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Quality Evaluation of Stiff Dough Produced from Unripe Plantain, Tiger Nut Residue, and Orange Fleshed Sweet Potatoes Blends

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Abstract - This research evaluated Stiff dough from unripe plantain flour, tigernut Unripe residue, and orange flesh sweet potato blend. The processed unripe plantain flour, tigernut residue flour and orange flesh sweet potato flour was blendedin varying proportion to obtain six different formulations.

All the formulation was done using completely randomized design, packaged and then analyzed. The analysis carried out includes; proximate composition of the samples, functional and sensory properties, the result from the statistical analysis showed that moisture content ranged; (8.00-10.56 %), ash (1.73-2.39 %), fibre (2.20-2.39%), fat (0.63-0.97 %), protein (1.17-4.92 %), carbohydrate (77.71-86.33 %) and energy (340.05-349.22. Functional properties of the sample ranged; WAC (2.95-4.00 %), OAC (0.91-0.91 %) bulk density (2.95-4.00g/ml), gelatinization temperature (71 -76 °C), dispersibility (63.21-69.63%) and swelling power (2.12-3.01 %). The sensory attributes of the samples ranged; colour (7.00-7.70), flavour (7.20-7.85), texture (6.70-8.40) and taste (7.45-7.80). To improve the nutritional composition, sensory properties and enhance the functional properties of stiff dough (swallow) from unripe plantain, tigernut residue and orange, it is recommended to investigate the shelf-life and storage conditions of the stiff dough (swallow) so as to increase its potential for marketability.

Keywords : plantain, Tigernut Residue, Orange fleshed sweet potato

1. INTRODUCTION

Malnutrition and micronutrient deficiency remain critical public health challenges in many developing countries, particularly in sub-Sahara Africa. Stiff dough meals commonly known as "swallow" foods, are staple components of many traditional African diets (Olorunda *et al.,* 2018). These meals are often consumed with soups and sauces but are typically made from refined cereals like maize, cassava and yam flour, which may lack essential nutrients such as fiber, vitamin and minerals. Consequently, there is a growing need to enhance the nutritional profile of these traditional food using underutilized, nutrient rich crops (Low *et al.,* 2017). Stiff dough is a common food product in many African countries, especially Nigeria, where it is consumed as a staple food. However, dough meal is mainly starchy and lacks the biochemical diversity required for normal healthy living (Badejo *et al.,* 2022). Therefore, there is a need to improve the nutritional and functional properties of stiff dough (Swallow) meal by incorporating other ingredients that have beneficial effects on human health (Zuo *et al.,* 2023).

Unripe plantain (*Musa paraisiaca*) is a good source of dietary fiber, resistant starch and contain micro-nutrient such as potassium and magnesium (Igbabu *et al.,* 2016). It's low glycemic index also makes it suitable for managing blood sugar levels, particularly in diabetic individuals. Tigernut (*Cyperus esculentus*), although often consume as snacks are used in beverage production, it produces a nutrient-rich residue after milk extraction (Adejuyitan *et al.,* 2022). This residue, commonly discarded as waste, is high in fiber and still retain appreciable levels of fat, protein and mineral, making it valuable ingredient for food fortification and waste minimization.

Cyperus esculentus (also called tiger nut sedge, chufa sedge or earth almond) is a crop of the sedge family widespread across much of the world and widely cultivated for its edible tubers (Adejuyitan *et al.,* 2020). Tigernut protein has a high biological value due to the many required amino acids included in it, the high dietary fibre content of tiger-nut suggests that it could be beneficial in the treatment and prevention of a range of diseases, including colon cancer, coronary heart disease, rotundity, diabetes, and gastrointestinal issues (Ndikom *et al.,* 2021).

Orange flesh sweet potato (*Ipomoea batatas*) is rich in beta- carotene, a provitamin A carotenoid, which plays a critical role in preventing vitamin A deficiency, especially in children and pregnant women (Uchechukwu-Agu *et al.,* 2021). The crop contains vitamins such as (B_1, B_2, B_3, B_5, B_6, B_9, C and E), minerals (iron, calcium, magnesium, phosphorus, potassium and zinc), dietary fiber, protein and carbohydrates (Nwankwo *et al.,* 2020). The crop is also known to contain high amount of soluble sugar such as cellulose, pectin, and hemi cellulose. Sasha (2023) reported that the roots and leaves of orange flesh sweet potato contain appreciable amount of protein (about 5% of the dry matter), Lipid (approximately 1.2-2.7% of the total fresh weight), amylases and phytochemicals such as ascorbic acid.

The combination of these three ingredients presents an opportunity to develop a functional stiff dough (Swallow) product that is not only culturally acceptable but also nutritionally enhanced. The incorporation of orange flesh sweet potatoes and tiger nut residue into unripe plantain-based dough could improve the product vitamin A content, fiber and overall nutrient density.

Additionally, utilizing tigernut residue supports sustainable food production practices through by-products utilization. Several researchers have explored the use of functional and underutilized crops to improve the nutritional quality of the traditional food products such as stiff doughs (Swallows). The inclusion of unripe plantain, orange flesh sweet potato (OFSP), and agro-industrial by-products like tiger nut residue in food formulations has attracted increasing academic interest in recent years. Studies have shown that unripe plantain flour is a rich source of resistance starch, dietary and essential minerals. Olorunda *et al.* (2018) found that stiff dough made from unripe plantain had a lower glycemic index compared to cassava-based dough making it a suitable option for diabetic and overweight individuals. Similarly, Igbabu *et al.* (2016) reported improved functional properties of consumer acceptability of unripe plantain flour when blended with legume flour. OFSP is widely recognized with high beta-carotene content. According to Low *et al.*, (2017), incorporating OFSP into staple foods significantly improves vitamin A intake in population at risk of deficiency. A study by Nnabuke *et al.* (2019) showed that adding OFSP to cereal-based dough enhance both the colour and vitamin A content of the product while maintaining acceptable taste and texture.

