Production and Quality Assessment of Whole-Wheat Bread Substituted with Peanut Peel

AMADI, Allbright Ovuchimeru*, OBINNA-ECHEM, Patience Chisa and EGBULEFU, Delight Chidera
Department of Food Science and Technology, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State, Nigeria
*Corresponding author: allbright.amadi@ust.edu.ng
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Abstract

This study evaluated the quality of whole wheat bread substituted with peanut peel flour. The whole-wheat flour was supplemented with peanut flour at a ratio of 97.5:2.5 (sample B), 95:5 (sample C), 92.5:7.5 (sample D), 90:10 (sample E), while 100% whole wheat flour served as the control and was tagged sample A. Functional properties analysis was carried out on the flours, while antioxidant, proximate, sensory analysis and physical properties was carried out on the bread produced from the flours. Functional properties of the flour samples ranged from 1.16-1.49g/g, 1.44-1.64g/g, 0.45-0.51g/ml, 5.19-7.81%, and 42.07-44.35%, for water absorption capacity, oil absorption capacity, bulk density, solubility, and swelling index, respectively. Inclusion of peanut peel flour increased the functional properties of whole wheat flour. Antioxidant properties of the bread samples ranged from 11.18-15.93 mg/kg, 4.24-11.41%, and 0.21-0.33 mg/100g, for tannin, flavonoid, and total phenol contents, respectively. The antioxidant properties showed significant differences ($p<0.05$) with higher peanut flour incorporation compared to the control. Proximate composition of the bread samples ranged from 22.07-29.54%, 1.75-1.99%, 0.80-2.49%, 8.76-10.11%, 4.39-9.75%, and 46.22-58.60%, for moisture, ash, fat, crude protein, crude fibre, and carbohydrate contents, respectively. Inclusion of peanut peel flour significantly ($p<0.05$) improved the ash, fat, crude protein and crude fibre content, while carbohydrate content reduced. Sensory properties of the bread samples were determined using 9-point hedonic scale, and ranged from 7.10-7.80, 7.30-8.10, 6.90-7.50, 6.40-6.80, 6.10-6.30, and 6.76-7.10, for crust color, crumb color, aroma, texture, taste and overall acceptability, respectively. There was no significant difference ($p>0.05$) amongst samples in the overall acceptability as well as the physical properties of the bread samples which ranged from 153.06-160.00 g, 442.01-456.00 ml, 2.85-2.89 cm^3/g, for weight, volume and specific volume, respectively. This study showed that the inclusion of peanut peel flour to whole wheat improved the ash, fat, crude fibre and crude protein composition of whole wheat bread, as well as the antioxidant properties of the bread. Sample E with 10% peanut peel flour is recommended as it improved better, the nutritional composition of whole wheat bread, and had better aroma and taste score. Achieving food waste reduction is possible as it has shown feasibility in bread production. Further research on incorporating other food wastes into food processing is highly recommended.

Keywords: *Whole-wheat bread, peanut peel, food waste, antioxidant properties*

Introduction

Food waste has become an increasingly recognized environment issue over the last decade, as population and urbanization grows, more food is being produced and wasted especially by products (Raak *et al.,* 2017). Most of these food waste as useful as they can possess good nutritional properties to serve as a supplement to some food. They can be used as source of bioactive compounds, which serves as functional food ingredients or nutraceuticals (Ben-Othman *et al.,* 2020; Panzella et al., 2020). Efforts have been made to convert these refused materials into valuable products (Raak *et al.,* 2017) especially since food industries are redesigning their production chains to address the emerging consumer demand for high-nutritional foods, products with enhanced functional and physical properties, and enriched with health-promoting constituents (Galanakis, 2021).

