

QUALITY ASSESSMENT OF FLOUR, ACCEPTABILITY AND INVITRO DIGESTIBILITY OF SNACK FROM WHEAT/PLANTAIN/SUGAR CANE BAGASSE

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Abstract: This study investigated the functional properties of wheat-plantain-sugarcane bagasse composite flour blends fortified with 10% tilapia scale powder and the proximate composition, sensory acceptability and in-vitro digestibility and protein solubility of shortbread-type biscuits produced from them. Six blends were formulated: 90:7.5:2.5; 85:10:5; 80:12.5:7.5; 75:15:10; 70:17.5:12.5; and 0:50:50 wheat, plantain and bagasse respectively, each fortified with 10% tilapia scale powder. Proximate composition showed moisture ranged from 5.55 to 8.20%, ash 2.42 to 3.95%, crude fibre 4.33 to 8.88%, fat 5.16 to 6.84%, protein 15.18 to 21.53% and carbohydrate 54.52 to 69.10%. Functional properties showed bulk density 0.65-0.92 g/ml, water absorption 193.54-250.30%, oil absorption 132.27-161.20%, solubility 17.45-40.27%, wettability 23.40-45.21% and swelling 12.60-23.45%. Sensory scores for appearance, taste, aroma, mouthfeel, crispiness and overall acceptability of the biscuits ranged from 5.73-8.66, 6.05-8.63, 6.03-8.56, 5.09-8.76, 6.04-8.66 and 5.00-8.30 respectively, higher than unfortified hardtack biscuit of previous study. The 90% wheat, 7.5% plantain, 2.5% bagasse +10% tilapia scale powder biscuit was most preferred with mean score 8.30 out of 9. In-vitro digestibility showed RDS 18.63-23.45 g/100g, SDS 12.50-15.00 g/100g, RS 5.60-13.50 g/100g and TS 36.96-40.00 g/100g and protein solubility 57.35-61.46% at pH 6.5 and 25.60-33.70% at pH 7.5. In conclusion, shortbread biscuit from wheat, plantain and sugarcane bagasse composite flour fortified with tilapia scale powder showed improved nutritional composition and in-vitro digestibility with good sensory acceptability.

Keywords: Shortbread biscuit; composite flour; tilapia scale powder; proximate composition; sensory acceptability; in-vitro digestibility; valorization.

1. INTRODUCTION

In recent years, the use of agricultural by-products as functional ingredients in bakery foods has received increasing attention. Dietary fiber is now recognized for improving texture and shelf life and for its role in reducing risk of chronic diseases. Sugarcane bagasse is one of the most abundant lignocellulosic residues rich in dietary fiber and phenolic compounds. Plantain (*Musa paradisiaca*) is a staple across West Africa; unripe plantain flour contains high levels of resistant starch and dietary fiber. Tilapia fish scale is rich in collagen, calcium phosphate and protein, making it an invaluable fortifying agent in baked products (Olowosegun et al., 2021).

Wheat remains the dominant flour in biscuit production but low in cellulose and presents gluten concerns. Bawa et al. (2023) evaluated cookies produced by partial replacement of wheat flour with plantain and cocoyam flours and reported 20–30% more fiber with comparable sensory attributes at 20–40% substitution. Despite this potential, there is limited published information on the combined effect of plantain and sugarcane bagasse fortified with tilapia fish scale powder on functional properties, proximate, sensory, and in vitro digestibility and protein solubility of shortbread-type biscuits. Therefore, this study aims to develop a composite shortbread-type biscuit from wheat, plantain, sugarcane bagasse flours fortified with 10% tilapia scale powder for valorization. This study builds on the earlier work on unfortified hardtack biscuit (Adenekan et al., 2020) by converting it to fortified shortbread biscuit using 10% tilapia scale powder.

2. MATERIALS AND METHODS

2.1 Source of Materials

Sugarcane was purchased from Papalanto Township, Ogun State while freshly harvested unripe plantain was purchased from Kuto market, Abeokuta, Ogun State. Tilapia fish scales were obtained as animal waste from Olomore market also in Abeokuta, Ogun State, washed thoroughly to remove sand and flesh, sun-dried for 3 days, milled using a mechanical miller (Disc Attrition Mill, HUUT A47) and sieved to obtain fine tilapia scale powder used at 10% fortification level for valorization. Potassium metabisulphite and combined enzymes used for in vitro digestibility were purchased from Libertas laboratory while other ingredients for processing of biscuit were procured from Kuto market, Abeokuta, Ogun State, Nigeria

2.2 Preparation of Sugarcane bagasse Flour

Method described by Sangeetha *et al.* (2011) was used with a minor modification. 30kg of sugarcane was cleaned, cleaned, washed and peeled, it was diced into small portion for steaming for 15minutes at 60-70°C, the steamed cooked cane was mashed using mortar and pestle to reduce the eater to a minimum barest level to facilitate drying. The sugarcane bagasse was sun dried and then milled using mechanical miller (Disc Attrition Mill, HUUT A47). The milled sugarcane bagasse was sieved to obtain fine bagasse flour which was stored in a Ziplock bag for necessary use.