However, studies such as those by Adejuyitan *et al.* (2020) and Olatunde *et al.* (2020) emphasized the nutritional potential of tiger nut residue, noting it high fiber, residue fat and mineral content. Olatunde *et al.* (2020) demonstrated that inclusion of tiger nut-based foods improves the dietary fiber and the lipid profiles without negatively affecting sensory acceptability when used in moderate proportion. Recent work by Uchechukwu-Agu *et al.* (2021) combined unripe plantain and sweet potato flour to create a novel stiff dough, finding improvements in nutritional content, texture and shelf life. However, most studies have either focuses on binary blends (e.g plantain and legumes or sweet potato and cereal) with limited research on synergistic effect of combining unripe plantain, tiger nut residue and orange flesh sweet potato.

Most existing research focuses on binary formulations, neglecting the potential nutritional and functional and synergy of a ternary blend. The use of tigernut residue in traditional swallow foods is still underexplored, especially in terms of how it's high fiber and fat content affects dough texture, binding and shelf stability (Nnabuke *et al.,* 2019). Therefore, this study seems to formulate and evaluate a stiff dough meal from blends of unripe plantain, tigernut residue and orange-fleshed sweet potatoes flours, the research focuses on the nutritional composition, functional properties and sensory acceptability of the developed product with view to enhancing the dietary quality of commonly consumed staple meal in resource-limited societies.

2. MATERIAL AND METHOD

2.1. Source of Materials

The raw materials (Unripe plantain, Tigernut and Orange flesh sweet potato) for this research was purchased at Eke-Awka market, Awka South Local government area, Anambra State. These raw materials were conveyed to Food Science and Technology laboratory, Nnamdi Azikiwe University Awka, Anambra state for production and analysis.

2.2 Experimental Design

The Experimental Design used for this research was Completely Randomized Design (CRD) as presented in Table 1

Table 1 Design table

Sample code	unripe plantain	Tigernut residue flour	orange flesh sweet potato
UPF	100	-	-
UTOF1	90	5	5
UTOF2	80	10	10

UTOF3	70	15	15
UTOF4	60	20	20
UTOF5	50	25	25

Source: Ahemen *et al.* (2019)

Unripe plantain

2.3 Processing of unripe plantain flour

Unripe plantation flour was prepared following the methods of Falade and Olugbuyi (2022). 20kg of the unripe plantain was weighed, and the fingers of matured unripe plantain was removed, rinsed in clean water and peeled manually with knives. It was sliced manually with a knife, and the sliced pulp was blanched in boiling water for 10 minutes to inactivate enzymes and dried at 80°C for 6 h in a hot air oven (Memmert) and was allowed to cool. Thereafter, the dried plantains were milled in a Qlink blender and sieved (Sieve aperture size: 350 µm) into flour, sealed in a polythene nylon and used for analysis purpose.

Fresh Tigernut Seed

2.4 Processing of Tigernut residue flour

The method of Ahemen *et al.* (2019) was used in the preparation of tiger nut flour with slight modification. 20g of tiger nuts were sorted to remove unwanted materials like stones, pebbles and other foreign seeds, before washing with tap water and then drained and dried in a cabinet dryer (Excalibur) at 60°C for 6h to a moisture content of about 13%. The dried nuts were milled and sieved through 600-µm mesh size sieve. The resultant flour was packed and sealed in polythene bags until analyzed.

Raw Orange Fleshed Sweet Potatoes

2.5 Processing of Orange flesh sweet potato flour

The orange flesh sweet potato flour was produced by a slightly modified method of Falade and Olugbuyi (2022). The orange fresh sweet potato was washed to remove dirt and soil particles, pat dried to expel water from the skin of the potato, peeled, sliced, tray dried (Tranter tray dryer) at 60°C for 6 hours, milled and sieved to fine flour.

2.6 Production of stiff dough (Swallow)

Stiff dough was prepared by the method of Ahemen *et al.* (2019). Briefly, both control and composite flour (200g) was prepared separately. Then composite flour from unripe plantain, Tiger nut residue and orange flesh sweet potato were mixed homogenously. It was boiled to form paste, the paste was covered and left on the fire for about 5 min to cook. It was further be stirred, packed and wrapped with thin labeled polythene wraps.

Sample UPF= 100:0:0
UPF = (Control 100% Unripe Plantain)

Sample UTOF1= 90:5:5

UTOF1 = (Unripe Plantain Flour 90%, Tigernut flour 5%, Orange Flesh Sweet Potato 5%)

Sample UTOF2= 80:10:10

UTOF2 = (Unripe Plantain Flour 80%, Tigernut flour 10%, Orange Flesh Sweet Potato 10%)

Sample UTOF3= 70:15:15

UTOF3 = (Unripe Plantain Flour 70%, Tigernut flour 15%, Orange Flesh Sweet Potato 15%)

Sample UTOF4= 60:20:20

UTOF4 = (Unripe Plantain Flour 60%, Tigernut flour 20%, Orange Flesh Sweet Potato 20%)

Sample UTOF5= 50:25:25

UTOF5 = (Unripe Plantain Flour 50%, Tigernut flour 25%, Orange Flesh Sweet Potato 25%)

2.7 Sensory evaluation

Sensory evaluation A semi-trained panel of 25 judges made up of male and female staff and students of the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka was used. Participants evaluated the products seated in individual booths under cool, natural, fluorescent lights. The panelists were educated on the respective descriptive terms of the sensory scales and requested to evaluate the various cereal samples for taste, appearance, texture, aroma, and overall acceptability using a 9-point Hedonic scale, where 9 was equivalent to like extremely and 1 equivalent to dislike extremely. Presentation of coded samples was done randomly and portable water was provided for rinsing of the mouth in between the respective evaluations (Sasha, 2023).

2.8 Ethics approval and consent to participate.

The researchers applied the principle of voluntary participation confidentiality and anonymity in the study to ensure that the rights of the panelists were respected. A letter of approval for the study was obtained from the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria and informed consent (verbal) was obtained from each of the panelists before the sensory evaluation was conducted.