There are some nutritional wastes such as peanut peels that are considered important factors of therapeutic diets and nutrient effect supplying essential nutrient elements (Akram *et al.*, 2018). Peanut skins have a pink-red color and an astringent mouthfeel when consumed. They are typically removed before peanut consumption or inclusion in confectionary and snack products. The high concentration of phenolic compounds presents in peels, skins and seeds support the utilization of agricultural by-products as source of natural antioxidants (Sarnoski *et al.,* 2012). These potent antioxidants and could provide an inexpensive source of phenolic compounds for use as functional ingredients in foods or dietary supplements (Galanakis, 2021). The search for inexpensive, renewable and abundant sources of antioxidant compounds is attracting worldwide interest (Udeh *et al.,* 2023). Because of the growing concern for the potential health hazards of synthetic antioxidants, there is renewed interest in the increased use of naturally occurring antioxidants (De Camargo *et al*., 2012). Much research is needed in order to select raw materials of lower costs and especially promising are those of underutilized by-products in the agricultural value chain.

Bread is a staple food that closely related to people's daily life. It is prepared by baking dough which consists of flour, leavening agents and water. Bread is popular around the world and one of the oldest foods (Ibrahim *et al.,* 2015). Bread is an important source of proteins, fibres, complex carbohydrates, vitamins, and minerals, in addition to antioxidants and phytochemicals (Refat *et al.,* 2020). However, processing wheat flour generally reduces the content of these nutrients and their content of bioprotective substances (Abu-Hussein and Takruri, 2016). Interests in incorporating active ingredients such as dietary fibre and phenolic antioxidants into popular foods such as bread have grown rapidly, due to the increased consumer health awareness (Ibrahim *et al.*, 2015).

Whole-wheat (*Triticum aestivum L.*) flour (Graham flour) is the entire wheat grains ground, including all the bran of grains. This quality of flour is considered the healthiest flour (Khalid *et al.*, 2023). On the average, wheat kernels composition is 68% carbohydrates, 55% of it is starch, with 6% pentosans and 2% sugars. The wheat kernels contain also 2.3% crude fibre, 2% fat, 13% crude protein, and 2% minerals (Medhat *et al.*, 2021). However, poor quality wheat flour can be enriched with many other plant origin materials. The easy one is mixing wheat flour with an optimum percent of durum flour. Some other additives such as, flours of peanuts, oats, rye, barley, and sorghum could be used to improve nutrient value but not bread baking quality (Sharma *et al.,* 2015). Some other additives spread on the surface of breads are also being used. These additives include seeds of peanut, sesame, quinoa, amaranth, flaxseed, and other seeds favoured in that society. (Medhat *et al.,* 2021).

Materials and methods

Collection of raw materials:

Whole wheat flour was purchased from Port Harcourt Mall (Spar), while peanut (*Arachis hypogaea L.*) was purchased from Mile 3 market both in Port Harcourt, Rivers State, Nigeria. Other ingredients such as compressed baker's yeast, sucrose, salt and shortening were purchased from Mile 1 Market, Port Harcourt, Rivers State, Nigeria.

Chemicals/Reagents:

All chemicals/reagents and equipment used for this study were of analytical grade and were obtained from the Department of Food Science and Technology, Rivers State University.

Peanut Peels Preparation

The peanut peel flour was prepared from mature and healthy peanut seeds. The peanut seeds were sorted to remove dirt and stones, washed and drained. The seeds were then roasted for 10 minutes, de-hulled to get the peels, and allowed to cool for 5 minutes. The peels were blended using a Buchymix blender (Turbocrush Digital BM0421DL) and sieved through a 150µm sieve size to obtain the flour.

Whole wheat-peanut peel bread preparation

Bread was made using the 100 g straight dough method as described by Sulieman *et al.* (2014) with modification. The basic ingredients were 100 g of whole wheat flour, 3 g baker's yeast, 11 g of honey, 2 g of salt, 4 g of shortening (vegetable oil), 70 g of lukewarm water, and different concentrations of peanut skin flour, which were added at 2.5, 5, 7.5 and 10% concentration on a flour replacement basis. After mixing, the dough was covered and allowed to rest for 45 min at room temperature, and was scaled to three portions for 120 g each, molded into round balls and allowed to rest for another 30 min. It was then put in pans and allowed to proof for a period of 15 min. The fermented doughs were baked in Simon Rotary baking oven at 180°C for 30 min.