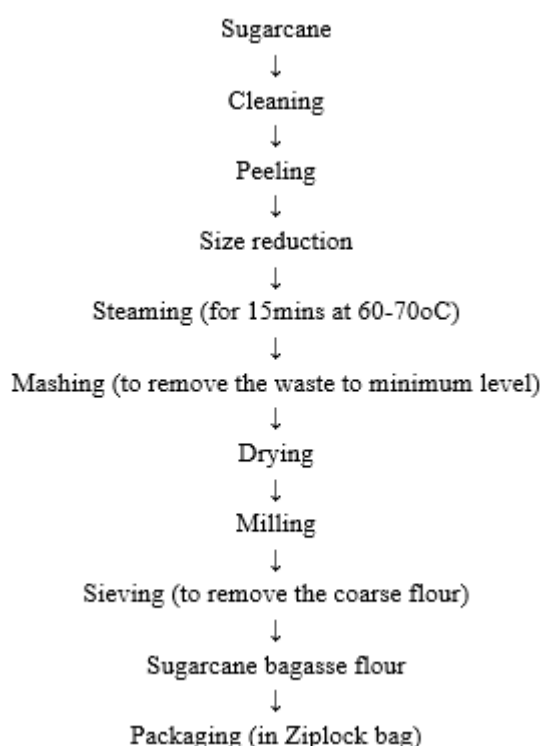


Fig. 1: Preparation of sugarcane bagasse flour

Source: (Sangeetha *et al.*, 2011) with minor modification

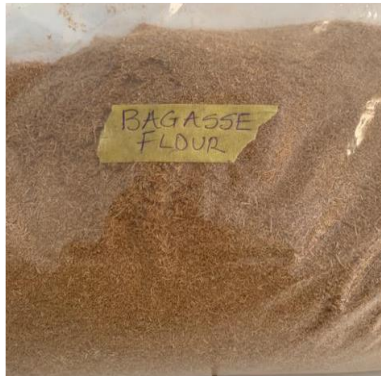


Plate 1: Sugarcane bagasse flour



Plate 2: Sugarcane



Plate 2: Sugar bagasse

2.3 Preparation of Plantain Flour

Method described by Ajala et al. (2022) with minor modification. Plantain was washed, peeled, put inside a bowl of water containing 1% potassium metabisulphite for 15-20 mins, sliced into 3cm thickness, sun dried, milled, and sieved.

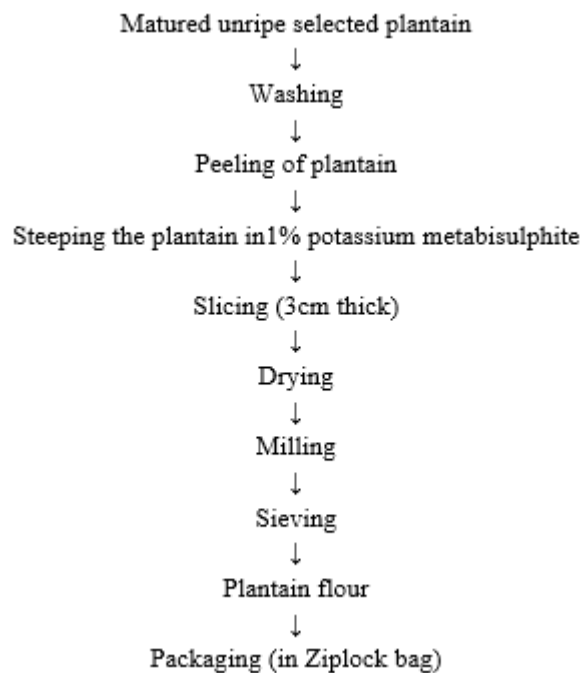


Fig. 2: Preparation of plantain flour.