2.9 Determination of Proximate Composition of Stiff dough

2.9.1 Moisture Content Determination of Stiff dough

The moisture content was determined using the method described by AOAC (2010). 5g of milled sample was weighed and in a cleaned crucible of known weight. A lid was placed on the disband transferred into an air calculated oven set at 105°C for four hours until a constant weight was obtained. The sample was removed using crucible tongue and placed on a dessicator to cool, thereafter, it was weighed. Replicate determinate was made and the percentage moisture content was calculated as:

$$\% \text{ Moisture} = \frac{W1-W2}{Weight\ of\ Sample} \times 100 \qquad (1)$$

Where: W_1= Weight of sample + dish before oven drying
W_2=Weight of sample + dish after oven drying

2.9.2 Determination of Ash content of Stiff dough

Ash content was determined using the method described by AOAC (2010). The crucible was preheated in a muffle furnace at 550°C for one hour, cooled in a desiccator and weighed. 2g of sample was transferred into the crucible and weighed, the crucible and its content were placed in a muffle furnace and the temperature was allowed to rise to 550°C. After maintaining the temperature at 550°C for four hours, the crucible and its contents were allowed to cool to 200°C before it was transferred to the desiccator to cool to room temperature and then it was weighed. Replicate determinate was made and the ash was calculated as:

$$\text{Crude Ash\%} = \frac{\text{W2}-\text{W1}}{\text{weight of Sample}} \times 100 \qquad (2)$$

Where: W_1=Weight of empty crucible
W_2=Weight of crucible with ash

2.9.3 Determination of crude fiber of Stiff dough

Fiber was determined using the method described by AOAC (2010). Exactly 2.0g of milled sample was placed in a round bottom flask.100cm^3 of 0.25 moldm-^{3} H_2SO_4 was added and the mixture boiled under the reflux for 30 minutes. The hot solution was filtered under suction. The insoluble matter was washed several times with hot water until it was acid free. Thereafter it was transferred into a flask containing 100cm^{-3} of hot (0.312 moldm^3) NaOH solution. The insoluble residue was washed with hot water until it was base free, the residue was dried to constant weight of 100°C and cooled in a desiccator and weighed. The weighed sample was incinerated in a muffle furnace at 525°C for 2 hours, cooler in a desiccator and reweighed; the percentage fiber was then calculated. Triplicate determinations were made in each case and the average determined as:

$$\text{Crude fiber \%} = \frac{W1-W2}{Sample\ weight} \times 100 \qquad (3)$$

Where W_1= The weight of oven dry sample after treatment by H_2SO_4 and KOH
W_2= The weight of treated sample after ashing

2.9.4 Determination of Fat content of Stiff dough

Lipid was extracted using the method described by AOAC (2010). One gram of sample was weighed into pre weighed fat free thimble, 350cm^3 of petroleum ether (40-60°C) was poured into a previously weighed 500cm^3 round bottom flask containing few anti-bumping granules, The Soxhlet extractor was fitted into the 500cm^3 flask and the extraction was carried out for six hours.

Petroleum ether was then distilled off using a rotary evaporator leaving the lipid in the flask; this was dried on a water bath to constant weight. The percentage lip was calculated as:

$$\% \text{ Crude fat} = \frac{W2-W1}{Weight\ of\ Dry\ Sample} \times 100 \qquad (4)$$

Where: W_2= The weight of extraction flask after extraction process with fat
W_1= The weight of empty extraction flask

2.9.5 Determination of crude protein of Stiff dough

Protein was determined using the method described by AOAC (2010). Two grams of sample was weighed into a 100cm^3 khedahl digestion flask and few anti-bumping granules were added. A catalyst mixture of 1.0g of K_2SO_4 and anhydrous $CUSO_4$ was also added to the flask. 25.0cm^3 of sulphuric acid was added, the flask was fixed on the kjhedahl digestion rack and was heated slowly at first until frothing subsided and the vigorously with occasional rotation (to ensure even digestion and avoid over heating of content) until a clear solution was obtained, The solution was diluted to 250cm^3 and transferred in to the distillation flask, Few drops of phenolphthalein and 70cm^3 of 40% (w/v) sodium hydroxide solution was added, the ammonia liberated will be trapped in 4% (w/v) boric acid solution (100cm^3) contained in a 500cm^3 conical flask to which two drops of methyl red indicator was added. Distillation was stopped after the color change, the content of the conical flask was titrated with 0.1mol dm^{-3} hydrochloric acid, the percentage nitrogen was calculated and the crude protein determined as:

Crude protein % =

$$\frac{(TV)\times\times V\times M}{Dry\ sample\ weight} \times 100 \qquad (5)$$

Where: N=Nitrogen molecular weight
V=convert from g equivalent to mg
M=Protein conversion factor

2.9.6 Determination of carbohydrates of Stiff dough

This was obtained by difference, that is; difference between the total summation of percentage moisture, fat, fiber, ash and 100%

Hence,

$$\text{Carbohydrate } (\%) = 100 - (\%\text{ moisture} + \%\text{ fat} + \%\text{ protein} + \%\text{ fiber} + \%\text{ ash}) \qquad (6)$$

2.10 Functional Properties of Stiff Dough

2.10.1 Water Absorption Capacity of Stiff dough

Water absorption of flour was measured according to the centrifugation method described by Adejuyitan *et al.* (2022). 1g of sample was weighed in a centrifuge tube and 10 ml of water was added and mixed thoroughly. The dispersion was allowed to stand for 30mins, followed by centrifugation for 15 mins at 3000 rpm. The sample was re-weighed; the amount of water retained in the sample was recorded as weight gained.

The water absorption capacity (WAC) was calculated as:

WAC =

$$\frac{Volume\ of\ water\ absorbed}{Weight\ of\ sample\ used} \times 100 \qquad (7)$$

2.10.2 Oil Absorption Capacity of Stiff dough

Oil absorption capacity was also determined using the method described by (Abiodun and Akinoso 2022). 1g of sample was mixed with 6ml of com oil in pre-weighed centrifuge tubes. The content was stirred for 1 minute with a thin brass wire to dispense the sample evenly in the oil. After a holding period of 30 minutes; the tubes were centrifuged for 25 minutes to drain the oil prior to reweighing. Oil absorption capacity (OAC) was weighed as weight of oil bound per weight of the sample on a dry basis.

