Original Research Article

Physicochemical, nutritional and functional properties of composite flour blends from whole wheat, sweet potato, defatted peanut and rice bran

Abstract

The surge in import duty has affected the cost of production of baked products. Hence, an impetus to the formulation of composite flour from locally available food cropswith improved nutritional and functional properties as well as health-promoting components for baked food products. This study thus, aimed to formulate and determine the nutritional, phytochemical, functional and pasting properties of composite flour from blends of whole wheat, sweet potato, defatted peanut and rice bran while commercial wheat flour (CWF) was used as the control. The protein (15.81-21.98%) and the fiber (7.93-10.82%) contents of the composite flour were significantly ($p \leq 0.05$) higher than that of the control 13.69% and 1.86%, respectively. The composite flour had improved essential minerals elements (magnesium, zinc, calcium and phosphorus). Similarly, the total essential amino acids (26.73-34.27 g/100g), essential amino acid index (80.03-102.13%) and biological value (75.53-99.62%) of the composite flour were higher than that of the control (25.79 g/100g, 76.85% and 72.07%), respectively. Moreso, the flour blends also demonstrated better phytochemical and pasting properties over the control samples. This study therefore, established thatcomposite flour with improved macro- and micro-nutrients could be formulated from blends of whole wheat, sweet potato, defatted peanut and rice bran.The composite flour, which could serve as better replacement for commercial wheat flour in baked products, thereby reducing the cost incurred on wheat importation as well as ensuring food security in most developing nations like Nigeria.

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The raw materials used for the formulation of the composite flour such as whole wheat grains, sweet potato and peanut seeds were purchased from the Shasha market in Akure, Nigeria while rice bran was obtained from a local rice mill in Ise-Ekiti, Nigeria. The food crops were authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Nigeria.

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Keywords: Composite flour, amino acids, phytochemical, pasting properties, sweet potato, defatted peanut

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1 Introduction

Composite flour is the combination of two or more flour in different quantity with or without the addition of wheat flour for the development of various baked products. This is donewith the aim of improving the nutritional composition as well as promoting the utilization of locally available food crops [1]. For instance, food crops that are not expensive, locally available and culturally acceptable with appropriate functional properties and improved nutritional valueswere found useful to replace wheat flour in the production of baked products [2]. This is because, the composite flour from mixture of cereal, legume or tuber had been found to produce better nutritional value than flour from single food crop [2]. Hence, the composite flour technology has been a major means of meeting the nutritional needs, especially theprotein and fibre needs of most consumers in some underdeveloped and developing nations in the world[3].

Wheat (*Triticumaestivum*) is an important grain for human consumption globally with annual production of over 600 million tons [4].Meanwhile, the whole wheat flour has been found to be superior to the refined wheat flour due to its high dietary fibre, vitamins, minerals, antioxidants and phytochemicals [5]. Notably, the consumption of whole grains has been encouraged to manage the incidence of type-2 diabetes and cardiovascular diseases [5]. Interestingly, the wheat grain is commonly utilized in the production of baked products due to the viscoelastic nature of its protein [6]. However, the utilization of locally available food crops has been limited due to a total reliance on wheat flour for production of baked products, thereby leading to the increasing but unaffordable costs of baked products. It is noteworthy to know that the composite flour from roots and tubers, legumes and other locally available crops has been used to either partially or totally replace wheat flour.These concerted effortswere made by the government and various researchers to ensure improved nutritional qualities of the final baked products at affordable prices for all households [7].

Sweet potato (*Ipomoea batatas*L.) is the seventh most important food crop in the world and fifth in the developing countries after rice, wheat, maize and cassava. It is the next root and tuber after cassava that is commonly grown in the world [8]. Sweet potato has great potential for food in developing countries due to its ability to survive under different climatic conditions and short period of maturity [2]. However, it is reported as an important food crop with health promoting components like beta-carotene, fiber, phenolic acids, anthocyanins, carbohydrates, minerals and vitamins [9]. This is due to its low glycemic index status with important potential role in the management of type-2 diabetes [10]. Besides, sweet potato has been previously used as natural sweetening agent in snacks and beverages [11].

