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Research Article

Quality Evaluation of Fibre-Rich Cookies Produced from Flour Blends of Wheat (*Triticum aestivum*), Plantain (*Musa paradisiaca*) Peel and Oyster Mushroom (*Pleurotus ostreatus*)

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ABSTRACT

The use of flour blends of wheat, plantain peel, and oyster mushroom in the production of cookies was studied. Fibre-rich cookies were produced using wheat, plantain peel, and oyster mushroom flour blends in the ratios: 100:0:0, 90:5:5, 80:15:5, 70:25:5, and 60:35:5 and were labeled A, B, C, D, and E respectively. Sample A (100% wheat flour) served as the control. The functional properties of the flour blends were determined, as well as the proximate, energy value, and vitamin composition of the cookies using standard analytical methods. Also, the sensory qualities of the fibre-rich cookies were evaluated using the 9-point hedonic scale. The results depicted significant differences ($p<0.05$) in the functional properties of the flour blends. The moisture, protein, fat, fibre, ash, and carbohydrate content of the cookies ranged from 3.95 to 5.06%, 11.30 to 13.39%, 10.74 to 11.54%, 2.54 to 5.10%, 3.03 to 4.92%, and 63.22 to 65.80% respectively. The energy value ranged from 401.83 to 411.25 kcal/100g. The retinol, thiamine, and tocopherol content increased significantly ($p<0.05$) from 396.4 to 508.3mg/100g, 1.05 to 2.13mg/100g, and 1.94 to 3.11mg/100g respectively as the inclusion of plantain peel flour in the blends increased. Sensory analysis showed that sample B with 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour had better organoleptic characteristics among the composite cookies. The composites have good utilization potential in fibre-rich cookies production and could be used as a substitute for wheat in human nutrition and in the food industries.

Keywords: Wheat flour; Plantain peel flour; Oyster mushroom flour; Fibre-rich cookies; Blends; Organoleptic

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INTRODUCTION

Cookies are popular snacks in Nigeria consumed by people of all ages. They are usually made from wheat flour, sugar, butter, and eggs and can be flavoured with various ingredients such as chocolate, nuts, and fruits. However, the quality of cookies in the market varies, with some being of poor quality due to the use of low-quality ingredients or poor processing methods. The use of alternative flours such as plantain peel flour and oyster mushroom flour in cookie production can improve the nutritional and sensory properties of the products, as well as reduce the cost of production.

Wheat is a staple crop in Nigeria and a major raw material for the production of baked goods such as bread, biscuits, and cakes. However, the increasing cost of wheat flour and other ingredients that are rich in fibre, vitamins, and minerals that are required in cookie production, and the non-availability of wheat in some parts of the country have led to a search for alternative flours that can be used in baking. One such alternative is plantain peel flour, which is a by-product of plantain processing and is rich in dietary fibre, vitamins, and minerals (Ade-Omowaye *et al.,* 2003). Oyster mushroom *(Pleurotus ostreatus*) is another potential alternative flour that has been used in bakery products due to its high protein, dietary fibre, vitamins and minerals content (Oyetayo *et al.,* 2015).

Plantain is a major staple food in Nigeria and its processing generates large quantities of peel waste. The use of plantain peel flour as an alternative flour in bakery products can help reduce waste and improve the nutritional quality of the products. Oyster mushroom is a popular edible mushroom in Nigeria and is cultivated in different parts of the country. Its use in bakery products can improve the nutritional value of the products, as well as their sensory properties. Several studies have been conducted on the use of either plantain peel flour or oyster mushroom flour in bakery products such as in bread and cake production (Ade-Omowaye *et al*., 2003; Oyetayo *et al*., 2015). However, there is a dearth of information on the combined use of plantain peel flour and oyster mushroom flour in cookie production, hence this study.

Wheat flour is commonly used in the production of cookies in Nigeria. However, the high cost and limited availability of wheat flour and other ingredients needed in the production of cookies have led to a search for alternative flour that will enhance its qualities. Plantain peel flour and oyster mushroom flour have been identified as potential alternative flours due to their availability, nutritional composition, and cost-effectiveness. Despite the potential benefits of using these alternative flours in cookie production, there is limited research on their use in this context. Therefore, the main problem this study seeks to address is the need to convert the waste of plantain (peel) to wealth, making it a source of economic growth. Plantain peel flour is a value-added product that utilizes a waste material that would otherwise be discarded. This contributes to the reduction of environmental pollution and provides an opportunity for income generation (Oluwole *et al.,* 2019). Therefore, this study has important implications for the food industry, consumers, and the economy as a whole. The main objective of the study was the quality evaluation of fibre-rich cookies produced from flour blends of wheat, plantain peel and oyster mushroom.

MATERIALS AND METHODS

Raw Materials Procurement

The wheat (*Triticum aestivum*), plantain peel (*Musa paradisiaca*) and other baking ingredients used for this work was purchased from Orie-Ugba market Umuahia, Abia State. The oyster mushroom (*Pleurotus ostreatus*) also used for the study was purchased from a cultivator based in Owerri, Imo State.