The oil adsorption capacity (OAC) was calculated as:

OAC =

$$\frac{Density\ of\ oil \times volume\ absorbed}{Weight\ of\ sample\ used} \times 100 \qquad (8)$$

2.10.3 Bulk Density of Stiff dough

Bulk density was determined by the method described by Abioye *et al.* (2021). 10 mL capacity graduated measuring cylinder was filled gently with each sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level.

The Bulk density was calculated as:

B.D =

$$\frac{Volume\ of\ smple\ gml}{Volume\ of\ sample\ after\ tapping\ (ml)} \qquad (9)$$

2.10.4 Gelatinization Temperature

The Gelatinization temperature was done using the method described by Wakil *et al.* (2021) with little modification. A starch-water sample mixture with a specific starch concentration and water content was prepared and placed in hermetically sealed aluminum pans. The sample was heated from room temperature to a temperature range above the expected gelatinization temperature at a controlled heating rate of 10°C for 30 minutes.

2.10.5 Dispersibility

The Dispersibility was done using the method described by Shima *et al.* (2019) with little modification. 5g of sample was placed on the surface of a water. The time taken for the samples to disappear beneath the surface while stirring was measured.

2.10.6 Swelling Capacity

The swollen capacity was determined using the method described by Truong, (2021). 1 g of dried sample was weighed and placed the sample in a petri dish. 25 mL of distilled water was added. The sample was allowed for 1 hour at temperature of 20°C. Then its excess water was removed using filter paper. Then the swollen sample was weighed.

The Swelling Capacity was calculated:

$$\frac{Vs}{Vd} \qquad (10)$$

Where = Vs is the swollen volume
Vd = is the dry volume.

2.11 Statistical Analysis

The results were analyzed and expressed as mean values with standard deviations. One-way ANOVA statistical analysis was performed to determine significant differences amongst means. When significant differences ($p < 0.05$) were found, results were compared using a post-hoc test (Ducan's multiple range test). All statistical analyses were run using SPSS version 23.

RESULTS AND DISCUSSION

Sensory Properties of Stiff Dough

The sensory properties of the stiff dough (swallow) made from the blend of unripe plantain, tiger nut residue and orange flesh sweet potato flour compared to the control are shown in Table 2. The colour ranged from 7.00 to 7.70, all the samples have no significant difference ($P < 0.05$), which is as a result of the very dark colour of unripe plantain flour. The control sample UPF produced with 100% of unripe plantain and sample UTOF2 produced 90% of unripe plantain flour with a blend of 5% of tiger nut residue and orange flesh sweet potato flour respectively, had the most preferred colour while sample with the highest ratio 25:25 of tiger nut residue and orange flesh sweet potato flour was the least preferred. The approximate colour score for all the stiff dough was 7; meaning the colours of all the stiff dough samples were moderately liked by the consumers. Colour, like any other sensory attribute, pays major role in determining consumer acceptance of food products. Particularly in blended products, colour constitute one major sensory characteristic that determines consumer choice (Dada, 2022) Colour, therefore is important sensory properties considered in all food product development efforts. The decrease in colour score of blended for stiff dough as substitution increased has been noticed by (Abiodun and Akinoso 2022).

The scores recorded for the stiff dough flavour varies across different blend, ranged 7.20 - 7.85, with the control sample UPF having lowest value compared to the blended sample UTOF5 having the highest score, the range recorded was in within the range 7.15 - 8.00 obtained by Uzoukwu *et al.* (2015) for stiff dough from wheat-Bambara groundnut flour blend. There was no significant difference ($P < 0.05$) between the sample blend of various ratios compared to the control. The blend sample were more preferred by the consumers with increased addition of orange flesh sweet potato flour because orange-fleshed sweet potato brings a natural sweetness and a subtle earthy flavor to the blend (Johnson and Thompson 2019).

The scores for texture depict softness of the stiff dough samples, ranging from 6.70 - 8.40, with the control sample UPF recording the highest score while the blended sample UTOF5 with ratio 50:25:25 of unripe plantain, tiger nut residue and orange flesh sweet potato had the least value. There was significant difference ($P < 0.05$) between the control sample UPF compared to blended samples of different ratio, but there was no significant difference ($P > 0.05$) within the blend samples. The consumers preferred the texture of the control sample produced 100% of unripe plantain due to its superior textural qualities, particularly its firmness and elasticity (Nwokocha and Nzewi 2021). The contribution of additional fibre ostensibly from tiger nut residue flour and orange flesh sweet potato blends might have resulted in the hard texture of the stiff dough relative to the control (Suresh *et al.,* 2021).

According to Bassy and Akinwunmi (2020) taste is a primary driver of food selection, it is a primary factor in determining whether a food will be enjoyed. The Taste scores ranged from 7.45±1.43 to 7.80±1.1.5. Stiff dough produced from 100% of unripe plantain flour (UPF) had the highest taste score compared to blend sample UTOF5 which recorded the least score. The approximate taste score for the stiff dough samples was 7, indicating that their taste was moderately liked and that no significant differences ($p > 0.05$) were observed between their mean tastes.

Overall acceptability scores for stiff dough also ranged from 7.45 to 8.20, the control sample was preferred compared to the blend samples. Although there was no significant difference ($P > 0.05$) observed between the control sample UPF and the other blend samples, yet control sample recorded the highest value compared to the blend samples. Therefore, based on consumer preference, stiff dough produced from 90% of unripe plantain, 5% of tiger nut residue and 5% of orange flesh sweet potato will be suitable for production on a larger scale for economic purposes.