Peanut (*Arachishypogeae*L.) is an important oilseed crop commonly utilized in the oil producing industries [12]. It is an excellent source of protein (22-30%), vitamins like niacin and vitamin E, magnesium, phosphorus, antioxidants and dietary fiber. Infact, over 70% of harvested peanut is being used for production of oil[12]. The nuts could also be roasted and consumed as snacks or processed as peanut butter because it is known to be excellent source of polyunsaturated fatty acids [12]. Another study showcased the defatted peanut flour as an excellent source of proteins, fiber, antioxidants, vitamins, and minerals, which was found applicable in the human food formulations [13].Hence, the use of defatted meal in food products has been reported as a potential means of incorporating protein into food to address the problem of malnutrition in developing countries [14]. Previous finding [14] corroborated the utilization of the defatted peanut flour as an added ingredient to wheat flour so as to serve as potential component of composite flour in most baked foods, complementary foods, breakfast cereals and extruded food products.

Rice bran, a by-product obtained during the rice milling process, constituted about 8% of the total weight of padded rice grain [15]. Rice bran, which was previously being discarded as waste with adverse impact on the environment or used for animal feed, is now of interest in research for food formulation due to its bioactive components [16]. It is reportedly an excellent source of soluble fibre such as beta-glucan, gums and pectins with potentials to reduce blood cholesterol and improved cardiovascular health [17]. Several studies have successfully included rice bran as part of the components of their composite flours for the production of baked products [17, 18-19].

Although, various studies have exploited composite flour from cereals, root and tuber, legumes and cereal bran in the production of snacks [1, 4, 20-22]. Nevertheless, there is paucity of information on the nutritional, phytochemical and functional properties of composite flour from single blends of whole wheat, sweet potato, defatted peanut and rice bran composite flours. Therefore, this study aimed to determine the nutritional, phytochemical, functional and pasting properties of composite flour blends from whole wheat, sweet potato, defatted peanut and rice bran.

2 Materials and methods

2.1 Sources of raw materials

The raw materials used for the formulation of the composite flour such as whole wheat grains, sweet potato and peanut seeds were purchased from the Shasha market in Akure, Nigeria while rice bran was obtained from a local rice mill in Ise-Ekiti, Nigeria. The food crops were authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Nigeria. Reagents and chemicals used were of analytical grade from Sigma-Aldrich, London, UK and Fischer Chemicals, USA.

2.2 Flour samples preparation

The previously described procedure [6] was employed for the preparation of whole wheat flour. Briefly, whole wheat grains were sorted to remove extraneous materials, washed with portable water, drained and dried at 60 °C for 12 h in hot-air oven (Plus11 Sanyo Gallenkamp PLC, UK). Dried whole wheat grains were milled with laboratory blender (Model KM 901 D, Hertfordshire, UK), sieved with 200 mm sieve and packed for further use in airtight container. Sweet potato tubers were washed with water to remove dirt, peeled, cut into thin slices and oven-dried (Plus11 Sanyo Gallenkamp PLC, UK) at 60 °C for 48 h.

Dried sweet potato was milled with the aid of Laboratory Kenwood Electronic blender (Model KM 901 D, Hertfordshire, UK), sieved with 200 mm mesh sieve and packed for further use in an airtight container as previously reported [23].

Peanut seeds were sorted, roasted in oven for 15-20 mins at 170 °C and dehulled according toAmanyunose et al. (2022). Roasted peanut seeds were milled into cake and defatted using Soxhlet apparatus with n-hexane for 12 h, dried in the oven for 2 h at 40 °C, pulverized into peanut flour and sieved with 200mm sieve as described [24].

Rice bran flour was obtained as described [25]. The extraneous materials were removed from the rice bran, cleaned with water, drained and oven-dried for 10 h at 60°C. The dried rice bran was milled using Laboratory mill and sieved with 200 mm mesh sieve. Afterwards, the omposite flour was finally formulated using theNutriSurvey Linear Programming Software to obtain different blends as shown in Table 1.