Production of Wheat Flour

The method described by Peter-Ikechukwu *et al.* (2017) was used to process the wheat grains into flour. The wheat grains were sorted manually to remove impurities and unwanted materials. After this, the grains were washed severally with clean water and the water was drained. The clean wheat grains were oven-dried at 60°C for 8 hours. The dried grains were milled using a hammer mill (LM-05, Fuji Paudal Co. Ltd) and the resulting flour was sieved using a 250 μm mesh size sieve to obtain fine wheat flour. The wheat flour was packaged in a transparent cellophane bag and stored at room temperature for further use.

Production of Plantain Peel Flour

The method described by Akubor and Ishiwu (2013) was used to process the plantain peel into flour. The plantains from which the peels were obtained were washed with clean flowing water before the peels were obtained. The unripe plantain peels were peeled off the fruit pulp, cut into pieces and blanched at 60°C for 5 min, after which it was dried in an oven at 60°C for 12 hours, milled (LM-05, Fuji Paudal Co. Ltd) into flour and sieved using a 2 mm mesh sieve to obtain a fine plantain peel flour. The flour obtained was packaged in a cellophane bag and stored for further use.

Production of Oyster Mushroom Flour

The fresh mushroom was processed using the method by Singh and Thakur (2016). The fresh mushrooms were first sorted and washed to remove dirt, damaged fruiting bodies, and unwanted materials. The fresh cleaned mushrooms were chopped into smaller pieces with a knife and blanched in hot water (80°C) for 3 min to completely inactivate the polyphenol oxidase in the mushroom. When the blanching was done, the water was drained and the mushrooms were spread on trays and dried in a dryer at 55°C for 8 hours after which they were allowed to cool at room temperature. The dried mushrooms were blended with a manual blender, sieved and packaged in a cellophane bag for further use.

Formulation of Wheat, Plantain Peel and Oyster Mushroom Composite Flour

Table 1 shows the formulation of the composite flour for the production of cookies, where sample A served as control.

Table 1: Formulation of composite flour (%) for cookie production

Flour blend	Wheat flour	Plantain Peel Flour	Oyster Mushroom Flour
A	100	-	-
B	90	5	5
C	80	15	5
D	70	25	5
E	60	35	5

PRODUCTION OF COOKIES

The cookies were produced using the method described by Ndife *et al.* (2014) with slight modification. The blended samples (Table 1) containing different proportions of wheat, plantain peel and oyster mushroom flours were measured out into different previously washed bowls. The margarine and sugar were creamed and the composite flour with other baking ingredients (Table 2) were added and blended properly using a hand mixer and kneaded for 12 min into a consistent dough. The resulting dough was cut into uniform sizes and passed through a series of molding, shaping and stamping to obtain desired shapes. Then, the dough was baked in the oven for 50 min at 180^{o}C to produce the cookies. The cookies were allowed to cool, packaged in polyethylene bags and stored at room temperature away from light to prevent oxidation.

Table 2: Recipe for the cookies production

Ingredients	Sample A	Sample B	Sample C	Sample D	Sample E
Whole-wheat Flour (g)	200	180	160	140	120
Plantain peel Flour (g)	-	10	30	50	70
Oyster mushroom Flour (g)	-	10	10	10	10
Margarine (g)	220	220	220	220	220
Sugar (g)	75	75	75	75	75
Egg (g)	5	5	5	5	5
Baking powder (g)	1	1	1	1	1
Total weight of Dough (g)	501	501	501	501	501

KEY:

Sample A = 100% wheat flour

Sample B = 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour

Sample C = 80% wheat flour: 15% plantain peel flour: 5% oyster mushroom flour

Sample D = 70% wheat flour: 25% plantain peel flour: 5% oyster mushroom flour

Sample E = 60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour

Analysis

Determination of functional properties of the composite flours

Bulk density: This was determined using the method described by Onwuka (2005). The sample (2.5g) was filled in a 100ml-graduated cylinder and its bottom was tapped on the laboratory bench until there was no decrease in the volume of the sample. The new volume was recorded.

$$\text{Bulk Density} = \frac{grams\ of\ sample}{volume\ of\ Sample} \quad (1)$$

Water and oil absorption capacities: These were determined according to the method of Onwuka (2005). The sample (1g) was weighed into a clean conical graduated centrifuge tube and thoroughly mixed with 10ml distilled water/oil in a warring mixture for 30 sec. The sample was allowed to stand for 30 min at room temperature after which it was centrifuged at 5,000 rpm for 30 min. After centrifugation, the volume of the supernatant, water or oil was read directly from the graduated centrifuge tube. The absorbed oil/water was converted to weight (in grams) by multiplying by the density of oil (0.894g/ml) and water (1g/ml) respectively. The oil and water absorption capacities were expressed as grams of oil/water retained per gram of sample used.