Table 2 Sensory Attributes of Stiff Dough

Sample	Colour	Flavour	Texture	Taste	Overall Acceptability
UPF	7.70^{a}±1.30	7.20^{a}±1.23	8.40^{a}±0.69	7.80^{a}±1.15	8.20^{a}±0.69
UTOF1	7.70^{a}±1.42	7.35^{a}±1.42	7.95^{ab}±1.19	7.80^{a}±1.24	7.95^{a}±1.15
UTOF2	7.55^{a}±1.40	7.40^{a}±1.43	7.55^{abc}±1.36	7.75^{a}±1.29	7.70^{a}±1.08
UTOF3	7.39^{a}±1.41	7.45^{a}±1.23	6.95^{bc}±1.99	7.75^{a}±1.29	7.65^{a}±1.32
UTOF4	7.35^{a}±1.31	7.55^{a}±1.19	6.85^{bc}±2.16	7.60^{a}±1.09	7.60^{a}±1.32
UTOF5	7.00^{a}±1.62	7.85^{a}±1.09	6.70^{c}±2.13	7.45^{a}±1.43	7.45^{a}±1.23

Values are mean ± standard deviation of 20 panelists. Any value that is not followed with same superscription each column is significantly different ($p \leq 0.05$).

KEYS:

UPF = (Control 100% Unripe Plantain)

UTOF1 = (Unripe Plantain Flour 90%, Tigernut flour 5%, Orange Flesh Sweet Potato 5%)

UTOF2 = (Unripe Plantain Flour 80%, Tigernut flour 10%, Orange Flesh Sweet Potato 10%)

UTOF3 = (Unripe Plantain Flour 70%, Tigernut flour 15%, Orange Flesh Sweet Potato 15%)

UTOF4 = (Unripe Plantain Flour 60%, Tigernut flour 20%, Orange Flesh Sweet Potato 20%)

UTOF5 = (Unripe Plantain Flour 50%, Tigernut flour 25%, Orange Flesh Sweet Potato 25%)

Proximate Composition of Stiff Dough

The results of the statistically analyzed stiff dough produced from unripe plantain, tigernut residue and orange flesh sweet potato flour was shown in Table 3. The percentage moisture content of the samples ranged from 8.0% for control Unripe plantain flour sample UPF (Control.100% Unripe Plantain) to 10. 56% for blended UTOF5 (Unripe Plantain Flour 50%, Tigernut flour 25%, Orange Flesh Sweet Potato 25%). The value obtained in this study was within the range of 2.50 –13.2% reported by Obinna-Echem *et al.* (2021) for stiff dough produced from tigernut-Cowpea blend. There was significant difference ($P < 0.05$) between the blended samples of different ratios of unripe plantain, tiger nut residue and orange flesh sweet potato flour respectively and the control sample produced only with 100% of unripe plantain flour (UTOF1 – UTOF5). Generally, Stiff dough samples contained very low moisture 8.00%, the higher moisture content in the blended products (UTOF3 and UTOF4) relative to the control sample may be attributed to the bend composition of the flours. Soluble protein contained in range flesh sweet potato contributes to a greater moisture holding capacity (Gopalakrishnan *et al.,* 2021). Bibiana *et al.* (2022) also confirmed that orange fleshed sweet potato contains high percentage of moisture content, therefore, the increased addition of orange flesh sweet potato flour in sample UTOF4 contributed to the high moisture 10.56% content obtained in sample. This can be attributed to the high water-binding capacity of orange flesh sweet potato starch and weak intermolecular forces, which enhance moisture retention in stiff dough (Sindi *et al.,* 2019). According to the AACC (2018) standard for flour, the moisture content is not supposed to exceed 14%.

However, moisture content below 15.5% has also been reported for some other standards. Thus, the moisture content obtained in this study were much lower than the standard. According to Anajekwu *et al.* (2020), the moisture content of flour is relevant as it serves as the shelf life and stability indicator. Low levels of moisture inactivate the activity of enzymes thus, preventing the growth of bacteria and fungi. In addition, the high fibre content in the blend (UTOF4) caused retention of moisture, because according to report by Shima *et al.* (2019) high fibre content in foods is known to be associated with moisture retention.
Although the moisture content of the blended Stiff dough UTOF4 (Unripe Plantain Flour 60%, Tigernut flour 20%, Orange Flesh Sweet Potato 20%) was greater than the control sample (UPF), the corresponding water values did not follow the same trend. The presence of Unripe plantain flours in the blend bound some of the available water to reduce the moisture content, this result concurred to the study by Idowu *et al.* (2020). The moisture content obtained from each sample were generally lower than the recommended (12 – 14%) moisture content for plant-based flour (FAO, 2019).

Ash content is considered very essential as it gives a measure of the mineral elements that can be obtained from the food sample (Adebowale *et al.*, 2020). The ash content of the samples ranged from 1.73 to 2.39%, with blend sample UTOF5 having the value while the control sample UTOF1 produced with 100% unripe plantain flour had the least value.

Table 3 Proximate Composition (%) of Stiff Dough

Sample	Moisture	Ash	Fibre	Fat	Protein	Carbohydrate	Energy (Kj/100g)
UPF	$8.00^{f}\pm0.01$	$1.73^{b}\pm0.47$	$2.20^{f}\pm0.01$	$0.63^{d}\pm0.06$	$1.17^{f}\pm0.01$	$86.33^{a}\pm0.06$	$335.28^{a}\pm0.01$
UTOF1	$9.00^{e}\pm0.01$	$2.05^{ab}\pm0.01$	$2.43^{e}\pm0.01$	$0.63^{bc}\pm0.00$	$3.60^{e}\pm0.01$	$82.33^{b}\pm0.06$	$349.22^{b}\pm0.00$
UTOF2	$9.19^{d}\pm0.04$	$2.10^{a}\pm0.01$	$2.66^{d}\pm0.01$	$0.65^{bc}\pm0.01$	$3.93^{d}\pm0.06$	$81.47^{c}\pm0.01$	$347.45^{c}\pm0.01$
UTOF3	$9.64^{c}\pm0.07$	$2.17^{a}\pm0.02$	$2.90^{c}\pm0.01$	$0.68^{c}\pm0.00$	$4.20^{c}\pm0.05$	$80.41^{d}\pm0.01$	$344.52^{d}\pm0.00$
UTOF4	$10.02^{b}\pm0.10$	$2.33^{a}\pm0.01$	$3.03^{b}\pm0.06$	$0.78^{b}\pm0.00$	$4.53^{b}\pm0.08$	$79.31^{e}\pm0.01$	$342.38^{e}\pm0.01$
UTOF5	$10.56^{a}\pm0.01$	$2.39^{a}\pm0.01$	$3.25^{a}\pm0.03$	$0.97^{a}\pm0.00$	$4.92^{a}\pm0.06$	$77.91^{f}\pm0.00$	$340.05^{f}\pm0.01$

Values are mean ± standard deviation of 20 panelists. Any value that is not followed with same superscription each column is significantly different ($p \leq 0.05$).