Determination of the functional properties of whole wheat-peanut peel flour blends

Bulk density, water and oil absorption capacity were determined according to the method described by Onwuka (2018). Swelling power and solubility were determined according to the method described Aidoo *et a*l. (2022). Briefly, water and oil absorption capacity were determined by centrifugal-gravimetric method after the centrifugation of 1 g of the samples in 10 mL of distilled water and pure gino oil respectively. Bulk density was determined gravimetrically before and after gentle tapping of 10 mL graduated cylinder filled with the samples until there was no further diminution of the sample levels. Swelling power and solubility were determined gravimetrically after heating to 85°C, holding for 30 min before centrifugation at 1000 rpm for 15 min. Swelling capacity was calculated by dividing the sediment weight with the sample weight. The soluble component in the supernatant after evaporation of water was used in the computation of solubility (%) by dividing the soluble component weight with the sample weight multiplied by 100.

Determination of the proximate composition of whole-wheat bread produced from blends of whole-wheat and peanut peel flour

The moisture, protein, crude fibre, fat and ash contents of samples were analysed using the standard analytical method described by Association of Official Analytical Chemists (2012). Moisture was obtained gravimetrically after drying to a constant weight at 70^{o}C in a hot air oven (DHG 9140A). Fat was determined using soxhlet extraction method with ethyl ether. Kjeldahl method and a nitrogen conversion factor of 6.25 was used for crude protein determination. Ash content was determined gravimetrically after the incineration of the samples in a muffle Furnace (Model SXL) at 550^{o}C for 2 h. Enzymatic gravimetric method was utilized in the determination of crude fibre. Carbohydrate was calculated by difference {100 - (Crude protein + crude fibre + ash + fat)}.

Determination of the physical properties of whole-wheat bread produced from blends of whole-wheat and peanut peel flour

The methods described by Mamat *et al.* (2021) with modification, was used to determine the specific volume, loaf weight and loaf volume of the bread. The loaf weight was determined by the average value of a direct measurement of three breads, using a semi-analytical balance. The loaf volume was determined by placing the bread sample inside a graduated container filled with 3000 ml of water. The volume of water displaced was noted, and recorded as loaf volume. The specific volume of the bread was determined by dividing the loaf volume by weight of bread.

Determination of the antioxidant properties of whole-wheat bread produced from blends of whole-wheat and peanut peel flour

The method described by Nbaeyi-Nwaoha and Onwuka (2014), was used to determine the tannin, phenol and flavonoid content of the bread samples. The tannin and phenol content were determined by the Folin-Ciocalteu method, while the flavonoid content of the bread samples was determined by gravimetric method after evaporation.

Sensory properties of whole-wheat bread produced from blends of whole-wheat and peanut peel flour

Twenty (20) member panelists consisting of students of the Rivers State University, Port Harcourt who are regular consumer of whole-wheat bread, and not allergic to any of the raw materials used for the bread production were used for the sensory evaluation. The samples were evaluated for crumb colour, crust colour, aroma, texture, taste and overall acceptability. Each attribute was rated on a 9-point hedonic scale where: 1 = dislike extremely, 2 = dislike very much, 3 = dislike slightly, 4 = dislike moderately, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = liked very much, 9 = liked extremely (Iwe, 2010).

Statistical analysis

Data obtained for all the analysis carried out was subjected to statistical analysis using IBM SPSS Statistics (version 26). Statistical differences and relationship among variables were evaluated by analysis of variance under general linear model and Tukey pairwise comparison at 95% confidence level.

Results and discussion

Effect of peanut peel flour inclusion on the functional properties of whole-wheat flour

The Functional Properties of whole-wheat and composite flours of whole-wheat and peanut peel is represented in table 1.0. Water absorption capacity (WAC) of the flours ranged from 1.16-1.49 g/g, oil absorption capacity (OAC) ranged from 1.44-1.64 g/g, bulk density of the flour samples ranged from 0.45-0.51 g/ml, while solubility and swelling index ranged from 5.19-7.81% and 42.07-44.35%, respectively.