$$\text{Water Absorption Capacity} = ml\ of\ water\ added - ml\ of\ supernatant \quad (2)$$

Swelling capacity: This was determined using the method of Abbey and Ibeh (1988). The samples (1g) were weighed into a 10 ml graduated measuring cylinder, 5 ml of distilled water was carefully added and the volume occupied by the sample recorded. The samples were allowed to stand undisturbed in water for 1hr and the volume recorded again.

$$\text{Swelling Index} = \frac{Volume\ occupied\ by\ sample\ after\ swelling}{Volume\ occupied\ by\ sample\ before\ swelling} \quad (3)$$

Wettability: The method described by Onwuka (2005) was used. A graduated cylinder (25 ml) was washed and dried in the oven and one gram of sample was weighed out and filled into the cylinder. A 600 ml beaker was filled with distilled water up to the 500 ml mark. A finger was placed over the open end of the 25 ml cylinder containing the sample. The cylinder was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing distilled water. The finger was then removed to allow the test flour sample to be dumped into distilled water. The wettability was recorded as the time required for the sample to be completely wet.

Foam capacity: The foam capacity of the flour was determined by the method of Coffman and Garcia (1977). The flour (2g) was dispersed in distilled water (100 mL) and homogenized properly for two min in a kitchen blender. Volumes were recorded before and after homogenization and the percent increase in the volume was calculated as FC of the flour by using the following formula:

$$\text{FC}\ \% = [\frac{(V2-V1)}{V1}]x\frac{100}{1} \quad (4)$$

Determination of proximate composition

Moisture content: This was determined by the AOAC (2005) method. Crucibles were washed and dried in an oven at 80 ^{0}C for some minutes. They were then removed and cooled in a desiccator weighed and the weight was recorded as (W_1). Two grams (2g) of the "cookie" sample was weighed and placed in the weighed moisture dish and the weight was taken as (W_2). The crucible containing the sample was kept in an oven at 105 ^{0}C for 24 hours and weighed. It was kept back in the oven and reweighed after about 3 hours to ensure a constant weight and recorded as (W_3). The moisture content was calculated using:

$$\text{Moisture}(\%) = \frac{W2-W3}{W2-W1}x\frac{100}{1} \quad (5)$$

Protein content: The protein content was determined using a micro-kjedahl method as described by AOAC (2005). It involves wet digestion, distillation and titration. The sample (1g) was accurately weighed into a standard 50 ml Kjedahl flask containing 1.5g $CuSO_4$ and 1.5g of Na_2SO_4 as catalyst and 5 ml concentrated H_2SO_4. The Kjedahl flask (digestion) was placed on a heating mantle and was heated gently to prevent frothing for some hours until a clear bluish solution was obtained. The digested solution was allowed to cool by the careful addition of distilled water and 20 ml portion of the digest was pipette into a semi micro Kjedahl distillation apparatus and treated with equal volume of 40% NaOH solution. The ammonia evolved was steam distilled into a 100 ml conical flask containing 10 ml solution of saturated boric acid to which 2 drops of Tashirus indicator (double indicator) were added. The tip of the condenser was rinsed with a few millilitres of distilled water in the distillate which was then titrated with 0.1M HCl until a purple-pink endpoint was observed. The blank determination was also carried out similarly as described above except for the omission of the sample. The crude protein was obtained by multiplying the % Nitrogen content by a factor (6.25)

Crude protein = % Nitrogen x factor (6)

$$Nitrogen(\%) = \frac{(Sample\ titre - blank\ titre)}{Weight\ of\ sample} \quad (7)$$

Crude fat content: Fat content was determined using the method described by AOAC (2005). The sample (2g), wrapped in filter paper was weighed using a chemical balance. It was then placed into an extractor thimble which had already been washed and dried in an oven, and 150 ml of petroleum ether with boiling point 60-80^{O}C was poured into a 250 ml capacity round bottom flask. The Soxhlet extractor was fitted into the round bottom flask which was seated on a heating mantle. The Soxhlet apparatus was assembled and allowed to reflux for 4h. The extract was poured into a dried pre-weighed beaker (W1) and the thimble was rinsed with a small quantity of the ether back into the beaker. The beaker was heated in a steam bath to drive off the excess solvent. The beaker was then cooled in a desiccator and weighed (W2).

$$\text{Fat}\ (\%) = \frac{W1-W2}{Weight\ of\ Sample}x\frac{100}{1} \quad (8)$$

W2 = weight of beaker + fat

W1 = weight of empty beaker only

Ash Content: Ash content was determined using the method of AOAC (2005). The crucible with lid was ignited in a muffle furnace at the temperature of 105 ^{0}C for an hour. It was transferred to a desiccator to cool and weighed (W_1). The sample (5 g) was put into the pre-weighed crucible. The weight of the crucible and its content (sample) was taken (W_2). The crucible and its content were then transferred to a muffle furnace and heated at 500-600 ^{0}C to burn off all the organic matter and left at this temperature for 2 hours. The crucible was then taken off, cooled and weighed (W_3).

