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Nutritional Quality, Amino Acid Profile and Phytochemicals of High Protein-fibre Cookies Produced from Whole Wheat, Orange-fleshed Sweet Potato, Defatted Peanut and Rice Bran Composite Flour

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Authors' contributions

This work was carried out in collaboration among all authors. Author UCC did Formal analysis, investigation, searched resources and wrote original draft. Author MSA helped in conceptualization, did supervision, Investigation, wrote, reviewed and edited the manuscript. Author IOS did formal analysis and searched for resources. Author ATJ wrote, reviewed and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the nutritional qualities of cookies from whole wheat (WW), orange-fleshed sweet potato (OFSP), defatted peanut (DPN) and rice bran (RB) composite flour. The flours (WPRG 1, 2 and 3) were formulated at different ratios (5.00-37.50%) and 100% WW flour (as control). The improved protein (13.54‐ 18.91%) and fibre (2.96‐ 8.65%) of the cookies depicted the positive inclusion of OFSP, DPN and RB flours. However, the essential minerals were significantly (p≤0.05) high in the composite cookies with no traces of heavy metals. Besides, the hydrophobic amino acids (24.10‐28.91%) and biological value (74.07‐89.77%) of the cookies showcased their potential bio-availability in some cardio-disease management. Their phenol (100.28-220.35 mg/100g) and tannin (53.40-76.50 mg/100 g) contents significantly (p≤0.05) enhanced their antioxidative power. The cookies produced from 56.25% WW, 18.75% OFSP, 5% RB and 20% DPN composite flour were mostly preferred by the consumers' ratings. Finally, the added peanut and rice bran flours showed no significant ($p<0.05$) effect on the physical properties, acceptability and preference of the cookie samples. Hence, we conclude that it is possible to produce better and high nutritional (protein, fibre, etc.) cookies from whole wheat, OFSP, defatted peanut and rice bran composite flours.

Keywords: Cookies; whole wheat; defatted peanut; orange-fleshed sweet potato; phytochemicals; hydrophobic amino acid.

1. INTRODUCTION

Cookies are baked food products globally consumed because of their relative cheap and availability as ready-to-eat snacks with appreciable quantities of iron, calcium, protein, calorie, fibre and B-vitamins needed for daily food requirements [1]. Consumers have currently developed a nutrition trend towards the consumption of low-carbohydrate diets, including slowly digested food products, as well as an increased intake of functional foods [2]. This new trend has positioned the food professionals/industries to face the challenges of producing food products containing functional ingredients in order to meet the nutritional requirements of individuals with health challenges [3]. Therefore, cookies could serve as vehicle for delivery of important nutrients if made readily available to the population in a small flat, either crisp or soft but firm qualities [4]. Nutritionally, cookies are consumed extensively all over the world as a snack food and on a large scale in developing countries where protein and caloric malnutrition are prevalent [4]. It is majorly produced from wheat flour and other ingredients but research has shown that it could also be produced from other composite flour that are of more health benefits than the regular wheat flour [5].

Composite flour is the flour with combination of flours from roots and tubers, whole grains, oilseeds and legumes to either partially or totally replace wheat flour in the production of baked products [6]. The use of composite flour has been promoted due to the viscoelastic property of gluten in wheat flour that has been linked with celiac disease in gluten-sensitive people [7]. Hence, the adoption of composite flour for the production of baked products to improve the nutritional quality of baked products, promoted the use of locally available crops and reduced the use of wheat flour thereby reducing the cost incurred on wheat importation [6]. The incorporation of flours from locally grown crops, either singly or in composite form, during the production of cookies or other readily-available foods have been previously reported. Notably, crops like plantain [8], OFSP ([9], groundnut [10], cocoyam [11], cassava [12], bambara groundnut [7] and pigeon pea [13] have been concisely exploited in various novel snacks and food productions. Nevertheless, there is scarcity of information on the nutritional and chemical properties of cookies produced from combination of processed flours obtained from whole wheat, OFSP, defatted peanut and rice bran due to their compositions.

For instance, whole wheat (*Triticum monococcum* L.) is richer in vitamins, minerals, fibre and antioxidants than refined wheat, which is mainly starch [14]. Moreso, whole wheat has been linked with reduced risk of diabetes, cardiovascular diseases and cancer as a result of its nutritional and antioxidant components including flavonoids, carotenoids, tocopherols, and phenolic acids [15-16]. The report also shown that cereal proteins were limiting in lysine and tryptophan, which were essential amino acids needed in the body [6]; hence, the need for utilization of composite flour with a good source of protein, such as peanut to complement the deficiency. The use of defatted peanut (*Arachis hypogaea* L.) meal has been reported with capability to address the issue of malnutrition in developing countries due to its high protein [11] in baked, complementary, breakfast cereals and extruded food products [17].