Source: (Ajala et al., 2022) with minor modification



Plate 4: Plantain fruits



Plate 5: Dried plantain



Plate 6: Plantain flour

Table 1: Formulation of Wheat-plantain-sugarcane bagasse flour blends fortified with 10% tilapia scale powder for the production of Shortbread-type biscuit

Wheat flour	Plantain flour (%)	Sugarcane bagasse (%)
90	7.5	2.5
85	10	5
80	12.5	7.5
75	15	10
70	17.5	12.5
0	50	50

Table 2: Ingredients formulation

Ingredient	Quantity
Flour	200g
Sugar	100g
Margarine	150g
Milk	100g
Egg	80g
Baking powder	8g
Vanilla	2g

2.4 Preparation of Shortbread - type biscuit fortified with 10% tilapia scale powder

Oven pre-heated to 180°C according to Adebayo–Oyetoro et al. (2014) with modification. Method adapted from previously reported formulation for unfortified hardtack biscuit (Adenekan et al., 2020) with modification. Composite flour ratios: 90:7.5:2.5; 85:10:5; 80:12.5:7.5; 75:15:10; 70:17.5:12.5; and 0:50:50 wheat, plantain and bagasse, each fortified with 10% tilapia scale powder. Dry ingredients including 10% tilapia scale powder placed in a large bowl and mixed, a well-made in center, fat, sugar and water added and mixed until dough formed. Dough turned onto floured board, kneaded, shaped into balls, rested half hour, divided, rolled into thick 1cm sheets, cut into 9cm squares, regular pattern of holes made, placed on slightly greased baking tray, baked at 180°C for 30-40 minutes until golden brown.

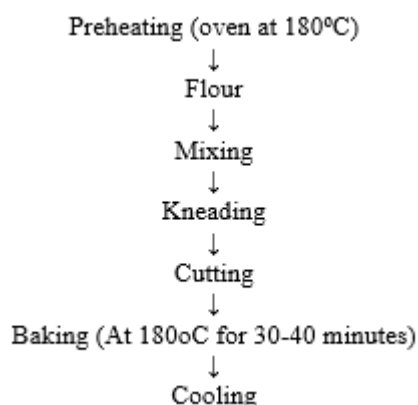


Fig. 3: Preparation of shortbread-type biscuit fortified with 10% tilapia scale powder

Source: (Adebayo – Oyetoro et al., 2014 with minor modification)



Plate 7: Shortbread- type biscuit fortified with 10% tilapia scale powder

2.5 Determination of Functional Properties

2.5.1 Water and Oil Absorption Capacity Determination

Water and oil absorption were determined according to the method of AOAC (2006) from each sample, one gram was weighed into a conical graduated flask and 10ml of water or oil was added to weighed sample. A warning whirl was used to mix the sample for 30seconds. The sample was allowed to stand at room temperature for 30minutes and then transferred to graduated centrifuges tube and centrifuged at 500rpm for 30minutes. Afterward, the mixed sample was transferred from the graduated tube into 100ml measuring cylinder to know the volume of free water or oil. The absorption capacity was expressed as gram of oil or water absorption of sample. Water and Oil absorption capacity = total/water absorbed free oil/water x density of oil/water.

2.5.2 Solubility Index Determination

Solubility was determined according to the method of Ukpabi and Ndimole (1990). Flour dispersion (10g/w/v, dry base) was prepared with each of this starch samples flour by dispersing one gram (dry base) of flour in 5ml distilled water and making it up to 10ml. It was left for 60mins while it was stirred every 10mins, then it was allowed to settle for 15mins after which 2ml of the supernatant was weighed in a Petri dish, evaporated to dryness and re-weighed the difference in mass in the total soluble solids.

V_3 = Total supernatant/filtrate

M_d = Mass of empty Petri dish

M_c = Mass of Petri dish plus residue solid after evaporating drying

M_d = Mass of flour sample used in the preparation of dispersion

2.5.2 Wettability

Wettability was determined by the method of Onwuka (2005). One gram (1g) of sample was poured into 500 ml beaker containing 100ml of distilled water. The time taken for the sample to become completely wet was recorded as its wettability in seconds.

2.5.3 Swelling Capacity Determination

Swelling index was determined according to the Ukpabi and Ndimole (1990). One gram of each starch sample was transferred into a dry graduated cylinder. The flour samples were gently leveled and the volume noted. Distilled water was added to each sample of different ratios to make up to 10ml. The cylinder was swirled and allowed to stand for 60mins while the range in volume swelling was recorded every 15minutes. The swelling power of each flour sample was calculated as a multiple of the original volume.

2.6 Proximate Composition

2.6.1 Moisture Content Determination

The method described by AOAC (2019) was used. A porcelain crucible was washed and dried in a hot air oven for 30 minutes at 105°C. It was then cooled in a desiccator for another 30 minutes. The crucible was then weighed and 0.5g of the sample was poured into the crucible dish and recorded as W1 and W2 respectively. The crucible and content were placed in an oven at 105°C for 2 hrs. it was then removed cooled and weighed recorded as W3.