$$\text{Ash}\ (\%) = \frac{W3-W1}{W2-W1}x\frac{100}{1} \quad (9)$$

where;

W_1 = weight of empty crucible

W_2 = weight of crucible + sample before ashing

W_3 = weight of crucible + ash

Crude fibre content: Two (2) grams of the material was defatted with petroleum ether and boiled under reflux for 3 min with 200 ml of a solution containing 1.2 g of H_2SO_4 per 100 ml of solution. The solution was filtered through linen and washed with boiling water until the washings was no longer acidic. The residue was transferred to a beaker and boiled for 30 min with 100 ml of a solution containing 1.2 g of carbonate-free NaOH per 100 ml. The final residue was then filtered and dried in an oven and weighed. The residue was then incinerated, cooled and weighed.

$$\text{Crude fibre (\%)} = \frac{W_1 - W_2}{weight\ of\ sample} \times 100 \quad (10)$$

Where: W_1= weight of crucible + sample after boiling, washing and drying

W_2= weight of crucible + sample as ash

Carbohydrate content: The carbohydrate content on a dry weight basis was determined by difference using the method of Ihekoronye and Ngoddy (1985). This was done by subtracting the total sum of the percentage fat, ash, crude fibre and protein content from 100.

$$\text{Carbohydrate}(\%) = 100 - (\%Protein + Fat + Ash + Crude\ fibre) \quad (11)$$

The energy value determination

The caloric value was calculated using Atwater factor as described by Osborne and Voogt (1978). The formula is as follows.

$$\text{Caloric value} = Crude\ Protein\ x\ 4 + Crude\ fat\ x\ 9 + carbohydrate\ x\ 4 \quad (12)$$

Determination of vitamin composition

The vitamins in the cookies were determined by the official methods of the Association of Official Analytical Chemists (AOAC, 1990).

Vitamin A: One gram (1 g) of the various cookies sample was weighed and macerated with 20ml of n- hexane in a test tube for 10 min. Then 3ml of the upper hexane extract was transferred into a dry test tube in duplicates and evaporated to dryness. Following this, 0.2ml of acetic anhydride chloroform reagent was added and 2ml of 50% trichloroacetic acid (TCA) in chloroform was also added. The absorbance was taken at 15 seconds and 30 seconds intervals at 620nm.

Vitamin B_1: The extraction methodology used was based on that described by Esteve *et al.,* (2001) and all determinations were carried out in duplicate. The various cookie sample was ground to complete liquefaction and homogenized using a domestic blender, followed by immediate analysis. For the acid hydrolysis, 2 g of previously disintegrated sample were used and 30 mL 0.1 N HCl added. This solution was heated in a water bath at 95–100 ^oC for 30 minutes. The extract was then cooled and the pH adjusted to 4.0–4.5 using a 5 M sodium acetate solution. Then, 500 mg of the enzyme takadiastase were added to this extract and incubated in a water bath at 45–50^oC for 5 hours. After the enzymatic hydrolysis, 1 mL 50% trichloroacetic acid was added to the extract, which was heated in a water bath for 5 minutes at 95–100^oC. After cooling, the volume was completed to 50 mL with 0.1N HCl and filtered. 300 µL of potassium ferricyanide (1% in 15% NaOH) were added to 5 mL of the filtrate and left to react for 10 min in the dark. The extract was then neutralized with 200 µL of 15% orthophosphoric acid, filtered through a filter with a pore size of 0.45 µm and immediately injected into the chromatograph.

Vitamin E (Tocopherol): One gram (1 g) of the original sample was weighed, macerated with 20 ml of n- hexane in a test tube for 10 minutes and centrifuged for 10 minutes. The solution was filtered, 3ml of the filtrate was transferred into a dry test tube in duplicates and evaporated to dryness in a boiling water bath. Following this, 2ml of 0.5N alcoholic potassium hydroxide was added and boiled for 30 minutes in a water bath. Then 3ml of n-hexane was added and was shaken vigorously. The n-hexane was transferred into another set of test tubes and evaporated to dryness. A volume, 2ml, of ethanol was added to the residue. Another volume, 1ml of 0.2% ferric chloride in ethanol was added. Then 1ml of 0.5% 1 1 -dipyridyl in ethanol was added followed by the addition of 1ml of ethanol to make it up to 5ml. The solution was mixed and absorbance taken at 520nm against the blank.

Sensory evaluation of the cookies

Sensory characteristics of the coded cookies were evaluated for different sensory attributes by twenty (20) semi-trained panelists drawn from the Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike. All the panelists were briefed before the commencement of the evaluation process. Sensory attributes evaluated were appearance, taste, texture, crispiness and overall acceptability. The rating was on a 9-point hedonic scale ranging from 9 (like extremely) to 1(dislike extremely) (Ihekoronye and Ngoddy, 1985). All panelists were regular consumers of cookies, and water at room temperature was provided to rinse the mouth between evaluations.