There was significant difference ($p<0.05$) among samples in their WAC. Inclusion of peanut peel flour increased the WAC of the whole wheat flour sample, which could be attributed to higher fibre content of the peanut peel flour (Sulieman *et al.,* 2014). The water absorption capacity in this study was high compared to sample made 100% wheat flour (0.98g/g) as reported by Awuchi *et al.,* (2019) but similar when compared with samples made from 95% wheat flour 5% defatted peanut flour (1.33g/g).

The OAC of the whole wheat flour increased with inclusion of peanut peel flour. The Oil absorption capacity is an essential functional property that contributes to enhancing mouth feel while retaining the food products' flavor (Iwe *et al.,* 2016). There was significant difference ($p<0.05$) among the samples.

There was significant difference ($p<0.05$) across sample except for Sample A and B in the bulk density of the samples. The value of bulk density in this study was low compared to 100% wheat flour (0.59 g/ml) and 95% wheat flour 5% defatted peanut flour (0.56 g/ml) as reported by Nwatum *et al.* (2020).

Solubility of the whole wheat flour sample increased with increase in inclusion level of peanut peel flour. There was significant difference ($p<0.05$) between the control and the peanut peel included samples. The solubility of the flour samples from this study were higher than 2.00-4.13% for wheat and tigernut flour blends reported by Obinna-Echem *et al*. (2024). High solubility of food can show high digestibility of the food which may indicate excellent use for infant formula and food.

Swelling index is considered a quality measure in some food products such as bakery products. It is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the α-amylose and amylopectin ratios (Iwe *et al.,* 2016). Sample A and E was significantly different ($p<0.05$) from other samples. The swelling index of the samples increased with increase in inclusion level of peanut peel flour, and was higher than 6.45-7.48% reported by Obinna-Echem *et al*. (2024).

Table 1.0 Functional Properties of whole wheat flour and composite flours of wheat and peanut peel

Sample	Water Absorption Capacity (g/g)	Oil Absorption Capacity (g/g)	Bulk Density (g/ml)	Solubility (%)	Swelling Index (%)
A	$1.16^{d}\pm0.00$	$1.44^{e}\pm0.00$	$0.45^{d}\pm0.00$	$5.19^{e}\pm0.00$	$42.79^{c}\pm0.00$
B	$1.43^{c}\pm0.00$	$1.52^{d}\pm0.00$	$0.45^{d}\pm0.00$	$7.39^{c}\pm0.00$	$42.07^{e}\pm0.00$
C	$1.41^{b}\pm0.00$	$1.64^{a}\pm0.00$	$0.46^{c}\pm0.00$	$7.36^{d}\pm0.00$	$42.64^{d}\pm0.00$
D	$1.43^{b}\pm0.00$	$1.55^{c}\pm0.00$	$0.48^{b}\pm0.00$	$7.55^{b}\pm0.00$	$43.76^{b}\pm0.00$
E	$1.49^{a}\pm0.00$	$1.58^{b}\pm0.00$	$0.51^{a}\pm0.00$	$7.81^{a}\pm0.01$	$44.35^{a}\pm0.00$

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

Key:
A= 100% Whole wheat flour
B= 97.5% Whole wheat flour and 2.5% Peanut peel flour
C= 95% Whole wheat flour and 5% Peanut peel flour
D= 92.5% Whole wheat flour and 7.5% Peanut peel flour
E= 90% Whole wheat flour and 10% Peanut peel flour

Effect of peanut peel flour inclusion on the antioxidant properties of whole-wheat bread

Antioxidant properties of the bread samples are shown in Table 2.0. Tannin content ranged from 11.18 – 15.93 mg/kg, flavonoid content ranged from 4.24-11.41%, while total phenol content ranged from 0.20-0.33 mg/100g.