$$\% \text{ moisture} = \frac{W3-W1}{W2} \times 100$$

2.6.2 Ash Content Determination

The method described by AOAC (2019) was used. The weight of the crucible dish was taken and 0.5g of the sample was added to the crucible and placed in a furnace rack and the temperature was set at 500°C for 16 hrs until there was completed ash. The ash in the crucible dish was removed and kept in desiccators to cool before it was weighed and the percentage ash calculated as:

$$\% \text{ ash} = \frac{\text{total weight of extracted ash}}{\text{Weight of sample}} \times 100$$

2.6.3 Fat Content Determination

The methods described by AOAC (2019) was used 0.5g was weighed and the weight of flat bottom flask was also weighed with the extractor in it. The weighed sample was carefully transferred into the thimble. Extraction was carried out using petroleum ether. (Boiling point at 60°C), the thimble was blocked with cotton wool and extraction carried out continuously for 8 hrs. The solvent was evaporated using water bath and the remaining sample dried at 105°C for 60 minutes. In an oven after which it was placed in a desiccator to cool. The flask was weighed again and % fat was calculated as follows:

$$\% \text{ fat} = \frac{\text{weight of extract fat}}{\text{Weight of sample}} \times 100$$

2.6.4 Carbohydrate Content Determination

Total carbohydrate was determined by difference i.e. Carbohydrate content = 100% — (% protein + % fat + % fibre + % ash + % moisture).

2.6.5 Crude Fiber Content Determination

The method described by AOAC (2019) was used 0.5g of the sample weighed into 500ml beaker and boiled in 200ml HCL (100% v/v) for 30 minutes. The suspension was filtered and the residue was weighed vigorously with distilled water until there was no longer acidic. It was then boiled in 200ml 1.5M NaOH for 30 minutes and filtered through Whatman filter paper (No1) and then washed with distilled water. The residue obtained was transferred into a pre-weighed crucible in desiccators and reweighed.

$$\% \text{ crude fiber} = \frac{W2-W3}{W1} \times 100$$

Where, W1=weight of sample used; W2= weight of crucible +sample, W3 = weight of sample in crucible +ash

2.6.6 Crude Protein Content Determination

Determination of crude protein was done first by determining all the total organic nitrogen using the macro Kjeldhal method (AOAC, 2019). This involves digestion, distillation and titration. 2.0g of the sample was weighed and placed in digestion flasks. The ground defatted sample was dropped into a 300 cm³ Kjeldhal flask. The flask was then transferred to the Kjeldhal digestion apparatus. The sample was digested until a clear green color was obtained. The digestion was

cooled and diluted with 100 cm³ with distilled water. Distillation of the digest: into 500 cm³ Kjeld Hal flask containing anti bumping chops and 40 cm³ of 40% NaOH was slowly added to the flask containing mixture of 50cm³ 2% boric acid and 3 drops of mixed indicator was used to trap the ammonia being liberated. The conical flask and the Kjeld Hal flask were then placed on Kjeld Hal distillation apparatus with the tubes inserted into the conical flask, heat was applied to distill out the NH₃ evolved with the distillation collected into the titrated with 0.1M HCl

Calculation: % N₂ = 14 x M x V_t

Weight of sample (mg) x V_a % crude protein = acid; V = Titre value (volume) of HCl used;

V_t = total volume of diluted digest; V_a = Aliquot volume distilled (6.25 is a general factor suitable for product in which the proportions of specific proteins are not well defined).

2.6.7 Sensory evaluation Determination

Sensory evaluation of shortbread-type biscuit fortified with 10% tilapia scale powder was carried out to determine acceptability in terms of appearance, taste, aroma, mouthfeel, crispiness and overall acceptability. Produced shortbread-type biscuit samples fortified with 10% tilapia scale powder were assessed by thirty (30) panelists. Panelists were briefed, rinsing mouth with water between testing. Samples were coded with three-digit random numbers. A 9-point hedonic scale was employed.

2.7 Invitro starch-Digestibility Determination

Determined according to Chiemela et al. (2022) with modifications. Samples (0.5g dry basis) mixed with water (5mL), left uncooked or cooked 10min, cooled, placed at 37°C, 20mL water and 0.8mL 1M HCl added to obtain pH 2.5, 1mL 10% pepsin added, shaken at 37°C for 30mins, neutralized using 2mL 1M NaHCO₃ and 5mL 0.2M maleate buffer pH 6.0, 1ml 2% pancreatin and 0.1ml amyloglucosidase added. Digestion timed, aliquots removed at 0, 10, 20, 30, 60, 90, 120, 180min. RDS as reducing sugar after 20min, SDS as sugar released after 120min minus RDS, RS as difference between RDS+SDS and total starch. Starch fractions expressed as mg glucose x0.9.