Statistical Analysis

All the data obtained were subjected to statistical analysis using Analysis of Variance (ANOVA). The means were then separated with the use of Tukey's test for Pairwise Mean Comparisons using the Minitab Statistical Software. Difference at a p value <0.05 was regarded as statistically significant.

Results were expressed as mean ± standard deviation (SD).

RESULTS AND DISCUSSION

Functional Properties of Flour Blends of Wheat, Plantain Peel and Oyster Mushroom

Table 3 shows the functional properties of blends of wheat, plantain peel and oyster mushroom flours. Bulk density of the composites ranged from 0.70 to 0.80 g/ml. Sample E (60% wheat flour, 35% plantain peel flour and 5% oyster mushroom flour) had the highest value while the lowest value was observed in sample A (100% wheat flour). Bulk density was observed to increase as the level of wheat flour substitution with plantain peel and oyster mushroom flour increased. The bulk density observed in this study is within the range (0.77 – 0.81 g/ml) reported by Ubbor *et al*. (2022) for blends of wheat, Bambara nut and orange fleshed sweet potato flour. It has been well established that knowledge of the bulk density of a food material is important for its packaging and handling. The result obtained from this study indicates that more of the flour could be packaged in constant volume which ensures an economical packaging.

Sample A (100% Wheat flour) exhibited the least water absorption capacity of 1.75 g/g while sample E (60% wheat flour: 35% plantain peel flour and 5% oyster mushroom flour) had the highest water absorption capacity of 3.35 g/g. Water absorption capacity increased with increasing replacement of wheat flour with plantain peel and oyster mushroom flours. The increase in water absorption capacity of composite flours means that the composite flours absorbed water greatly compared to wheat flour. Arukwe *et al*. (2021) reported an increased water absorption capacity as composite flours were incorporated into wheat flour in the production of cookies. Water absorption capacity is essential in bulking and consistency of product and in baking applications (Niba, *et al.,* 2002). The high water absorption capacity recorded in this study implies that the flours will be very useful in bakery products and that it could prevent staling by reducing moisture loss (Ndulaka and Obasi., 2018).

Oil absorption capacity (OAC) is the ability of flour to absorb oil, which is important as oil acts as flavor retainer and improves mouth feel (Onimawo and Akubor*,* 2012). The values of the OAC ranged from 1.37 to 1.83 g/g with sample A (control) having the highest and sample E having the lowest. There was a significant ($p<0.05$) decrease in the oil absorption capacity as inclusion of wheat flour with plantain peel increased. OAC is mainly attributed to the entrapment of oils physically, and it is an indication of the rate at which protein bind to fat in food formulations (Oppong *et al.,* 2015). Ingredients with high oil absorption capacity play important role in stabilizing food systems with high fat content and can also act as emulsifiers (Akubor, 2017). Oil absorption capacity is important for nutrient and energy dense food products especially for infant and young children (Berul, 2015).

Table 3: Functional properties of flour blends of wheat, plantain peel and oyster mushroom

Sample Code	BD (g/ml)	WAC (g/g)	OA C (g/g)	S C (%)	FC (%)	Wettability (g/sec)
A	0.70^{d}±0.00	1.75^{e}±0.07	1.83^{a}±0.13	2.35^{a}±0.07	16.28^{e}±0.03	5.83^{e}±0.01
B	0.72^{cd}±0.00	2.15^{d}±0.07	1.79^{ab}±0.13	2.05^{b}±0.07	22.73^{d}±0.02	6.05^{d}±0.02
C	0.73^{bc}±0.00	2.45^{c}±0.07	1.75^{bc}±0.00	1.75^{c}±0.07	23.01^{c}±0.01	6.33^{c}±0.03
D	0.76^{b}±0.01	2.95^{b}±0.07	1.70^{c}±0.00	1.45^{d}±0.07	25.52^{b}±0.01	6.65^{b}±0.02
E	0.80^{a}±0.00	3.35^{a}±0.07	1.37^{d}±0.13	1.25^{e}±0.07	26.47^{a}±0.02	6.91^{a}±0.00

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscript are significantly different at $p<0.05$

KEY: BD = Bulk density, WAC = water absorption capacity, OAC = Oil absorption capacity, SC = Swelling capacity, and FC = Foam capacity.