The tannin content reduced with addition of peanut peels to wheat and there was significant difference (<0.05) between the control and the peanut peel included samples. Tannins are chelating agents for metals and can form complexes with macromolecules. Through this process, essential substrates and enzymes of micro-organisms are depleted leading to cell death (Okerulu *et al.*, 2017). The concentration of tannins recorded in this study for the processed African elemi is within the permissible limit of 20 mg/g (Orisa *et al.*, 2024). High tannin content is responsible for the bitter taste of some food (Nwatum *et al.*, 2020).

The flavonoid content increased with increase in inclusion of peanut peel flour. There was significant difference ($p<0.05$) between the control sample and the peanut peel included samples. Flavonoids have antimicrobial properties (Cushnie and Lamb, 2005) and also shows anti-cancer properties.

Total Phenol content increased with increase in peanut peel flour inclusion. There was significant difference ($p<0.05$) among the samples. The total phenol content from this study were lower than 2.20-4.10 mg/100g reported by Owuno and Wabali (2024) for cookies produced from wheat and banana peel flour.

Table 2.0 Antioxidant Properties of whole wheat bread produced from blends of whole wheat and peanut peel flour

Sample	Tannin (mg/kg)	Flavonoid (%)	Total Phenol (mg/100g)
A	$15.93^{a}\pm0.25$	$4.24^{e}\pm0.06$	$0.20^{d}\pm0.0$
B	$14.36^{b}\pm0.41$	$8.34^{d}\pm0.04$	$0.21^{cd}\pm0.00$
C	$11.55^{c}\pm0.31$	$8.84^{c}\pm0.08$	$0.22^{c}\pm0.00$
D	$12.47^{c}\pm0.47$	$9.55^{b}\pm0.11$	$0.23^{b}\pm0.00$
E	$11.18^{c}\pm0.26$	$11.41^{a}\pm0.08$	$0.33^{a}\pm0.01$

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

Effect of peanut peel flour inclusion on the proximate composition of whole wheat bread

The proximate composition of the bread samples is shown in Table 3.0. Moisture content, ash, fat, crude protein, crude fibre and carbohydrate contents of the samples ranged from 22.07-29.54%, 1.75-1.99%, 0.80-2.49%, 8.76-10.11%, 4.39-9.75% and 46.2-58.6%, respectively.

The moisture content from this study were high compared to moisture content of 9.98-11.40% for wheat, defatted peanut and avocado flours as reported by (Nwatum *et al.*, (2020). There was an observed decrease in moisture content of the bread samples with increase in inclusion level of peanut peel flour. The reduction in moisture content with increase in peanut flour proportion can be attributed to lack of starch for gelatinization, which is responsible for moisture retention. Moreover, higher peanut flour content may have caused a distorted gluten network.

The ash content of the bread sample increased with addition of peanut peel flour. This may be attributed to the high ash content of peanut peel (9.42%) as reported by Sulieman *et al.* (2014). The value of ash from this study (1.75-1.99%) were similar to ash content of 08.6-2.23% for white wheat and whole wheat flour at different proportion as reported by Agiriga (2014). Ash content is an overall estimate of the total mineral elements present in food (Orisa *et al.*, 2023).

Samples D and E with 2.5% and 10% peanut peel flour respectively, showed a significant increase ($p<0.05$) in crude fat content, when compared with the control. The increase of fat content in the samples with increase in inclusion level of peanut peel flour might be due to the high fat content of peanut skin powder (4.6%) (Sulieman *et al.*, 2014).

There was significant difference ($p<0.05$) among samples in their crude protein content which increased with increase in inclusion level of peanut peel flour. formulation of bread. Peanut being a good source of protein, increase in protein content is expected, and similar effect has been also reported for bread and other baked products. Similar observation has been reproted for bread and other baked products with inclusion of peanuts and other nut flours (Chinma *et al*., 2016).