Furthermore, sweet potato (*Ipomoea batatas* L.), especially the orange-fleshed one is an excellent source of beta-carotene (the precursor of vitamin A) hence, its utilization in food products to combat vitamin A deficiency [18-19]. OFSP is a World Health/ Food Organization-recognized root crop with dietary fibre that helped in digestion and blood cholesterol regulation [20] and regarded for its antidiabetic potential due to its low glycemic index [21-22]. Although rice (*Oriza sativa* L.) bran is a by-product of rice milling industry, which is usually discarded as waste and used for animal feed production but it is now being considered for food and health application due to its high dietary fibre and minerals to promote the nutritional quality baked products [23]. It has been reported as an excellent source of bioactive compounds such as polyphenols and flavonoids with antioxidant, antiviral and antimicrobial effects on human health [24-25]. Therefore, this study aimed to investigate the nutritional effects of substituting wheat flours with OFSP, defatted peanut and rice bran composite flour on the nutrient bioavailability and consumer acceptance of the produced cookies.

2. MATERIALS AND METHODS

2.1 Sources of Raw Materials

Rice bran was obtained from a local rice mill in Ise-Ekiti, Nigeria while the OFSP, whole wheat grains, peanut seeds, commercial wheat flour and other baking ingredients (sugar, vegetable oil, baking powder, salt and egg) were obtained from *Erekesan* market, Akure, Nigeria. The whole wheat grains, OFSP and peanut seeds were authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Nigeria. All chemicals and reagents used were of analytical grade and obtained from Sigma-Aldrich, London, UK and Fischer Chemicals, USA.

2.2 Preparation of whole wheat flour

The whole wheat flour was prepared as described [14]. Briefly, the grains were sorted to remove unwanted materials such as stones and immature grains, washed with clean water, drained, dried in hot-air oven (Plus11 Sanyo Gallenkamp PLC, UK) at 60 °C for 12 h, milled using Laboratory Kenwood Electronic blender (Model KM 901 D, Hertfordshire, UK), sieved through 200 mm mesh sieve (British Standard) and stored.

2.3 Preparation of OFSP flour

The procedure previously described [26] was employed for the production of the OFSP flour. Freshly harvested OFSP tubers were sorted, washed, peeled, sliced into thin pieces and dried in hot-air oven (Plus11 Sanyo Gallenkamp PLC, UK) at 60 °C for 48 h, milled using Laboratory Kenwood Electronic blender (Model KM 901 D, Hertfordshire, UK), sieved through 200 mm mesh sieve (British Standard) and stored for further use.

2.4 Preparation of Defatted Peanut Flour

The peanut seeds were sorted to remove stones, immature seeds and other unwanted materials. The seeds were roasted at 170 °C for 15-20 min in hot-air oven (plus11 Sanyo GallenKamp PLC, UK), dehulled and cooled at room temperature as previously described [11]. The roasted peanut seeds were milled with Philips laboratory blender (model HR2811) and defatted as described [25] using n-hexane as extraction solvent in a Soxhlet apparatus for 12 h. The defatted peanut flour was oven-dried (Plus11 Sanyo Gallenkamp PLC, UK) at 40 °C for 2h to allow the solvent to evaporate, milled, sieved using 200 mm mesh sieve (British Standard) and stored for further use.

2.5 Preparation of Rice Bran Flour

Rice bran flour was produced as previously described [27]. Fresh rice bran was washed with clean water, drained, dried in hot-air oven (Plus11 Sanyo Gallenkamp PLC, UK) at 60 °C for 10 h, milled using Laboratory Kenwood Electronic blender (Model KM 901 D, Hertfordshire, UK), sieved through 200 mm mesh sieve (British Standard) and stored for further use.

2.6 Formulation of Composite Flour

The composite flour (Table 1) used for the production of the cookies was formulated from whole wheat, orange-fleshed sweet potato, defatted peanut and rice bran flours using.

NutriSurvey Linear Programming Software version 20.0 (NSLPS Inc. Chicago, Illinois, USA) to obtain different formulations as presented in Table 1. The composite flour obtained was homogenously mixed together using Philips laboratory blender (model HR2811) and stored for further use.

2.7 Production of the Cookies

The creaming method previously described [4] was used for the production of the cookies. Briefly, date (20 g), vegetable oil (10 g) and salt (0.1 g) were thoroughly mixed together using Philips laboratory mixer (model HR2586), after which composite flour (100 g), baking powder (1 g), whole egg (20 g) and water were also added to the mixture. The resulting batter was baked in the oven at 180 °C for 20 min, cooled at room temperature and packed in high-density polyethylene film for further analyses.