2.8 Determination of Protein Solubility Index

Determined according to Klompong et al. (2007). 200mg sample dispersed in 20ml deionized water, pH adjusted to 6.5 and 7.5 with 0.1M HCl or NaOH, stirred at room temperature 30 minutes, centrifuged at 7500 rpm 15 minutes, protein content in supernatant determined by Bradford method. Solubility (%) = Protein content of supernatant / Total protein content x 100.

2.9 Statistical Analysis

All experiments were performed in duplicate and expressed as mean ± standard deviation. Data were analyzed using ANOVA. Duncan's multiple range tests were conducted to assess significant differences among mean values (P < 0.05)

3. RESULTS

3.1 Functional properties of the flour blends fortified with 10% tilapia scale powder

Results of functional properties of wheat-plantain-sugarcane bagasse flour blends fortified with 10% tilapia scale powder are shown in Table 3. Significant differences (P < 0.05) were observed among blends. Fortified blends showed enhanced bulk density, water and oil absorption capacity, solubility index, and wettability. A reverse trend was observed in terms of swelling capacity.

3.2 Proximate Composition of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Significant differences (P < 0.05) were observed among biscuit samples (Table 4). Moisture content decreased significantly with increase in substitution level. Highest moisture was recorded for biscuit with lowest level of substitution. Ash, crude fiber, and protein increased progressively while fat and carbohydrate decreased with increase in substitution, except WPBSBft which recorded the highest carbohydrate content.

Table 3: Functional Properties of the Flour Blends for the production of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Sample	Bulk Density (g/ml)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Solubility (%)	Wettability Index (%)	Swelling Capacity (%)
WPBSB _{At}	0.65 ^f ±0.00	193.54 ^f ±0.13	149.20 ^a ±0.05	17.45 ^f ±0.06	23.40 ^f ±0.22	23.45 ^a ±0.08
WPBSB _{Bt}	0.75 ^e ±0.00	197.84 ^e ±0.06	150.21 ^b ±0.08	19.52 ^e ±0.08	26.57 ^e ±0.18	21.67 ^b ±0.07
WPBSB _{Ct}	0.76 ^d ±0.00	215.02 ^d ±2.03	152.26 ^c ±0.03	23.40 ^d ±0.24	28.45 ^d ±0.04	18.45 ^c ±0.03
WPBSB _{Dt}	0.81 ^c ±0.00	230.75 ^c ±0.56	158.43 ^d ±0.07	28.62 ^c ±0.01	34.36 ^c ±0.07	17.26 ^d ±0.05
WPBSB _{Et}	0.82 ^b ±0.00	242.62 ^b ±0.08	161.20 ^e ±0.05	34.37 ^b ±0.05	37.34 ^b ±0.10	15.36 ^e ±0.05
WPBSB _{Ft}	0.92 ^a ±0.00	250.30 ^a ±0.04	132.27 ^f ±0.12	40.27 ^a ±0.21	45.21 ^a ±0.02	12.60 ^f ±0.21

Values with similar letters within the same column are not significantly (P<0.05) different

W – wheat flour P-plantain flour B – sugarcane bagasse powder, S = Shortbread biscuit, t = tilapia scale powder, WPBSB_{At} = 90% : 7.5% :2.5%, WPBSB_{Bt} = 85% : 10% : 5%, WPBSB_{Ct} = 80% : 12.5% : 7.5% and 10% , WPBSB_{Dt} = 75% : 15% : 10% , WPBSB_{Et} = 70% : 17.5% : 12.5%, WPBSB_{Ft} = of 0% : 50% : 50% . +10% tilapia scale powder each.

Table 4: Proximate composition of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Parameters	Moisture Content (%)	Ash Content (%)	Crude (%)	Fibre	Carbohydrate (%)	Fat Content (%)	Crude Protein (%)
WPBSB _{At}	8.20 ^b ±0.10	2.42 ^f ±0.02	4.33 ^f ±0.03		60.48 ^e ±0.01	6.41 ^b ±0.02	17.62 ^a ±0.32
WPBSB _{Bt}	7.45 ^a ±0.01	2.67 ^e ±0.01	4.92 ^e ±0.02		59.71 ^e ±0.03	6.84 ^a ±0.02	18.20 ^b ±0.23
WPBSB _{Ct}	7.34 ^c ±0.03	3.15 ^d ±0.02	5.60 ^d ±0.04		58.60 ^d ±0.01	6.22 ^e ±0.05	19.32 ^e ±0.02
WPBSB _{Dt}	6.40 ^d ±0.02	3.54 ^c ±0.03	6.77 ^e ±0.05		56.50 ^c ±0.08	5.36 ^d ±0.10	20.45 ^d ±0.04
WPBSB _{Et}	6.30 ^e ±0.03	3.67 ^b ±0.01	7.86 ^b ±0.04		54.52 ^b ±0.07	5.24 ^e ±0.02	21..53 ^e ±0.02
WPBSB _{Ft}	5.55 ^e ±0.01	3.95 ^a ±0.02	8.88 ^a ±0.02		69.10 ^a ±0.05	5.16 ³⁰ ±0.04	15.18 ^f ±0.05