2.3 Determination of proximate composition

Proximate compositions of the composite flour were determined according AOAC[26]. The moisture content was determined by drying a known quantity of the samples in a hot air oven to a constant weight.The protein content was determined using the Kjeldahl apparatus based on nitrogen. The fat content was determined using a soxhlet apparatus with n-hexane under reflux. The ash content was determined using muffle furnace for calcination at 550 ^{o}C and crude fibre content was determined by alkali treatment method.The carbohydrate content was calculated by difference while energy value was calculated using the Atwater factor [27].

2.4 Determination of mineral elements

The standard methods of AOAC [26] were used for the determination of mineral contents of the composite flour. Flame emission photometer (Sherwood Flame Photometer 410,Sherwood Scientific Ltd. Cambridge, UK) was used for the determination of sodium and potassium with NaCl and KCl as the standards.

Table 1 **Formulation of whole wheat and sweet potato-based composite flour**

Samples	Raw materials	CW	WW	SP	DPN	RB	Total (%)
WPRG-1	**WW + SP + DPN + Rice bran**	**-**	**56.25**	**18.75**	**20**	**5**	**100**
WPRG-2	**WW+ SP + DPN + Rice bran**	**-**	**37.50**	**37.50**	**20**	**5**	**100**
WPRG-3	**WW+ SP + DPN + Rice bran**	**-**	**18.75**	**56.25**	**20**	**5**	**100**
WWF	**WW**	**-**	**100**	**-**	**-**	**-**	**100**
CWF	**CW**	**100**	**-**	**-**	**-**	**-**	**100**

WW = Whole wheat; SP = Sweet potato; DPN = Defatted Peanut; RB = Rice bran; CW = Commercial wheat (Control)

However, the atomic absorption spectrophotometer (AAS Model SP9) was used for the determination of magnesium, zinc, iron, calcium, manganese, copper while vanado-molybdate colorimetric method was used for the determination of phosphorus. Besides, the Na/K and Ca/P molar ratios were calculated.

2.5 Determination of amino acid composition

The previously described method [28] was used for the determination of amino acid profile of the composite flour. The digestion of the samples was done with 6N HCl for 24 h and Beckman Amino Acid Analyzer (model 6300; Beckman Coulter Inc., Fullerton, Calif., USA) was used for the amino acid determination. Sodium citrate buffers was used as step gradients with the cation exchange post-column in the ninhydrinderivatization method. The data were calculated as grams of amino acid per 100 g crude protein of the composite flour. Moreso, protein quality indices such as the biological value (BV),protein efficiency ratio (PER) and essential amino acid index (EAAI) were estimated from the amino acid profile.

2.6. Determination of phytate

Phytate content of the composite flour was determined according to the method of AOAC [26]. The sample (2 g) was made into solution with 100 ml of 2% hydrochloric acid (v/v), allowed to dissolve for 3 h and filtered. About 5 ml of an indicator (0.03% ammonium cyanide) was added to the filtrate (25 ml) in a 100 ml conical flask and 50 ml of distilled water was also added. The resulting solution was then titrated against ferric chloride solution containing 0.005 mg of Fe^{3+} per ml of $FeCl_3$.The equivalent was obtained and used to calculate the phytate content.

2.7 Determination of tannin

Tannin content of the samples was determined according to the described method [30]. The samples (0.2 g) were weighed and 10 ml of 70% aqueous acetone was added to each sample in 50 ml sample bottles and covered tightly. The bottles were placed in bath shaker at 30 °C for 2 hr to shake vigorously. The resulting solution was centrifuged at 3000 ×*g* and the supernatant was stored in ice. The supernatant (0.2 ml) was measured into test tubes with 0.8 ml of distilled water. From a 0.5 mg/ml stock solution, standard tannic acid solution was prepared and was made up with distilled water to 1 ml. Folinciocalteau reagent (0.5 ml) was added to the sample and the standard and 2.5 mL of20%Na_2CO_3 solution was also added. The solutions were placed in the incubator at room temperature for 40 min and the absorbance was read at 725 nm against a reagent blank. Sample concentration was obtained from a standard tannic acid curve.