KEYS:

UPF = (Control 100% Unripe Plantain)
UTOF1 = (Unripe Plantain Flour 90%, Tigernut flour 5%, Orange Flesh Sweet Potato 5%)
UTOF2 = (Unripe Plantain Flour 80%, Tigernut flour 10%, Orange Flesh Sweet Potato 10%)
UTOF3 = (Unripe Plantain Flour 70%, Tigernut flour 15%, Orange Flesh Sweet Potato 15%)
UTOF4 = (Unripe Plantain Flour 60%, Tigernut flour 20%, Orange Flesh Sweet Potato 20%)
UTOF5 = (Unripe Plantain Flour 50%, Tigernut flour 25%, Orange Flesh Sweet Potato 25%)

The ash content in this study is within the range of 2.01% to 3.69% reported by Anajekwu *et al.* (2020). There was significant difference ($P < 0.05$) between the blended samples compared to the control sample, except for sample UTOF1 that had no significance difference ($P < 0.05$) with the control (UPF), similar result was reported by Dada (2022) for stiff dough. In this study, ash content of the control sample UPF was quite low; Eze and Anyanwu (2020) in a study stated that low ash content in unripe plantain flour stiff dough offers potential health benefits like improved digestion and reduced risk of certain diseases. However, the sample with higher blend of tigernut residue and orange flesh sweet potato exhibited the highest percentage (2.39%) of ash. Chukwuma (2018) found a higher ash percentage 4.3 - 4.5% when orange flesh sweet potato and tiger nut residue stiff dough were analyzed compared to what was revealed in this study due to the processing method used. Ash content of the blend increased due to the significantly higher mineral content of the unripe plantain and tiger nut residue flours (Bamigbola *et al.,* 2022). Greenway (2018), mentioned that, ash content in flour is influenced by the bran and germ present in the grain or nut as well as temperature and time combination for drying. Thus, the differences in percent ash content of flours in this study may be attributed to these factors as well as the composition of the raw material (unripe plantain, tiger nut residue and orange flesh sweet potato). Higher ash content obtained in sample UTOF5 (2.39) may contribute to the flavor of the product and the nutrients but also negatively affects the gluten strength (Greenway, 2018).

Dietary fibre forms a significant fraction of the stiff dough and their health promoting benefits have been researched extensively (Abiodun and Akinoso 2022). Finding from the study showed that the fibre content of the stiff dough significantly increased with continuous addition of tiger nut residue and orange flesh sweet potato sample, this result is in agreement with the study by Mbaeyi *et al.* (2020) for stiff dough. The blended sample UTOF5 (3.25%) had the highest value compared to the control sample UPF of 100% Unripe Plantain (**2**.20%) that had the lowest value, and there was significant difference ($P < 0.05$) between the blended samples and the control sample. The fiber content obtained from this study was within the range 3.30 - 4.02% report by Johnson and Thompson (2019). Bassey and Akinwunmi (2021) reported that low fiber content obtained the control sample UPF may be beneficial for managing certain digestive issues, or for individuals who need to restrict fiber intake, making it a deliberate choice to cater to specific preferences compared to the high fiber in the blended samples respectively.

The fat content of the samples varies across various blend of the sample ranging from 0.63 - 0.97% with blended sample UTOF5, produced with ratio (50:25:25) of unripe plantain, tigernut residue and orange flesh sweet potato flour having the highest value compared to the control sample UPF produced 100% which had the least value. The percentage of fat content in this study 0.63 to 0.97% was lower than 1.9% to 9.7 5% reported by Tan *et al.* (2020) Bambara-unripe plantain blend stiff dough. There was significant difference ($P < 0.05$) between the control sample UPF and the blended samples of different ratios of unripe plantain, tigernut residue and orange flesh sweet potato respectively. But sample UTOF1 and UTOF2 had no significant difference. This result was within the range 0.7 - 1.20% reported by Adeyemo and Oloruntoba (2020) for plant-based stiff dough. The fat content in stiff dough made from unripe plantain (control sample UPF) was low because the unripe plantain flour is naturally low in fat (Adegunwa *et al.,* 2022) and according to Fetuga *et al.* (2021), orange flesh sweet potato is known to contain low fat which implies that the significant increase in the blended sample was as a result of the addition of tiger nut residue flour. This concurred to the research by Obinna-Echem *et al.* (2021) who obtained high fat content in tigernut-cowpea flour blend and attributed it to the inherent fat content of tiger nut residue and the way it interacts with other ingredients. According to Oyeyemi *et al.* (2019), the role of fat in stiff dough (swallow) includes addition of richness and flavour of the stiff dough. It also adds taste and provides a good mouthfeel to the product, creating tenderness by shortening gluten strands and aids in leavening, compared to swallow from other plant-based flours (FAO, 2019).