Mean values along the same column with different superscripts are significantly (P>0.05) different

W – wheat flour P-plantain flour B – sugarcane bagasse powder, S = Shortbread biscuit, t = tilapia scale powder, WPBSB_{At} = 90% : 7.5% :2.5%, WPBSB_{Bt} = 85% : 10% : 5%, WPBSB_{Ct} = 80% : 12.5% : 7.5% and 10% , WPBSB_{Dt} = 75% : 15% : 10% , WPBSB_{Et} = 70% : 17.5% : 12.5%, WPBSB_{Ft} = of 0% : 50% : 50% . +10% tilapia scale powder each.

3.3 Sensory properties of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Results presented in Table 5 show significant differences (P < 0.05) among biscuit samples in terms of appearance, taste, aroma, mouthfeel, crispiness, and overall acceptability. Mean scores revealed panelists' strong preference for fortified shortbread biscuits, demonstrating that tilapia scale powder improved acceptability compared with unfortified hardtack (Adenekan et al., 2020).

Table 5: Sensory Qualities of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Sample	Appearance	Taste	Aroma	Mouth Feel	Crispiness	Overall Acceptability
WPBSB _{At}	8.66 ^a ± 0.66	8.63 ^a ± 0.66	8.56 ^a ± 0.93	8.76 ^a ± 0.62	8.66 ^a ± 0.54	8.30 ^a ± 0.79
WPBSB _{Bt}	7.60 ^b ± 1.03	7.83 ^b ± 0.98	7.80 ^b ± 0.6	8.60 ^a ± 0.72	8.13 ^b ± 0.73	7.63 ^{ab} ± 0.96
WPBSB _{Ct}	7.56 ^b ± 1.35	7.63 ^{bc} ± 1.35	8.00 ^{ab} ± 1.23	7.70 ^b ± 1.23	7.86 ^b ± 0.89	7.33 ^{bc} ± 1.56
WPBSB _{Dt}	7.20 ^b ± 1.76	7.13 ^b ± 1.22	7.86 ^b ± 1.22	7.60 ^b ± 1.32	7.83 ^c ± 0.87	6.96 ^{bc} ± 1.62
WPBSB _{Et}	6.93 ^b ± 2.11	7.06 ^c ± 1.83	8.13 ^{ab} ± 1.35	7.20 ^b ± 1.29	7.73 ^a ± 0.90	6.46 ^c ± 1.97
WPBSB _{Ft}	5.73 ^c ± 0.36	6.05 ^d ± 1.92	6.03 ^c ± 1.35	5.09 ^c ± 0.32	6.04 ^c ± 0.50	5.00 ^d ± 2.11

Values with similar letters within the same column are not significantly (P<0.05) different

W – wheat flour P-plantain flour B – sugarcane bagasse powder, S = Shortbread biscuit, t = tilapia scale powder, WPBSB_{At} = 90% : 7.5% : 2.5%, WPBSB_{Bt} = 85% : 10% : 5%, WPBSB_{Ct} = 80% : 12.5% : 7.5% and 10%, WPBSB_{Dt} = 75% : 15% : 10%, WPBSB_{Et} = 70% : 17.5% : 12.5%, WPBSB_{Ft} = of 0% : 50% : 50% . +10% tilapia scale powder each.

3.4 Invitro digestibility of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Results shown in Table 6 show significant differences (P < 0.05) among biscuit samples regarding starch digestibility and protein solubility. Increasing plantain flour and sugarcane bagasse shifted starch digestibility toward higher SDS and RS with lower RDS, indicating potential for a lower glycemic response. The highest RS value of 13.50 g/100g was recorded at the highest substitution level.

Table 6: Invitro-digestibility of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Sample	RDS (g/100g)	SDS (g/100g)	RS(g/100g)	TS(g/100g)	Protein Solubility PH.6.5 (%)	Protein Solubility PH.7.5 (%)
WPBSB _{At}	23.45 ^a ± 0.02	12.50 ^c ± 0.12	5.60 ^f ± 0.23	40.00 ^a ± 0.32	58.46 ^d ± 0.11	27.66 ^e ± 0.11
WPBSB _{Bt}	22.30 ^b ± 0.02	13.65 ^b ± 0.10	7.41 ^e ± 0.25	39.23 ^b ± 0.63	57.43 ^e ± 0.15	28.40 ^d ± 0.20
WPBSB _{Ct}	21.52 ^b ± 0.02	13.70 ^b ± 0.50	8.56 ^d ± 0.16	38.55 ^b ± 0.50	59.70 ^c ± 0.10	30.50 ^{bc} ± 0.10
WPBSB _{Dt}	20.32 ^c ± 0.02	13.72 ^b ± 0.20	9.72 ^c ± 0.20	37.45 ^b ± 0.52	60.50 ^b ± 0.10	32.50 ^c ± 0.20
WPBSB _{Et}	19.43 ^d ± 0.02	14.12 ^a ± 0.30	10.30 ^b ± 0.21	36.23 ^c ± 0.30	61.46 ^a ± 0.30	33.70 ^a ± 0.10
WPBSB _{Ft}	18.63 ^d ± 0.02	15.00 ^a ± 1.40	13.50 ^a ± 0.25	36.96 ^c ± 0.32	57.35 ^f ± 0.20	25.60 ^f ± 0.12