Sample A = 100% wheat flour
Sample B = 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour
Sample C = 80% wheat flour: 15% plantain peel flour: 5% oyster mushroom flour
Sample D = 70% wheat flour: 25% plantain peel flour: 5% oyster mushroom flour
Sample E = 60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour

The swelling capacity of the composites ranged from 1.25 to 2.35% with sample E (60% wheat flour: 35% plantain peel flour and 5% oyster mushroom flour) having the least value and sample A (100% wheat flour) having the highest value. There was significant ($p<0.05$) difference in the swelling capacity of the flour samples. The swelling capacity decreased with increasing replacement of wheat flour with plantain peel and oyster mushroom flours. High swelling capacity indicates good thickening and bulking agent (Achinewhu *et al.*, 1998). Therefore, the decreased the swelling capacity as the substitution of wheat flour with plantain peel and oyster mushroom flours increased implies that large quantities of the composite flours would be required to produce cookies as compared to 100% wheat flour.

Foam capacity of the flour samples ranged from 16.28% in sample A to 26.47% in sample E. The foaming capacity of a protein refers to the amount of interfacial area that can be created by the protein (Fennema, 1996). The result from this study shows that increasing inclusion of plantain peel led to an increase in the foam capacity of the samples.

Wettability of the flour samples ranged from 5.83 to 6.91ml/s. There was significant ($p<0.05$) increase in the wettability of the flour samples as inclusion of plantain peel was increased. Wettability of flour helps to determine the time it will take for a flour sample to dissolve completely in water, and the sample having the lowest value dissolves faster in water. The wettability result of this study implies that Sample E which had the highest wettability value required a longer time to wet and to also initiate reconstitution than the other flour samples. It also implies that increasing the inclusion of plantain peel led to an increase in the wettability of the samples. Wettability describes the capacity of the flour particles to absorb water on their surface, thus initiating reconstitution.

Proximate Composition and Energy Value of Cookies Produced from Blends of Wheat, Plantain Peel and Oyster Mushroom Flour

The results of the proximate composition and energy value of the cookies are presented in Table 4. There were significant differences ($p<0.05$) in the moisture, ash, crude fat, carbohydrate, protein, crude fibre and energy value content of the cookies. Cookies produced from the composite flours had lower moisture content when compared with the control sample. The moisture content ranged from 3.95% in sample E to 4.85% in sample B, while the control (sample A) exhibited the highest moisture content of 5.06%. Cookies are generally low moisture foods (Ndulaka and Obasi, 2018). Moisture content reduced with increasing substituting of wheat flour with plantain peel flour and oyster mushroom flour. The range of moisture content of the cookies recorded in this research will prolong the shelf-life of these products in storage. Ezeama (2007) and Akhtar *et al.* (2008) noted that at reduced moisture contents, spoilage of baked products would be reduced due to decreased activity of microorganisms and microbial proliferation will be minimal and it confers higher shelf-life stability to the product.

The crude protein content of the cookies ranged from 11.30% (sample E) to 13.39% (sample A), control sample (100% wheat cookie) had the highest value. Crude protein content significantly ($p<0.05$) decreased with increasing replacement of wheat flour with plantain peel flour and oyster mushroom flour. This decrease in protein could be attributed to the low protein content of plantain peel flour. Arun *et al.* (2015) reported a protein content range of 8.99 to 11.32% for plantain peel flour which is lower than what was observed in this study.

However, the high protein composition as observed in this work despite the substitution of wheat flour with plantain peel flour, can only be attributed to the addition of oyster mushroom flour. Okafor *et al.* (2012) discovered high protein content in bread made from blends of wheat flour and oyster mushroom flour which goes to show that the protein content of oyster mushroom (36%) is higher than that of other common seeds and grain legumes.

Table 4: Proximate composition and energy value of cookies prepared from blends of wheat, plantain peel and oyster mushroom flours

Sample Code	Moisture (%)	Crude Protein (%)	Fat (%)	Ash (%)	Crude Fiber (%)	Carbohydrate (%)	Energy Value (kcal/100g)
A	$5.06^a±0.03$	$13.39^b±0.13$	$10.74^e±0.02$	$3.03^e±0.04$	$2.54^e±0.05$	$65.80^a±0.04$	$411.25^a±0.12$
B	$4.85^b±0.04$	$12.87^a±0.12$	$10.91^d±0.02$	$3.40^d±0.04$	$3.15^d±0.03$	$64.32^b±0.00$	$409.07^b±0.32$
C	$4.53^c±0.04$	$12.34^c±0.13$	$11.20^c±0.02$	$3.95^c±0.07$	$3.72^c±0.02$	$64.30^b±0.06$	$407.14^c±0.10$
D	$4.16^d±0.03$	$11.82^d±0.12$	$11.35^b±0.03$	$4.60^b±0.07$	$4.43^b±0.04$	$63.65^c±0.01$	$403.10^d±0.20$
E	$3.95^e±0.03$	$11.30^e±0.13$	$11.54^a±0.05$	$4.92^a±0.04$	$5.10^a±0.02$	$63.22^d±0.05$	$401.83^e±0.13$

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscript are significantly different at $p<0.05$

KEY:

Sample A = 100% wheat flour

Sample B = 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour

Sample C = 80% wheat flour: 15% plantain peel flour: 5% oyster mushroom flour

Sample D = 70% wheat flour: 25% plantain peel flour: 5% oyster mushroom flour

Sample E = 60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour

The fat content of the cookies ranged from 10.74% (sample A) to 11.54% (sample E). The fat content increased significantly ($p<0.05$) with increasing substitution of wheat flour with plantain peel flour and oyster mushroom flour. This increase in fat content agrees with the findings of Okafor *et al. (*2012) and Arun *et al.* (2015) who respectively reported increased lipid content of bread and cookies due to the inclusion of mushroom flour and plantain peel flour.

