Folate content ranged from 3.93 - 12.27 mg. The increase was observed with incorporation of plantain flour. According to USDA (37), plantain contains about 22 μg /100g of folate which supplies about 5.5% of Daily Recommended Folate Intake (38) for adults. The biscuit samples were good sources of thiamine, providing more than the daily adult requirement (0.2 mg/day) of thiamine (38).

The sodium content of the samples was higher than that reported by Onabanjo and Ighere(39), for biscuit produced from wheat and sweet potato composite. Sodium helps the body to maintain normal fluid balance and also play a key role in normal nerve and muscle function. Calcium contents of the biscuit samples were high, contributing 8.48% to 9.50% of the daily recommended nutrient intake of calcium for children (7–9yrs). Magnesium contents of the biscuit samples were also high (9.36-20.40mg/100), this provides about 9.36-20.40% of the daily recommended nutrient intake of magnesium for children (7–9yrs). The iron content differs from the study by Islamiyat and Adekanmi (4) who reported higher iron content of biscuits made from malted sorghum and soybean flours.

All the evaluated sensory attributes (Colour, flavor, texture, taste and general acceptability) had the same pattern of score; WF > WBP > WBT > WPT > BPT (Table 5). This depicts that people are more likely to consume sample WBP than other composite biscuits. Incorporation of termite flour affected the degree of likeness of the composite biscuits especially in flavor and taste. This might have led to the wide difference in their general acceptability. WBP was comparable to the sample in all the sensory attributes especially texture and colour. Colour is one major factor that determines the level of acceptance of aproduct as individuals tend to prefer familiar colours. Incorporation of termites resulted to dark colour, which might have contributed to the low rating in colour. The low sensory score and acceptability of composite biscuits that contain termite flour were as a result of the poor functional properties of termite flour as shown in Table 1. Functional properties of flours are important physico-chemical properties that have direct effect on the utilization and quality of products produced from them. Sample BPT was generally disliked in all the sensory attributes and this could be ascribed to the absence of wheat flour. The uniqueness of wheat flour in baking is mostly due to its storage protein which has the capacity to form a viscoelastic network called gluten. This study was able to establish that termite flour should be incorporated in lower ratio (< 30%) to minimize the negative effect on acceptability.

Conclusion

Incorporation of breadfruit, unripe plantain and termite improved the nutrient contents of wheat based biscuit. This study has shown that acceptable baked products (WBP and WBT) could be produced from blend of wheat, breadfruit, unripe plantain and termite. The improved products were good sources of protein, crude fibre, and carbohydrate and contained appreciable amount of micronutrients such as vitamins A, calcium, magnesium, sodium and zinc. Biscuit made with wheat, breadfruit and plantain flours (WBP) was more acceptable, while addition of termite flour reduced the level of acceptability.

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