2.8 Determination of Proximate Composition

The proximate composition (moisture, protein, fat, ash and crude fibre contents) of the cookies was determined using the previously described methods [28]. Carbohydrate content was calculated by difference while the energy value was estimated using the At-Water factor for carbohydrate (4 kcal/g), protein (4 kcal/g) and fat (9 kcal/g) as previously described [29].

2.9 Determination of Mineral Composition

Mineral elements were determined as described [28]. For instance, calcium, magnesium, manganese, zinc, copper and iron were determined using atomic absorption spectrophotometer (AAS Model SP9). Sodium and potassium were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards, respectively. However, phosphorus was determined using the vanado-molybdate colorimetric method while Na/K molar ratio was also calculated.

2.10 Determination of Amino acid Profile

The amino acid profile of the cookies was determined using the previously described method [30]. The cookies were digested using 6 N HCl for 24 h and the amino acids were determined using the Beckman Amino Acid Analyzer (model 6300; Beckman Coulter Inc., Fullerton, CA, USA) while sodium citrate buffers were used as step gradients with the cation exchange post column in hydrin-derivatization method. Following the hydrolysis, 2.4 mol/L perchloric acid was used to neutralize KOH and the supernatant was adjusted with acetic acid to pH 3.0. The aliquot (20-µL) of the hydrolyzed cookies were subjected to derivatization as described above. Cysteine and methionine contents were determined after performic acid oxidation while colorimeter was used to measure the tryptophan content.

Table 1. Formulation of flour blends from whole wheat, OFSP, peanut and rice bran for cookies production

Samples	Raw materials	CW	WW	OFSP	DPN	RB	Total (%)
WPRG-1	Whole wheat + OFSP + DPN + Rice bran	-	56.25	18.75	20	5	100
WPRG-2	Whole wheat + OFSP + DPN + Rice bran	-	37.50	37.50	20	5	100
WPRG-3	Whole wheat + OFSP + DPN + Rice bran	-	18.75	56.25	20	5	100
WWF	Whole wheat flour	-	100	-	-	-	100
CWF	Commercial wheat flour	100	-	-	-	-	100

CW = Commercial wheat; WW= Whole wheat; OFSP = Orange-fleshed sweet potato; DPN = Defatted Peanut; RB = Rice bran

2.11 Estimation of Nutritional Quality Indices

Nutritional quality indices were estimated using the amino acids composition of the cookies. The essential amino acid index (EAAI) was estimated using the predictions [31], protein efficiency ratio (PER) was estimated according to the regression equations [32] while the biological value (BV) was calculated as described [33].

2.12 Determination of Phytochemical Properties

Phytate concentration of the cookies was determined according to the AOAC methods [28]. About 2 g of the sample was measured, dissolved in 100 ml of 2% hydrochloric acid for 3 hr and filtered through a No 1 Whatman filter paper. The filtrate (25 ml) was measured into a conical flask, 5 ml of 0.03% ammonium thiocyanate solution was added as indicator, 50 ml of distilled water was added and the resulting solution was titrated against standard iron (III) chloride solution containing 0.005 mg of iron per ml until a brownish colour that persisted for 5 min was observed.

Tannin concentration of the cookies was determined as described [34]. About 0.2 g of the cookies was weighed into a sample bottle, 10 ml of 70% aqueous acetone was added and the mixture properly covered. Each bottle containing the mixture for each sample was shaken in an ice bath shaker continuously at 30 ^{o}C for 2 h. Each solution was centrifuged at 3000 × g and the supernatant was stored in ice. The supernatant (0.2 ml) was pipetted into test tubes and 0.8 ml of distilled water was added. Standard solution of tannin was prepared with 0.5 mg/ml stock solution and made up with distilled to 1 ml. Folin-Ciocalteu reagent (0.5 ml) was added to the sample and the standard, followed by 2.5 ml of 20% sodium carbonate solution and the mixture was incubated at room temperature for 40 min. The absorbance of the samples was read at 725 nm against a reagent blank and the concentration of the sample was obtained from a standard tannic acid curve.