2.8 Determination of flavonoid

Flavonoid contents of the samples were determined as described [31]. The sample (10 g) was dissolved in 100 ml of 80% aqueous methanol at room temperature and filtered through Whatman filter paper No. 42 (125 mm). The filtrate was transferred into a crucible and dried to a constant weight in a water bath.

2.9 Determination of oxalate

The oxalate contents of the samples were determined as described [32]. Each sample (1 g) was weighed into 100 ml conical flask, 75 ml of 3 M H_2SO_4 was added and the solution was gently stirred with a magnetic stirrer at intervals for about 1 h. the solution was filtered through Whatman filter paper No. 1. The filtrate (25 ml) was titrated against 0.1 M $KMnO_4$ solution till the observed faint pink colour persisted for at least 30 s.

2.10 Determination of saponin

Saponin contents of the samples were determined as described [33]. Each sample (20 g) was weighed into a conical flask, 100 ml of 20% aqueous ethanol was added, heated over a hot water bath at about 55 °C and stirred constantly for 4 h. The resulting mixture was filtered and extracted again with another 200 ml of 20% ethanol. The mixed extracts were evaporated to 40 ml over water bath at about 90 °C. The concentrate was transferred into 250 ml separating funnel with the addition of 20 ml of diethyl ether and mixed vigorously. Thereafter, the aqueous layer was recovered while the other was disposed. The process of purification was repeated again and 60 ml of n-butanol was added. The mixed n-butanol extracts were washed two times more with 10 ml of 5% aqueous sodium chloride solution. The left-over solution was evaporated in a water bath and dried to a constant weight in the oven. The percentage weight of the sample was calculated as the saponin content.

2.11 Determination of total phenol

Total phenolic content of the composite flour was determined using Folin–Ciocalteuas described [34] with gallic acid as standard. The composite flour (5 mg) was dissolved in 5 ml of methanol and water mixture (50:50 v/v). The solution containing the composite flour was added to a series of tubes and made up to 100 ml with methanol and water mixture (50:50 v/v). Five hundred microlitres of 50% Folin–Ciocalteu reagent was added to each tube, mixed and allowed to stand for 10 min. Thereafter, 1.0 ml of 20% sodium bicarbonate was added to the mixture, incubated at room temperature for 10 min and centrifuged at 10,000 xg for 5 min. The absorbance of the supernatant was measured at 700 nm and the total phenol content was calculated as gallic acid equivalents (GAE) in mg per gram of the sample used.

2.12 Determination of bulk density

The bulk density of the samples was determined as described [35]. The sample (20 g) was weighed into a 100 ml graduated measuring cylinder and tapped on the laboratory bench till there was no reduction in the volume occupied by the sample. The bulk density was calculated as weight of the sample per unit volume of the sample.

2.13 Determination of water and oil absorption capacities

Water and oil absorption capacities of the samples were determined as described [28]. The sample (1 g) was weighed into a centrifuge tube, 10 ml of distilled water was added and mixed together for 30 s. The mixture was allowed to stand for 30 min at room temperature and then centrifuged at 3,000 rpm for 30 min. The supernatant was poured into a measuring cylinder and the volume was taken. Water absorption capacity was expressed as the percentage of water bound per weight of the sample. The same procedure was repeated for oil absorption capacity using refined soybean oil in place of distilled water.

2.14 Determination of solubility index

The solubility index of the sample was determined as described [36].The sample (1 g) was weighed into a centrifuge tube, 50 ml of distilled water was added and mixed gently. The mixture was heated at 80°C for 15 min in a water bath and stirred gently constantly. The slurry formed was centrifuged at 3000 rpm for 10 min and the supernatant was decanted immediately. The weight of the sediment was measured and the moisture content of the sediment gel was determined to get the dry matter content of the gel. Solubility index was calculated as the percentage of the dry matter content.