The result also revealed that Protein content varies across various blends of the samples, with sample UTOF5 having the highest value and the control sample being the least. Protein content (1.17±0.01-4.92±0.06%) was higher to the values of Uche and Osuji (2022) and Abioye *et al.* (2019) who reported protein content to be 1.56% and 1.32% respectively; this could be due to difference in the ratios of the blend. Abioye *et al.* (2019) reported 4.54% protein content for stiff dough and Eleazu *et al.* (2011) reported 3.15% protein content for stiff dough from plantain flour. Thus, Thus, the protein content obtained in this study did not differ from those already reported. According to Tan *et al.* (2020), high protein content is desired in foods and glutamic acid is reported to be the most abundant amino acid in tiger nut residue flour. The protein content of the orange fleshed sweet potato flour (OFSP) was found to be rather low (5.9%) (Sasha 2023) probably because it is a starchy root, but tiger nut residue flour is a relatively good source of protein, with values reported between 6.08-9.70% (Oladele *et al.,* 2021) and the increased addition to the blends significantly increased the amount of protein content as obtained in sample UTOF4 and UTOF5 respectively. The low level of crude protein in the control sample and sample UTOF1 and UTOF2 respectively would require dietary supplementation of animal protein or complementary protein from plant-bases ingredients, particularly in diets targeted to the target population of malnutrition (Nwokocha and Nzewi, 2021). The high protein obtained in sample UTOF5 made the stiff dough safe and nutritious for consumption compared to the control sample UPF.

The stiff dough samples showed high value for carbohydrate content for different ratios, this characteristic of stiff dough was expected because of the starchy ingredients used in the production. The samples ranged from 77.91 - 86.33%, with control sample UPF having the highest value compared to the blended samples of different ratios respectively. It was observed that the carbohydrate content decreased as unripe plantain flour decreased in the flour blends. Unripe plantain flour has been reported to have a high amount of starch compared to tiger nut residue flour and orange flesh sweet potato. Abioye *et al.* (2019) reported 83.1% carbohydrate content and Anajekwu *et al.* (2020) reported a range of 85.27% to 86.95% for the carbohydrate content of unripe plantain four. Comparing these to the carbohydrate content recorded in this study UPF (86.33%), it was observed to be the same due the high carbohydrate in unripe plantain flour. Functionally, carbohydrates are relevant in stiff dough, Simsek (2018) mentioned the following as some of the functional characteristics of carbohydrates in stiff dough: they act as gelling agents; starch damages the maintenance of sufficient gas produced by yeast and destroys the formation of fermentable carbohydrates.

All the samples recorded high content of energy but the control sample UPF (355.28KJ/100g) had the highest while the blended samples had the least values. The control sample produced with 100% unripe plantain flour was significantly different ($P < 0.05$) from the blended samples, this is primarily due to the higher starch content in unripe plantain (Simsek, 2018). The energy values (340.05 - 349.22KJ/100g) obtained from the blended flour products in this study was lower than the FAO/WHO (2019) recommended minimum energy content of 400Kcals/100g. Anajekwu *et al.* (2020) report 356Kcals/100g in a similar study and attributed the high value to the addition of unripe plantain flour in the blend, Sindi *et al.* (2019) stated that starch is a complex carbohydrate and a major source of energy, orange flesh sweet potato flour also contains starch but generally less than unripe plantain but tiger nut residue, is lower in starch content and the addition to the blend gradually decreased the energy content.

Functional properties of Stiff Dough

The result of the functional properties of Stiff dough was shown in Table 4. From the findings the water absorption capacity (WAC) of the control sample UPF (100% unripe plantain flour) and blended samples UTOF1 and UTOF2 respectively, recorded the least value (2.95%) compared to other samples (UTOF3, UTOF4 and UTOF5) of various ratios of unripe plantain, tiger nut residue and orange flesh sweet potato flour respectively.

According to Yusufu and Ejeh (2018), water absorption is the amount of water absorbed and retained by flour in order to obtain the consistency desired in a food product during processing. The addition of too much or less amount of water to flour will make the food product too sticky to undergo processing (Oyeyemi *et al.,* 2019). It was observed that WAC increased with the decrease in unripe plantain flour content in the blends. It was evident that WAC increased with the increase tiger nut residue and orange flesh sweet potato addition to the blend, from UTOF1 (2.95%) to UTOF5 (4.0%) respectively. Also, the increase in WAC of the stiff dough was influenced by increases in amylose leaching and solubility and the loss of starch crystal line structure. Thus, stiff dough UTOF6 that had a higher WAC may have quite a number of hydrophilic components, including polysaccharides (Suresh *et al*., 2021). Although blended samples UTOF1 and UTOF2 was not significantly different ($P < 0.05$) from the control sample, yet there was significant difference ($P < 0.05$) between UTOF3, UTOF4 and UTOF5. Thus, these samples (UTOF3, UTOF4 and UTOF5) will be preferred in food product formulations for which high water retention is desirable (Eze and Anyanwu, 2020)

Table 4 Functional Properties of Stiff Dough

Sample	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Bulk Density (G/Ml)	Gelatinization Temperature (^{O}c)	Dispersibility (%)	Swelling Capacity (%)
UPF	$2.95^{c}\pm0.07$	$0.95^{a}\pm0.06$	$0.91^{a}\pm0.00$	$76.10^{a}\pm0.02$	$63.21^{f}\pm0.02$	$2.27^{f}\pm0.01$
UTOF1	$2.95^{c}\pm0.07$	$0.91^{a}\pm0.00$	$0.77^{b}\pm0.00$	$75.35^{b}\pm0.05$	$64.79^{e}\pm0.04$	$2.12^{e}\pm0.03$
UTOF2	$2.95^{c}\pm0.07$	$0.91^{a}\pm0.00$	$0.72^{c}\pm0.01$	$74.23^{c}\pm0.01$	$65.33^{d}\pm0.04$	$2.37^{d}\pm0.01$
UTOF3	$3.00^{bc}\pm0.00$	$0.91^{a}\pm0.00$	$0.67^{d}\pm0.00$	$72.96^{d}\pm0.07$	$66.22^{c}\pm0.01$	$2.61^{c}\pm0.01$
UTOF4	$3.10^{b}\pm0.00$	$0.96^{a}\pm0.06$	$0.65^{e}\pm0.00$	$72.45^{e}\pm0.04$	$67.50^{b}\pm0.01$	$2.95^{b}\pm0.01$
UTOF5	$4.00^{a}\pm0.00$	$0.96^{a}\pm0.06$	$0.63^{f}\pm0.00$	$71.18^{f}\pm0.01$	$69.63^{a}\pm0.01$	$3.01^{a}\pm0.01$

Values are mean ± standard deviation of 20 panelists. Any value that is not followed with same superscription each column is significantly different ($p \leq 0.05$).