Oxalate concentration of the cookies was determined [35]. Each sample (1 g) was weighed into 100 ml conical flask, 75 ml of 3 ml of sulphuric acid was added, the solution was gently stirred with a magnetic stirrer for about 1 h and filtered using Whatman No. 1 filter paper. The filtrate (25 ml) was measured and titrated against hot (80 – 90 ^{o}C) 0.1 N potassium permanganate solution till the solution turned to faint pink that persisted for at least 30 s. The oxalate concentration of the cookies was calculated from: 1 mL 0.1 permanganate = 0.006303 g oxalate

The previous method [36] was employed for the determination of saponin content of the cookies. Each sample (5 g) was extracted with 20 % aqueous methanol (100 ml) in a conical flask at room temperature and the resulting solution was heated in a hot water bath at 55 ^{o}C for 4 h and stirred continuously. The mixture was filtered and extracted again with 200 ml of 20 % ethanol. The resulting extract was evaporated to 40 ml over water bath at 90 ^{o}C, the resulting concentrate was transferred into a separating funnel, 20 ml of diethyl ether was added and vigorously shaken. The aqueous layer was recovered, the other part was disposed and the purification process was repeated. The mixed n-butanol extracts were washed with 10 ml of 5% aqueous sodium chloride solution, the remaining solution was evaporated in a water bath and the sample was dried in the oven till constant weight was observed. Saponin content was calculated as the percentage weight of the sample.

Determination of flavonoid content of the cookies was determined as described [37]. Briefly, 10 g of the sample was extracted with 100 ml of 80% aqueous methanol at room temperature and filtered with Whatman filter paper No. 42 (125 mm). The filtrate obtained was transferred into a crucible and evaporated over a water bath to dryness and dried to constant weight.

Total phenolic content was determined as described [38] using gallic acid (Sigma, St. Louis, USA) as the standard. About 5 g of the sample was dissolved in 5 ml of a methanol: water mixture (50:50 v/v). Then, the resulting solution was poured into series of tubes and made up to 100 ml with the mixture of methanol and water already prepared. Five hundred microlitres of 50% Folin–Ciocalteu reagent was added to each tube and mixed. The mixture was then allowed to stand for 10 min, 1.0 mL of 20% sodium bicarbonate was added, incubated at room temperature, centrifuged at 10,000 x g for 5 min and the absorbance of the supernatant was measured at 700 nm.

2.13 Determination of Physical Properties of the Cookies

The weight, diameter, thickness and spread ratio of the cookies were measured as described [4].

The laboratory digital weighing balance was used to measure the weight of the cookies while vernier calliper was used to measure the diameter and the thickness of the cookies. The spread ratio of the cookies was calculated as the ratio of diameter to thickness.

2.14 Sensory Evaluation of the Cookies

The sensory properties of the cookies including appearance, aroma, taste, mouth feel, texture, crispiness, and overall acceptability were assessed for consumer acceptability by 50 semi-trained panellists who were regular consumers of cookies using 9-point hedonic scale where “9” represents extremely like and “1” represents extremely dislike, as previously described [4].

2.15 Statistical Analysis

The data were generated from the analyses in triplicate values and subjected to one-way analysis of variance using Statistical Package for Social Sciences (SPSS 21.0 SPSS Inc. Chicago, Illinois, USA). The means with significant difference were separated using Duncan’s new multiple range test at 95% ($p<0.05$) confidence level.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of the Cookies

The results in Table 2 showed that the fat and protein contents of the cookies ranged from 3.13-10.72 and13.54-18.91%, respectively with moisture contents (<6%) that were within the recommended moisture level (10%) for maximum shelf life of baked products [7]. Although, the fat contents of the cookies decreased as the level of wheat substitution increased as observed between samples WPRG-2 and CWF but contrarily the protein content of WPRG-2 increased (Table 2). The current fat and protein contents obtained were lower than those reported for biscuits from wheat and partially defatted groundnut paste flours [10]. The fibre contents of the cookies produced from composite flour were significantly ($p\leq0.05$) higher (7.09-8.65%) than that of WWF (3.5%) and CWF (2.96%) and this might be due to the addition of rice bran, a high source of dietary fibre with cholesterol lowering potential in cardiovascular health [39]. The obtained carbohydrate contents in this study (58.45-64.59%) agreed with the previous finding [10] that observed a higher carbohydrate content in biscuit from 100% wheat.

3.2 Mineral Composition of the Cookies

The essential minerals (phosphorus, magnesium, calcium, zinc and potassium) that were found in substantial amount in the cookies were presented in Table 3. For instance, the magnesium (48.21-59.37 mg/100g) and zinc (11.26-26.38 mg/100g) found abundant in WPRG-3, were co-factors involved in glucose metabolism by activating insulin receptors [40]; hence, their nutritional importance in diabetes management is crucial. Calcium is an important agent in blood clotting, bone and teeth development as well as prevention of osteoporosis in adult [25], whereas potassium is needed to regulate osmotic balance of the body fluids, body pH, irritability of nerve and muscle, absorption of glucose into the body and protein retention during growth [41]. However, study [42] reported iron to be part of important components of blood and enzymes responsible for transfer of electron (antioxidant). These three elements, calcium (30.20-34.20 mg/100g), potassium (32.98-83.61 mg/100g) and iron (1.25-1.70 mg/100g) were higher in the composite cookies than the control and this could be attributed to the inclusion of OFSP as previously reported [43].