Values with similar letters within the same column are not significantly (P<0.05) different

W – wheat flour P-plantain flour B – sugarcane bagasse powder, S = Shortbread biscuit, t = tilapia scale powder, WPBSB_{At} = 90% : 7.5% : 2.5%, WPBSB_{Bt} = 85% : 10% : 5%, WPBSB_{Ct} = 80% : 12.5% : 7.5% and 10%, WPBSB_{Dt} = 75% : 15% : 10%, WPBSB_{Et} = 70% : 17.5% : 12.5%, WPBSB_{Ft} = of 0% : 50% : 50% . +10% tilapia scale powder each. RDS - Rapidly digested starch, SDS - Slowly digested starch, RS -Resistant starch, TS - Total starch

4. DISCUSSION

4.1 Functional properties of the Wheat – Plantain – Sugarcane bagasse flour blends fortified with 10% tilapia scale powder

Bulk density ranged from 0.65 to 0.92 g/ml in present fortified blends compared to 0.69 to 0.95 g/ml in unfortified hardtack (Adenekan et al., 2020). Bulk density is a measure of heaviness of flour sample (Oladele and Aina, 2007). These ranges can be helpful for formulation of weaning foods (Millar-Carrillo et al., 2000). The slight decrease in WPBSB_{At} (0.65) is due to fat in the shortbread formulation.

Water absorption capacity ranged from 193.54 to 250.30% in the present study compared to 192.51 to 256.40% in previous unfortified study, suggesting blends will find useful applications in bakery products. Current values are higher than 76.45-94.63% reported by Ajala et al. (2022).

Oil absorption capacity ranged from 132.27 to 161.20% in the present study compared to 124.29 to 148.30% in unfortified hardtack. OAC contributes to enhancing mouthfeel while retaining flavour (Iwe et al., 2016). The increase in OAC from WPBSBA_t (149.20%) to WPBSBE_t (161.20%) except WPBSBF_t (132.27%) is due to protein from 10% tilapia scale powder, contrary to the decrease reported in unfortified flour blends.

Solubility index ranged from 17.45 to 40.27% compared to 16.37 to 38.43% in previous work. High solubility justifies application as an ingredient in infant formula (Oppong et al., 2015). Values are higher than 8.10–13.72% reported by Oguntoyinbo et al. (2023). Wettability ranged from 23.40 to 45.21% compared to 16.37 to 38.43% in unfortified study.

Wettability measures the ease of dispersing flour in water. Its increase with substitution is not in agreement with Olakunle and Olalekan (2020); properties such as particle size, density, and porosity influence wetting (Ji et al., 2016). Swelling capacity ranged from 12.60 to 23.45% compared to 14.40 to 22.67% in previous work. Swelling capacity measures starch's ability to absorb water and swell, reflecting associative forces in starch granules (Iwe et al., 2016). The decrease from 23.45% (WPBSBA_t) to 12.60% (WPBSBF_t) is similar to the trend in previous studies and in accordance with Anne et al. (2020).

4.2 Proximate Composition Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Moisture contents ranged from 5.55 to 8.20% in present fortified shortbread compared to 5.93 to 7.30% in unfortified hardtack (Adenekan et al., 2020). Highest moisture ($8.20 \pm 0.10\%$) was recorded for WPBSBA_t with lowest substitution, and lowest ($5.55 \pm 0.01\%$) for WPBSBF_t. Low moisture suggests ability to prolong storage life by preventing microbial growth, though slightly higher than 5.43% reported for cookies (USDA, 2009). Ash contents ranged from 2.42 to 3.95% compared to 2.30 to 3.62% in previous study, higher than 0.83–2.67% reported by Oguntoyinbo et al. (2023). The increase from 2.42% to 3.95% shows plantain is rich in mineral matter alongside contributions of tilapia scale powder rich in calcium. Ash is a reflection of mineral matter (Iwe et al., 2017).