The crude fibre content increased with increase in peanut peel inclusion level. The increase in crude fibre content of the samples might be as a result of high crude fibre content of peanut peel flour (11.70%) as reported by Nurilmi and Nurmahani (2024). Increase in fibre content of the bread samples suggests that these products will aid digestion thereby preventing constipation.

The carbohydrate content of the samples reduced with increase in inclusion level of peanut peel flour. There was significant difference ($p<0.05$) between the control and the peanut peel included samples. The difference in carbohydrate content of samples can be clearly attributed to differences in the levels of proximate ingredients, such as the protein content increasing as the quantity of peanut peel flour in the bread increased. This phenomenon was also reported by Ghoshal and Kaushik (2020).

Table 3.0 Proximate composition (%) of whole wheat bread produced from blends of whole wheat and peanut peel flour

Sample	Moisture	Ash	Fat	Crude Protein	Crude Fibre	Carbohydrate
A	$24.53^{b}\pm0.45$	$1.75^{b}\pm0.06$	$1.99^{b}\pm0.01$	$8.76^{e}\pm0.01$	$4.39^{c}\pm0.02$	$58.60^{a}\pm0.47$
B	$23.10^{c}\pm0.07$	$1.99^{a}\pm0.00$	$0.80^{c}\pm0.00$	$9.19^{d}\pm0.00$	$7.74^{b}\pm0.06$	$57.18^{b}\pm0.13$
C	$23.17^{c}\pm0.19$	$1.85^{ab}\pm0.06$	$0.99^{c}\pm0.01$	$9.48^{c}\pm0.05$	$7.91^{b}\pm0.09$	$56.63^{b}\pm0.26$
D	$22.07^{c}\pm0.01$	$1.94^{ab}\pm0.07$	$2.19^{b}\pm0.00$	$9.79^{b}\pm0.02$	$7.94^{b}\pm0.05$	$56.08^{b}\pm0.01$
E	$29.54^{a}\pm0.42$	$1.90^{ab}\pm0.00$	$2.49^{a}\pm0.13$	$10.11^{a}\pm0.02$	$9.75^{a}\pm0.27$	$46.22^{c}\pm0.27$

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

Effect of peanut peel flour inclusion on the sensory properties of whole-wheat bread

The sensory properties of the bread samples are shown in Table 4.0. Crust colour of the samples ranged from 7.10-7.80, crumb colour ranged from 7.30-8.10, aroma score of the samples ranged from 6.90-7.50, texture score ranged from 6.40-6.80, taste score of the samples ranged from 6.10-6.30, while the overall acceptability score of the samples ranged from 6.76-7.10. Sensory analysis according to Obinna-Echem *et al.* (2023), is an important criterion for assessing quality in the development of new products and for meeting consumer requirements.

The inclusion of peanut peel flour to whole wheat flour in bread making reduced the crumb and crust colour scores of the bread samples. There was no significant difference (p>0.05) between the control and the peanut peel included samples in the aroma, texture, taste, and overall acceptability scores of the bread samples. Increase in inclusion level of peanut peel flour however increased the texture and taste scores of the samples. This results also indicate that there is a possibility to increase the peanut flour proportion over 10% where the product may still be acceptable. Sensory panelists also liked the taste, aroma, and color of peanut peel bread at 10% or more peanut flour proportion (Adeboye *et al*., 2017).

Table 4.0 Sensory Properties of whole wheat bread produced from blends of whole wheat and peanut peel flour