Interestingly, there was no trace of heavy metals like selenium and lead in the produced cookies, which therefore made them not toxic nor posed any adverse effects on the body organs after consumption [25]. Besides, the low sodium contents (2.24-2.70 mg/100g) exhibited by the cookies also resulted in their low Na/K ratios (0.10-0.13). Meanwhile, the Na/K ratios (0.10-0.13) observed in this study were within the recommended value of <1 [44], which is a good indicator of the cookies suitable as potential functional food for people living with hypertension, obesity and other cardiovascular diseases.

Table 2. Proximate composition and Energy values of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Sample	Moisture (%)	Fat (%)	Protein (%)	Fibre (%)	Ash (%)	Carbohydrate (%)	Energy value (kcal/100g)
WPRG-1	5.23 ± 0.36^{b}	3.13±0.06^{b}	18.91 ± 0.12^{a}	8.65 ± 0.30^{a}	1.52 ± 0.04^{d}	62.56±0.90^{b}	366.06±1.00^{e}
WPRG-2	5.07 ± 0.06^{b}	9.25 ± 0.07^{c}	17.49 ± 0.05^{b}	7.09 ± 0.06^{c}	2.65 ± 0.14^{c}	58.45±0.64^{d}	387.01±2.46^{c}
WPRG-3	5.83 ± 0.05^{a}	8.68 ± 0.01^{d}	13.54±0.05^{d}	8.15 ± 0.00^{ab}	2.72±0.05^{bc}	61.08±0.12^{c}	376.60±3.12^{d}
WWF	5.11 ± 0.11^{b}	8.29 ± 0.03^{d}	15.73 ± 0.01^{c}	3.50 ± 0.05^{d}	2.98 ± 0.01^{b}	64.39±1.21^{a}	395.09±1.05^{b}
CWF	4.33 ± 0.11^{c}	10.72 ± 0.03^{a}	13.79 ± 0.01^{d}	2.96 ± 0.05^{e}	3.61± 0.01^{a}	64.59±1.38^{a}	410.00±3.68^{a}

Mean ± standard deviation (n=3) values with different superscripts in the same column are significantly different (p≤0.05)

WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% RB + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% RB + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% RB + 20% DPN; WWF = cookies produced form 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted Peanut; RB = Rice branflour compared to the wheat-partially defatted groundnut paste composite flour. Notably, the present study reported the high energy values of 366.06-410 kcal/100g, which could be attributed to the fact that wheat grains and OFSP were major pools of energy [21]

Table 3. Mineral composition (mg/100 g) of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Element	WPRG-1	WPRG-2	WPRG-3	WWF	CWF
Fe	1.70±0.12 ^{a}	1.45±0.15^{b}	1.30±0.10 ^{d}	1.40±0.15 ^{c}	1.25±0.05 ^{e}
Mg	59.02±1.25^{a}	58.00±1.74^{ab}	59.37±1.81^{a}	50.43±1.20^{c}	48.21±1.18^{d}
Zn	20.13±0.94^{c}	21.03±0.12^{b}	26.38±0.70^{a}	18.08±0.45^{d}	11.26±0.93^{e}
Ca	31.00±0.11 ^{c}	34.00±0.12 ^{a}	34.20±0.15 ^{a}	32.00±0.12 ^{b}	30.20±0.02^{d}
P	78.26±1.73^{b}	75.28±1.34^{c}	83.61±2.00^{a}	63.16±1.68^{d}	32.98±1.00^{e}
Na	2.24±0.13 ^{d}	2.70±0.10 ^{a}	2.50±0.12 ^{b}	2.27^{c}±0.15 ^{c}	2.57±0.04 ^{b}
K	22.00±0.15 ^{b}	24.00±0.12 ^{a}	20.00±0.01 ^{c}	19.00±0.14 ^{d}	20.34±0.07 ^{c}
Mn	1.12±0.02 ^{c}	1.16±0.36 ^{c}	1.21±0.01 ^{c}	1.72±0.03 ^{b}	1.81±0.02 ^{a}
Cu	0.05±0.01^{a}	0.07±0.01^{a}	0.07±0.02^{a}	0.08±0.01^{a}	0.08±0.02^{a}
Se	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND
Na/K	0.10±0.01^{d}	0.11±0.02^{c}	0.13±0.04^{a}	0.12±0.03^{b}	0.13±0.01^{a}

Mean ± standard deviation (n=3) values with different superscripts in the same row are significantly different (p≤0.05)

WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% Rice bran + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% Rice bran + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% Rice bran + 20% DPN; WWF = cookies produced from 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted peanut; RB = Rice bran

3.3 Amino acid Profile of the Cookies

Glutamic acid (10.52-13.30 g/100 g) and aspartic acid (7.62-12.87 g/100 g) were the predominant amino acids in the produced cookies with the highest contents in cookie sample WPRG-2 and WPRG-1, respectively as presented in Table 4. Past study reported the glutamic acid as the most abundant non-essential amino acid in most plant-based foods and invariably helped in promoting normal brain function, cognitive development in children as well as prevention of memory loss [25]. The total essential amino acids (TEAA), total non-essential amino acids (TNEAA) and total amino acids (TAA) of the cookies ranged from 26.14 to 31.11; 37.20 to 45.02 and 64.63 to 76.13 g/100 g, respectively. The TAA of the cookies obtained in this study (64.63-76.13 g/100 g) were lower than the77.50-87.26 g/100 g reported for cookies produced from sorghum, orange-fleshed sweet potato and mushroom protein isolate [9].

Some data were estimated from the amino acid profile (Table 4) as the nutritional quality indices of the cookies produced in this present study. For instance, the Arg/Lysine, EAAI, PER, BV of the cookies estimated from the amino acid profile of the different cookies obtained were 0.59-0.84, 78.69-93.09%, 0.61-0.97 and 74.07-89.77%, respectively, with the composite cookies WPRG-1 and WPRG-2 having the significant estimated values. It has been known that food products very rich in arginine possessed hypocholesterolemic properties on cardiovascular diseases [9]; hence, samples WPRG-1 and WPRG-2 would be a potential anti-hypocholesterolemic agents. The hydrophobic amino acids (HAA) of the cookies ranged from 24.10 in WPRG-3 to 28.91 in WPRG-2. Factually, the increase in HAA contents would help to increase lipid solubility of the resultant cookies, thereby enhancing their antioxidant activities in disease-management [21, 45]. The current study further revealed that the the EAAI and BV of the resultant cookies were greater than the 70% recommended by FAO/WHO for food products commonly found useful in disease managements [9].

The higher levels of these factors obtained from the composite cookies could be attributed to the use of multiple plant crops, which has been reported for better improvement of essential amino acids and nutritional quality of foods [25,46-47]. However, the Fischer ratio (FR) of the cookies were given as 1.08-1.29 and FR has been found helpful to determine biological activities of proteins [48].

Table 4. Amino acid profiles (g/100 g protein) of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flours

Amino acid	WPRG-1	WPRG-2	WPRG-3	WWF	CWF	FAO/WHO	Egg
Valine	4.76	4.56	3.64	4.48	4.28	3.5	4.3
Threonine	2.92	2.89	2.23	2.04	2.53	3.4	2.9
Isoleucine	2.70	2.69	2.69	2.27	2.67	2.8	4.0
Leucine	3.91	4.00	3.15	3.40	3.48	6.6	5.3
Methionine	2.62	2.56	2.91	2.94	2.14	2.2	3.2
Phenylalanine	4.42	5.57	3.41	4.19	4.32	2.8	5.1
Lysine	3.70	3.85	3.72	3.17	3.12	5.8	3.7
Histidine	3.72	3.75	3.49	3.29	3.40	1.9	2.4
Tryptophan	0.91	1.24	0.90	1.01	1.49	1.1	1.8
Alanine	2.52	2.76	2.18	2.57	2.58		
Aspartic acid	12.87	11.21	10.22	8.24	7.62		
Glutamic acid	12.01	13.30	11.41	11.34	10.52		
Serine	4.44	4.54	4.85	4.38	4.34		
Glycine	3.21	3.22	2.81	3.12	3.18		
Proline	2.78	2.31	2.41	2.00	2.10		
Arginine	2.88	3.03	2.19	2.28	2.61		
Tyrosine	3.49	3.61	3.31	3.32	3.03		
Cystine	0.39	1.04	1.49	1.22	1.22		

WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% Rice bran + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% Rice bran + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% Rice bran + 20% DPN; WWF = cookies produced from 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (control); OFSP = Orange-fleshed sweet potato; DPN = Defatted peanut; RB = Rice bran