Sample A exhibited the lowest ash content (3.03%) when compared with the flour composite cookies whose value ranged from 3.40% (sample B) to 4.92% (sample E). Ash content increased significantly ($p<0.05$) with increasing substitution of wheat flour with plantain peel flour and oyster mushroom flour. Atobatele and Afolabi. (2016) also observed an increase in the ash content of cookies with increasing levels of soy flour in the flour blends. Ash content is a representation of mineral content so, samples with high ash constituents are expected to have a relatively high mineral content (Olapade and Adeyemo, 2014).

The crude fibre content of the cookies ranged from 2.54% (sample A) to 5.10% (sample E). Crude fibre content increased with increasing substitution of wheat flour with plantain peel flour and oyster mushroom flour. This suggests that plantain peel flour is rich in fibre. The high fibre and the reduced carbohydrate content of cookies have several health implications. High levels of fibre have been confirmed to aid digestion in the colon and decrease constipation which is often associated with products from refined grain flours (Schaafsma and Slavin, 2015). Fibre plays an important role in the greater use of nitrogen and absorption of some other micronutrients (Arukwe *et al*., 2022). Fibre consists of hemicelluloses, cellulose and lignin which improves the health of the gastrointestinal system and metabolic system in humans (Atobatele and Afolabi, 2016).

The carbohydrate content of the cookies ranged from 63.22% in sample E to 65.80% in sample A. The cookies produced from the flour composite resulted in a significant ($p<0.05$) reduction in the carbohydrate content from 64.32% in sample B to 63.22% in sample E, the control sample exhibited the highest value of 65.80%. Carbohydrate content decreased with increasing substitution of wheat flour with plantain peel and oyster mushroom flour. Arun *et al.* (2015) also reported decreased carbohydrate content in cookies produced with blends of wheat and plantain peel flour.

The energy values of the cookies were significantly ($p<0.05$) different from each other, and with a decreasing trend as the level of wheat substitution increased. The values ranged from 401.83 to 411.25 kcal/100g with sample A (100% wheat flour) having the highest value and sample E (60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour) having the lowest value. This same reduction in energy value as a result of inclusion of composite flours was reported by Arukwe *et al*. (2022). However, the energy values recorded for the cookies were quite high and as such, the cookies can be used as energy-based snacks (Atobatele and Afolabi, 2016).

Vitamin Content of Cookies Produced from Blends of Wheat, Plantain Peel and Oyster Mushroom Flours

Table 5 shows the results of the vitamin composition of cookies produced from composites of wheat, plantain peel and oyster mushroom flours. There was a significant ($p<0.05$) increase in the retinol (vitamin A) content of the cookies ranging from 396.4 mg/100ml in sample A (100% wheat flour) to 508.3 mg/100ml in sample E (60% wheat flour: 35% plantain peel flour:5% oyster mushroom flour). This result suggests that plantain peel and oyster mushroom flour inclusion increased the Vitamin A content of the cookies. Vitamin A is important for normal vision, gene expression, growth and immune function by its maintenance of epithelial cell functions (Lukaski, 2004).

Thiamin (vitamin B1) content varied from 1.05 to 2.13 mg/100ml. The control sample exhibited the lowest value of thiamin, 1.05 mg/100ml when compared with composite flour cookies whose value ranged from 1.46 to 2.13 mg/100ml. This result suggests that plantain peel and oyster mushroom flour inclusion increased the thiamin content of the cookies. Thiamin plays a central role in cerebral metabolism. It is involved in membrane structure and function, including axoplasmic, mitochondrial and synaptosomal membranes, acts against agent-induced cytotoxicity and fixes membrane sites (Fattal *et al.*, 2011).

There was a significant ($p<0.05$) increase in the tocopherol (vitamin E) content ranging from 1.94 mg/100ml in sample A to 3.11 mg/100ml in sample E. This result suggests that plantain peel and oyster mushroom flour inclusion increased the Vitamin E content of the cookies. Vitamin E is a powerful antioxidant that helps to protect cells from damage by free radicals and it is vital to the formation and normal functioning of red blood cells and muscles (Lukaski, 2004).