Sample	Crust Colour	Crumb Colour	Aroma	Texture	Taste	Overall Acceptability
A	$7.80^{a}\pm0.89$	$8.10^{a}\pm0.97$	$7.00^{a}\pm1.03$	$6.50^{a}\pm0.95$	$6.10^{a}\pm0.97$	$7.10^{a}\pm0.72$
B	$7.10^{b}\pm0.31$	$7.30^{b}\pm0.80$	$6.90^{a}\pm0.72$	$6.40^{a}\pm0.82$	$6.10^{a}\pm1.07$	$6.76^{a}\pm0.61$
C	$7.10^{b}\pm0.72$	$7.50^{ab}\pm0.51$	$6.90^{a}\pm0.85$	$6.80^{a}\pm0.77$	$6.20^{a}\pm0.62$	$6.90^{a}\pm0.41$
D	$7.40^{ab}\pm0.50$	$7.70^{ab}\pm0.66$	$6.90^{a}\pm0.72$	$6.70^{a}\pm0.80$	$6.20^{a}\pm0.62$	$6.98^{a}\pm0.52$
E	$7.40^{ab}\pm0.94$	$7.50^{ab}\pm0.95$	$7.50^{a}\pm1.15$	$6.70^{a}\pm0.66$	$6.30^{a}\pm0.80$	$7.08^{a}\pm0.70$

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

Effect of peanut peel flour inclusion on the physical properties of bread produced with whole wheat and peanut peel flour blends

The physical properties of the samples are shown in Table 5.0. Weight of samples ranged from 153.06-160.00g, the volume ranged from 442.01-456.00 ml, while the specific volume of samples ranged from 2.850-2.895 cm^3/g.

There was significant difference (p<0.05) in the weight of the samples. The bread weight from this study (153.06-160.00 g) was higher than 150.00-158.00 g reported by Sulieman *et al.* (2014) for white wheat and peanut peel flour blends.

There was significant difference ($p<0.05$) in the volume of the samples. There was a reduction in the volume of the bread produced with peanut peel flour. The reduction in volume with increase in peanut flour has been attributed to poor gas retention and moisture diffusion ability. The reduction in volume is also attributed to the relative reduction in gluten, which is responsible for increase in bread volume, with increase in wheat replacement (Adeboye *et al.*, 2017). A decrease in bread volume was noted with increase in the inclusion of Bambara nut (Chinma *et al*., 2016).

The inclusion of peanut peel flour significantly ($p< 0.05$) affected the specific volume. The specific volume of the bread samples reduced with increase in peanut peel flour inclusion. Similar trend has been found in earlier studies where reduced-fat peanut flour was used to replace wheat up to 50% (Adeboye *et al*., 2017). The fibre content in peanut flour might have contributed for the decrease in the specific volume (Arya *et al*., 2016).

Table 5.0 Physical Properties of whole wheat bread produced from blends of whole wheat and peanut peel flour

Sample	Weight (g)	Volume (ml)	Specific Volume (cm^3/g)
A	$159.00^{b}\pm0.00$	$455.01^{b}\pm0.01$	$2.862^{c}\pm0.00$
B	$153.06^{e}\pm0.08$	$443.06^{d}\pm0.08$	$2.895^{a}\pm0.00$
C	$160.00^{a}\pm0.00$	$456.00^{a}\pm0.01$	$2.850^{e}\pm0.00$
D	$156.10^{c}\pm0.14$	$446.05^{c}\pm0.07$	$2.858^{d}\pm0.00$
E	$154.07^{d}\pm0.10$	$442.01^{e}\pm0.01$	$2.869^{b}\pm0.00$

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

Conclusion and recommendations

The use of peanut peel in whole wheat bread production has shown feasibility in food production and by extension, food waste reduction. Addition of peanut peel flour to bread baking has resulted in production of highly nutritious bread. There was an increased in fat, crude protein, crude fibre and ash contents of the samples, with reduction in moisture and carbohydrate content with increase in peanut peel inclusion level. There was no significant difference ($p>0.05$) between samples sensory overall acceptability scores. The sample with 10% peanut peel flour (sample E) had a darker colour, a firmer texture, and a more compact structure. Sample E also recorded the best antioxidant and proximate composition results. Thus, it can be concluded that 10% peanut flour in samples had the best sensory properties and was favorably accepted by the test panels.

Further research on incorporating other food wastes into food processing is highly recommended. Encouraging food waste reduction initiatives by advocating for the use of peanut peels and other underutilized ingredients in creative and innovative ways.

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