Table 5. Estimated nutritional quality indices of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Parameter	WPRG-1	WPRG-2	WPRG-3	WWF	CWF
HAA	27.83	28.91	24.10	25.98	26.24
AAA	8.82	10.42	7.62	8.52	8.84
NCAA	24.88	24.51	21.63	19.58	18.14
BCAA	11.37	11.25	9.48	10.15	10.43
Arg/Lysine	0.78	0.79	0.59	0.72	0.84
EAAI (%)	87.75	93.09	78.69	79.90	84.22
PER	0.94	0.97	0.61	0.73	0.79
BV (%)	83.95	89.77	74.07	75.39	80.10
Fischer ratio	1.29	1.08	1.24	1.19	1.18
TEAA	29.66	31.11	26.14	26.79	27.43
TNEAA	44.59	45.02	40.87	38.47	37.20

WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% Rice bran + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% Rice bran + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% Rice bran + 20% DPN; WWF = cookies produced from 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted peanut; RB = Rice bran; HAA = Hydrophobic amino acid; AAA = Aromatic amino acid; NCAA = Negatively charged amino acid; BCAA = Branched chain amino acid; EAAI = Essential amino acid index; PER = Protein efficiency ratio; BV= Biological value; TEAA = Total essential amino acids; TNEAA = Total non-essential amino acids; TAA = Total amino acid

3.4 Phytochemical Composition of the Cookies

Phytochemicals or plant chemicals is described as the secondary metabolites of the plants that were of health benefits to human. Hence, the current study had the flavonoid (43.00-76.50 mg/100 g), saponin (9.29-18.29 mg/100 g), tannin (1.23-2.67 mg/100 g), phenol (100.28-220.35 mg/100 g), oxalate (10.87-18.87 mg/100 g) and phytate (0.89-1.36 mg/100 g) contents (Table 6), respectively. The concentrations of phytochemicals observed in this study were low and within permissible levels (LD_{50} in Table 6). Report had shown that the dietary phytate assisted in reducing the rate of starch digestion and regulation of insulin secretion in the body [21] and this could have been a great tool for diabetes management. Interestingly, phenolic compounds, which have been regarded as the excellent antioxidants in most foods [21] were the predominant phytochemicals in the cookies produced in the present study. It was also observed in this study that the cookies produced from the composite flour blends had significant ($p \leq 0.05$) higher phenol contents than those from WWF and CWF (control). This, however might be due to the addition of orange-fleshed sweet potato [21,49] and rice bran [24] flours, which served as excellent sources of phenolic compounds conferring positive effects on human health.

Table 6. Phytochemical composition (mg/100g) of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Parameter	WPRG-1	WPRG-2	WPRG-3	WWF	CWF	LD_{50}(with references)***
Flavonoid	53.40±1.10^b	75.00±2.24^a	76.50±2.10^a	48.70±1.01^c	43.00±2.37^c	
Saponin	15.18±0.82^b	13.34±0.45^c	18.29±0.80^a	10.82±0.30^d	9.29±0.09^e	147.11^a ±1.34^1
Tannin	1.30±0.03^c	2.39±0.04^b	2.67±0.07^a	2.19±0.12^b	1.23±0.03^c	200.26±0.08^2
Phenol	183.20±0.20^c	190.7±0.00^b	220.35±0.20^a	100.28±0.00^d	100.63±0.06^d	
Oxalate	12.60±0.01^c	10.87±0.58^d	18.87±0.06^a	16.71±0.01^b	18.70±0.01^a	30.00^a±0.15^3
Phytate	1.12±0.05^b	1.36±0.02^a	1.34±0.06^a	0.89±0.40^c	1.03±0.05^b	83.00±0.10^4

Mean ± standard deviation (n=3) values with different superscripts in the same row are significantly different (p≤0.05)
WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% Rice bran + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% Rice bran + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% Rice bran + 20% DPN; WWF = cookies produced from 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted peanut; RB = Rice bran
LD_{50} = Lethal dose rate at 50% concentration.
****1 =Yang et al. (2013); 2 =Boyd (1965); 3 = de Siqueira et al. (2021); 4 = Chattopadhyay et al. (1995)*

3.5 Physical Properties of the Cookies

The physical properties of the cookies were presented in Table 7. The weights and diameters of the cookies ranged from 5.18 to 6.62 g and 45.90 to 45.95 mm with samples WPRG-1 and WPRG-3 having the significant ($p<0.05$) least and highest values, respectively when compared to those from common CWF. The highest diameter observed for cookie sample WPRG-3, with the lowest quantity of whole wheat flour (18.75%), might be as a result of low level of gluten composed in the quantity of flour used. This undoubtedly could make the dough to flow after moulding and had resultant consequence on the diameter of the final cookies [50-51]. The present study also agreed with the past finding [7] that reported an increase in the diameter of the supplemented biscuits due to reduction in the quantity of wheat flour. However, the thickness of the cookies ranged from 5.03 to 5.10 mm with no observable difference in cookie samples WPRG-1, WPRG-3 and WWF.