Table 5: Vitamin Content (mg/100g) of Cookies Produced from Blends of Wheat, Plantain Peel and Oyster Mushroom Flours

Sample Code	Retinol	Thiamin	Tocopherol
A	$396.4^{e}\pm1.36$	$1.05^{d}\pm0.04$	$1.94^{e}\pm0.02$
B	$416.7^{b}\pm2.72$	$1.46^{c}\pm0.04$	$2.19^{d}\pm0.01$
C	$442.7^{c}\pm1.36$	$1.70^{b}\pm0.07$	$2.43^{c}\pm0.01$
D	$474.5^{b}\pm2.72$	$2.00^{a}\pm0.07$	$2.72^{b}\pm0.01$
E	$508.3^{a}\pm1.36$	$2.13^{a}\pm0.04$	$3.11^{a}\pm0.00$

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscripts are significantly different at p<0.05

KEY:

Sample A = 100% wheat flour

Sample B = 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour

Sample C = 80% wheat flour: 15% plantain peel flour: 5% oyster mushroom flour

Sample D = 70% wheat flour: 25% plantain peel flour: 5% oyster mushroom flour

Sample E = 60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour

Sensory Properties of Cookies Produced from Blends of Wheat, Plantain Peel and Oyster Mushroom Flours

The mean sensory scores of the cookies produced from composites of wheat flour, plantain peel flour and oyster mushroom flour are shown in Table 6. The result showed that sample A (100% wheat) was rated the highest when compared with the composite samples in terms of appearance, taste, texture, crispiness, aroma and overall acceptability whose values were 8.00, 7.80, 7.35, 7.35, 7.55 and 8.05, respectively. The mean scores for appearance, taste and texture significantly (p<0.05) decreased from 8.00 to 4.95, 7.80 to 5.05 and 7.35 to 5.15 respectively due to the increased substitution of wheat flour with plantain peel and oyster mushroom flours. The same trend of decrement in the sensory scores with increased inclusion of plantain peel flour in the blends were observed for crispiness, aroma, and overall acceptability. However, sample B was rated significantly (p<0.05) higher by the panelists than the rest of the cookies produced from the composite flours in terms of appearance, taste, texture, crispness, aroma and overall acceptability.

Table 6: Sensory Properties of Cookies Produced from Blends of Wheat, Plantain Peel and Oyster Mushroom Flours

Sample Code	Appearance	Taste	Texture	Crispness	Aroma	Overall Acceptability
A	$8.00^{a}\pm0.56$	$7.80^{a}\pm1.01$	$7.35^{a}\pm0.98$	$7.35^{a}\pm1.39$	$7.55^{a}\pm1.15$	$8.05^{a}\pm0.95$
B	$6.25^{b}\pm1.12$	$6.60^{b}\pm1.39$	$6.70^{b}\pm1.08$	$6.60^{b}\pm1.39$	$6.35^{b}\pm1.27$	$6.80^{b}\pm1.19$
C	$5.65^{c}\pm1.53$	$5.50^{c}\pm2.04$	$6.20^{c}\pm1.47$	$5.70^{c}\pm1.35$	$5.50^{c}\pm1.39$	$6.00^{c}\pm1.49$
D	$5.00^{d}\pm1.84$	$5.30^{d}\pm1.87$	$5.30^{d}\pm1.95$	$5.65^{c}\pm1.87$	$4.95^{d}\pm1.79$	$5.80^{d}\pm1.51$
E	$4.95^{d}\pm2.19$	$5.05^{e}\pm1.79$	$5.15^{e}\pm1.57$	$5.35^{d}\pm1.63$	$4.75^{e}\pm1.71$	$5.40^{e}\pm1.57$

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscript are significantly different at p<0.05

KEY:

Sample A = 100% wheat flour

Sample B = 90% wheat flour: 5% plantain peel flour: 5% oyster mushroom flour

Sample C = 80% wheat flour: 15% plantain peel flour: 5% oyster mushroom flour

Sample D = 70% wheat flour: 25% plantain peel flour: 5% oyster mushroom flour

Sample E = 60% wheat flour: 35% plantain peel flour: 5% oyster mushroom flour

CONCLUSION

The findings in this research shows the possible use of wheat flour fortified with plantain peel and oyster mushroom flours in the production of fiber-rich cookies of high nutritional composition with acceptable sensory characteristics. The findings reveal that there was significant (p<0.05) increase in the fibre content of the cookies due to the increased inclusion of plantain peel flour. Hence, the consumption of the cookies produced from the composite flours could help in combating dietary fibre deficiency. The outcome of the present research can be used as valuable tool for the development of high fibre products that will help check and reduce the problems of constipation, heart disease, irritable bowel syndrome (IBS) and diverticulitis.

Fortification of wheat flour with plantain peel and oyster mushroom flours had varying effects on the functional properties of the flour as well as sensory qualities of cookies produced from the flour blends. The result obtained in this research could be valuable in decision making for industries that want to take nutritional advantage of plantain peel and oyster mushroom flours as alternatives to wheat flour. Continuous use of these locally grown crops to produce cookies will go a long way in reducing dependence on wheat flour, thereby reducing foreign exchange used in importing wheat.

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