Crude fiber ranged from 4.33 to 8.88% compared to 4.42 to 8.86% in previous work, higher than 0.81 to 0.61% reported by Oguntoyinbo et al. (2023). Crude fiber is not digested but essential for intestinal tract health. Low fiber diets are associated with heart disease, colon cancer, obesity, and diabetes (Barber et al., 2020). Carbohydrate ranged from 54.52 to 69.10% compared to 61.87 to 70.23% in unfortified hardtack. Highest 69.10% was recorded for WPBSBF_t (0:50:50 + tilapia). Fat contents varied from 5.16 to 6.84% compared to 5.16 to 6.41% in previous file. Highest $6.84 \pm 0.02\%$ in WPBSBB_t (85:10:5 + tilapia). Lower fat gives higher probability of longer shelf life against rancidity (Chukwu et al., 2013).

Crude protein ranged from 15.18 to 21.53% in present fortified shortbread compared to 6.17 to 17.67% in unfortified hardtack. This shows a significant increase due to 10% tilapia scale powder rich in collagen protein. Highest protein ($21.53 \pm 0.02\%$) was obtained in WPBSBE_t (70:17.5:12.5 + tilapia). Values were favorably higher than 9.50–12.08% reported by Oguntoyinbo et al. (2023), proving a strong valorization effect.

4.3 Sensory Qualities of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

Mean sensory scores ranged from 5.73-8.66 for appearance, 6.05-8.63 for taste, 6.03-8.56 for aroma, 5.09-8.76 for mouthfeel, 6.04-8.66 for crispness, and 5.00-8.30 for overall acceptability in present fortified shortbread compared to 2.73-5.87, 2.80-6.43, 3.10-6.97, 2.33-5.90, and 2.57-6.23 for appearance, taste, aroma, crispness, and overall in unfortified hardtack (Adenekan et al., 2020). Increase in plantain and bagasse with addition of tilapia powder caused a marked increase in consumer acceptance. Sample WPBSBA_t scored 8.66 appearance, 8.63 taste, 8.56 aroma, 8.76 mouthfeel, 8.66 crispness, and 8.30 overall acceptability. Conversion from hardtack to shortbread-type with fat, sugar, and 10% tilapia scale powder improved acceptability and masked bitterness from bagasse polyphenols. Acceptable composite shortbread biscuits can be produced with plantain and bagasse fortified with tilapia scale powder even at higher substitution levels up to WPBSBE_t (6.46 overall).

4.4 Invitro digestibility of Shortbread-type Biscuit fortified with 10% Tilapia Scale Powder

RDS ranged from 18.63 to 23.45 g/100g in present study compared to 21.63 to 28.63 g/100g in previous unfortified file, higher than 20.44 g/100g reported by Chiemela et al. (2022). Highest RDS (23.45 ± 0.02 g/100g) was in WPBSBA_t and lowest (18.63 ± 0.02 g/100g) in WPBSBF_t, showing decrease with substitution and tilapia addition. SDS ranged from 12.50 to 15.00 g/100g compared to 4.60 to 11.76 g/100g in previous file. Increase from 12.50 to 15.00 indicates a shift toward

slowly digestible starch. RS ranged from 5.60-13.50 g/100g in present fortified shortbread compared to 5.50-11.50 g/100g in unfortified hardtack (Adenekan et al., 2020). RS increased with substitution due to plantain resistant starch plus tilapia interaction. Total starch ranged from 36.96-40.00 g/100g. RS fraction resists enzymatic hydrolysis, thereby reducing digestible starch proportion and suggesting lower glycemic potential.

Protein solubility at pH 6.5 and pH 7.5 ranged from 57.35-61.46% and 25.60-33.70% respectively, which was not determined in previous unfortified hardtack (Adenekan et al., 2020). Highest solubility ($61.46 \pm 0.30\%$) at pH 6.5 was found in WPBSBEt. The influence of tilapia scale powder is evident as collagen becomes more soluble at acidic pH.

5. CONCLUSION

Partial substitution of wheat with plantain and sugarcane bagasse flours fortified with 10% tilapia scale powder significantly improved the crude fibre, ash, crude protein, and resistant starch contents of shortbread biscuits while maintaining high sensory acceptability. This innovative approach enhances nutritional value, promotes effective valorization of agricultural and animal waste residues, and contributes to food security and product diversification in bakery products

6. RECOMMENDATION

Wheat flour should be substituted with up to 17.5% plantain flour and 12.5% sugarcane bagasse flour fortified with 10% tilapia scale powder to improve fibre, ash, protein, and resistant starch. For optimal sensory acceptability, 7.5% plantain and 2.5% bagasse + 10% tilapia scale powder (WPBSBA_t) is highly recommended. Further research on shelf-life stability and calcium bioavailability is recommended.

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