KEYS:

UPF = (Control 100% Unripe Plantain)
UTOF1 = (Unripe Plantain Flour 90%, Tigernut flour 5%, Orange Flesh Sweet Potato 5%)
UTOF2 = (Unripe Plantain Flour 80%, Tigernut flour 10%, Orange Flesh Sweet Potato 10%)
UTOF3 = (Unripe Plantain Flour 70%, Tigernut flour 15%, Orange Flesh Sweet Potato 15%)

UTOF4 = (Unripe Plantain Flour 60%, Tigernut flour 20%, Orange Flesh Sweet Potato 20%)
UTOF5 = (Unripe Plantain Flour 50%, Tigernut flour 25%, Orange Flesh Sweet Potato 25%)

The Oil absorption capacity of the stiff dough samples varies across different blends, ranging from 0.91- 0.96%. There was no significant difference ($P < 0.05$) between the control sample UPF and the blended samples of different ratios respectively. However, UTOF4 and UTOF5 (0.96%) recorded a higher oil absorption capacity than UTOF1, UTOF3 and UTOF4 (0.91%) and the control sample UTOF1 (0.95%). Study by Uzoukwu *et al.* (2015) reported that differences in variations in the content of non-polar side chains, which might bind to the hydrocarbon side chains of oils, this explains the reason why there were differences in the values of oil absorption capacity despite having no significant difference ($P < 0.05$). According to Yusufu and Ejeh (2018), high oil absorption capacity is important for flavor retention, mouth feel, food and extending the shelf life of stiff dough.

The bulk density of stiff dough ranged from 0.63g/ml to 0.91g/ml. The bulk densities of the blended samples of unripe plantain, tiger nut residue and orange flesh sweet potato flour were significantly different ($P < 0.05$) from the control sample, the range obtained in this study was in accordance to the range 0.61-1.01g/ml reported by Simsek (2018) for Stiff dough from Bambara-Unripe plantain flour blend. The control sample recorded the highest value 0.91g/ml of bulk density, because it was produced with 100% unripe plantain flour and the decrease in the blend led to the lower values recorded. It can be said that unripe plantain flour had a higher bulk density compared to tiger nut residue and orange flesh sweet potato flour. The bulk density of the stiff dough is associated with the particle size and initial moisture content of flour (Suresh *et al.,* 2021). Suresh *et al.* (2021) also stated that samples UPF – UTOF2 (0.72-0.91) with high bulk density were appropriate for food preparation and helped in reducing paste thickness.

The Gelatinization temperature of the stiff recorded high values for both blended samples and control sample ranging from 71 - 76°C. The increased value recorded was due to the different starch compositions and properties of the unripe plantain, tiger nut residue and orange flesh sweet potato flour (Uche and Osuji, 2022). Anajekwu *et al.,* (2020) in a similar study also reported range of 69 - 77°C for unripe plantain stiff dough, this range is in agreement with the value obtained in the control sample UPF. The lower gelatinization temperature obtained in sample UTOF6 is safe and beneficial for consumption due to the report by Adeyemo and Oloruntoba (2020) who stated that the lower the minimum gelation concentration, the more effectively a protein component can gel. In the blended stiff dough samples, different starch components interact during heating which resulted to the high gelatinization temperature recorded yet the interaction can also hinder the ability of the starch granules to absorb water and swell (Tan *et al.,* 2020), this resulted to low value obtained in sample UTOF5 compared to the control sample UPF. The range obtained in this study falls within the recommended range 60°C and 80°C for gelatinization temperature range for starch, which is also crucial for stiff dough formation (FAO, 2019). Within this range, starch granules swell and absorb water, leading to the development of a stiff dough's structure.

The dispersibility, which indicates the reconstitution ability of the samples in water according to Oyeyemi *et al.* (2019) ranged 63.21 to 69.63%. Sample UTOF5 (69.63) with blend ratio of 50:25:25 of unripe plantain, tiger nut residue and orange flesh sweet potato flour had highest value compared to the control sample UPF (63.21) produced with 100% of unripe plantain that had lowest value. The deceased addition of unripe plantain flour led to the increase dispersibility, Adeleke *et al.* (2020) reported similar decrease and attributed it to the high starch content and specific properties of the starch in unripe plantain, which led to a dense stiff dough. There was significant difference ($P < 0.05$) between the blended samples of different ratios compared to the control sample. Gopalakrishnan *et al.* (2021) reported that starch of orange flesh sweet potato helps stabilize the fiber from tiger nut residue, leading to better dispersibility and the high value obtained in sample UTOF5 concurred to this report.

The swelling capacity of Stiff dough from unripe plantain, tiger nut residue and orange flesh sweet potato blend ranged 2.12 - 3.01% with sample UTOF1 showing the lowest value and sample UTOF5 having the highest swelling capacity value. The range is within the range 1.98 - 3.56% reported by Abiodun and Akinoso (2022) for stiff dough from unripe plantain-African yam bean flour blend. It was observed that the blend of tiger nut residue and orange flesh sweet potato contributed to increase in the swelling capacity, the presence of tiger nut residue and orange flesh sweet potato flour enhanced water retention and gelatinization of starch, which led to greater swelling (Shima *et al.,* 2019). There was no significant difference ($P < 0.05$) between control sample from all other samples. Idowu *et al.* (2020) stated that fluctuation in swelling capacity observed in sample UTOF1, UTOF2 and UTOF3 respectively vary at different temperature, indicating an extent of associative forces like protein and carbohydrate within the food sample. Swelling capability and water absorption capacity are important parameters which ultimately determine sample consistency and compositional structure (Abiodun and Akinoso, 2022).

Author contribution statement

Mofunanya Grace Nneka and Okafor Blessing Jerome: Conceived and designed the experiments; Performed the experiments; Wrote the paper. **Ugwu Linus Ejiofor, Okocha Kalu Sunday And Onyeneje Gladysmary Nonyelum:** Performed the experiments; Contributed reagents, materials, analysis tools or data and editing of the document

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