The spread ratio of cookies, which is an index of particle size and wettability of flour with the category of oil used in their production [50], ranged from 8.83 to 9.14. The qualities and leavening potentials of flours used in any snack formulation and production could be evaluated by the spread ratio of the snack [51-52]. Hence, the lowest spread ratio (8.83) and highest thickness (5.10 mm) obtained for sample CWF, when compared to other sample, could be due to the hydrophilic nature of the industrialized-refined flour [5] used for sample CFW.

3.6 Sensory Evaluation of the Cookies

Table 8 showed the sensory attributes of the cookies, which were impacted by flavour, taste, appearance, texture, colour, general acceptability and past knowledge of cookies by the panellists [53]. The result revealed that sample WPRG-1 (cookies produced from 56.25% WW + 18.75% OFSP + 5% RB + 20% DPN) had the best and significant ($p \le 0.05$) sensory attributes when

Table 7. Physical properties of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Sample	Weight (g)	Diameter (mm)	Thickness (mm)	Spread ratio
WPRG-1	5.18 ± 0.07^e	45.90 ± 0.17^a	5.03 ± 0.08^a	9.13 ± 0.01^a
WPRG-2	6.01 ± 0.02^c	45.93 ± 0.06^a	5.06 ± 0.28^a	9.08 ± 0.04^b
WPRG-3	6.62 ± 0.02^a	45.95 ± 0.46^a	5.03 ± 0.51^a	9.14 ± 0.02^a
WWF	5.41 ± 0.01^d	45.91 ± 0.14^a	5.03 ± 0.43^a	9.13 ± 0.04^a
CWF	6.51 ± 0.01^b	45.03 ± 0.58^a	5.10 ± 0.01^a	8.83 ± 0.01^b

Mean ± standard deviation (n=3) values with different superscripts in the same column are significantly different ($p \le 0.05$)
WPRG-1 = cookies produced from 56.25% WW + 18.75% OFSP + 5% Rice bran + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% Rice bran + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% Rice bran + 20% DPN; WWF = cookies produced from 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted peanut; RB = Rice bran

Table 8. Sensory attributes of cookies produced from whole wheat, sweet potato, peanut and rice bran composite flour

Sample	Appearance	Aroma	Taste	Mouth feel	Texture	Crispiness	Overall Acceptability
WPRG-1	8.20^b	7.50^b	7.70^b	7.90^b	7.45^b	7.75^b	8.20^{ab}
WPRG-2	7.05^c	6.65^{bc}	5.85^c	6.55^c	6.45^{bc}	6.40^c	6.95^c
WPRG-3	6.95^c	6.25^c	5.25^c	5.90^c	5.75^{cd}	5.85^{cd}	6.50^c
WWF	6.45^c	4.70^d	3.70^d	4.10^d	4.90^d	5.50^{cd}	4.55^d
CWF	8.90^a	8.70^a	8.80^a	8.90^a	8.85^a	8.65^a	8.92^a

Mean (n=50) values with different superscripts in the same column are significantly different (p≤0.05)
WPRG-1 = Cookies produced from 56.25% WW + 18.75% OFSP + 5% RB + 20% DPN; WPRG-2 = cookies produced from 37.50% WW + 37.50% OFSP + 5% RB + 20% DPN; WPRG-3 = cookies produced from 18.75% WW + 56.25% OFSP + 5% RB + 20% DPN; WWF = cookies produced form 100% Whole wheat flour; CWF = cookies produced from 100% Commercial wheat flour (Control); OFSP = Orange-fleshed sweet potato; DPN = Defatted Peanut; RB = Rice bran

compared to those from 100% whole wheat (WWF).

The sample WPRG-1 also showed a closer comparative in terms of overall acceptability of the cookies and those from the commercial sources (CWF) by the panelists. The taste of the cookies was given better ratings than the other parameters, which corresponded to the previous submission [54] that described the taste of any food product as an essential parameter that determined its acceptability.

4. CONCLUSION

This study revealed that the developed cookies from the composite flour of whole wheat, defatted groundnut, orange-fleshed sweet potato and rice bran exhibited improved protein, fibre and essential mineral elements with appreciable amount of essential amino acids. Besides, the produced cookies demonstrated health-promoting phytochemicals, especially phenols, with no adverse effect on bioavailability of the nutrients. This therefore showcased the feasibility of having acceptable cookies from blends of whole wheat, orange-fleshed sweet potato, defatted peanut and rice bran, thereby promoting a great opportunity of utilizing the locally available food crops. Finally, the added peanut and rice bran flours during the production process enhanced and nutritionally improved the physical properties, acceptability and preference of the cookie samples, which could serve as potential agents in the modulation or management process of several chronic diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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