2.15 Determination of least gelation concentration

The least gelation concentration of the samples was determined according to the previously described method [28]. The dispersions of the samples at 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22 and 30% (w/v) prepared in 5 ml distilled water were heated at 90 °C for 1 h in a water bath. The contents were allowed to cool under a running tap water and allowed to stand at 10±2 °C for 2 h. The least gelation concentration of the samples was taken as that concentration when the sample did not slip from the tube when inverted.

2.16 Determination of swelling capacity

Swelling capacity of the samples was determined as described [35]. The sample was poured into a 100 ml measuring cylinder up to the 10 ml mark, distilled water was added to make up the volume to 50 ml, and the measuring cylinder was covered tightly at the top and mixed by inversion. The inversion of the suspension was repeated after 2 min and allowed to stand for 30 min further. Swelling capacity was taken as the volume occupied by the sample after 30 min.

2.17 Determination of pasting properties

Pasting properties of the composite flour was determined according to the standard method [37]. The sample (2.5g) was weighed into a dried empty canister and 25 ml of distilled water was added into it. The resulting mixture was properly mixed and fixed into the Rapid ViscoAnalyzer (RVA). The mixture was maintained for 1 min at 50 ^{o}C, heated at 12.2 ^{o}C per min to 95 ^{o}C, kept for 2.5 min at 95 ^{o}C, followed by cooling at 11.8 ^{o}C per min to 50 ^{o}C for 2 min. Pasting parameters such as peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature were determined.

2.18 Colour determination

The colour properties of the composite flour and the control were measured as described [38] with the aid of a HunterLab colorimeter (A60-1012-402 Model, HunterLab, Reston, VA, USA). The colour parameters like L* (Lightness) value ranging from 0-100, a* (greenness to redness) value and b* (blueness to yellowness) value were measured while hue angle (h°) and Chroma (C*) were calculated.

2.19 Statistical analysis

All the analyses were carried out in triplicates and data generated were analysed with one-way analysis of variance using Statistical Package for Social Sciences (SPSS 21.0 SPSS Inc. Chicago, Illinois, U.S.A). The means were separated using Duncan's new multiple range test at $p \leq 0.05$.

3 Results and discussion

3.1 Proximate composition of whole wheat and sweet potato-based composite flour

Proximate composition of whole wheat and sweet potato-based composite flour is presented in Table 2. The moisture content of flour is an important determinant of quality that affects the storage life of flour [39]. The moisture contents ranged from 5.26% in WPRG-2 to 7.30% in WWF and these were lower than the recommended value of 10% for longer storage life by Standard Organization of Nigeria [40]. This is an indication that the samples would have longer shelf life during storage. The protein contents ranged from 11.33% in WWF to 21.98% in WPRG-1. The protein contents of the composite flour were significantly ($P \leq 0.05$) different from that of CWF and WWF and this may be due to the addition of defatted peanut flour which is a good source of protein.The fibre contents ranged from 1.86% in CWF (control) to 10.82% in WPRG-3. The fibre contents of the composite flour in this study were higher when compared to 2.75-3.56% previously reported for composite flour of whole wheat, soycake, oat bran and rice bran [24]. Consumption of food with adequate dietary fibre has been linked with the reduced risk of obesity, diabetes and coronary heart diseases [41]. The ash contents ranged from 1.49% in CWF to 4.41% in WWF. The ash contents observed in this study were lower than 2.37-5.67% reported forcomposite flour of wheat, Bambara nut and orange-fleshed sweet potato[1]. The improved nutritional composition of the composite flour over the control could be attributed to the addition of defatted peanut, sweet potato and rice bran and this corroborated with the past observation [42] that mixture of two or more food materials helped to improve the nutritional quality of the food product.

3.2 Mineral composition of whole wheat and sweet potato-based composite flour

The mineral composition of whole wheat and sweet potato-based composite flour is presented in Table 3. Magnesium (50.63-56.50 mg/100 g), zinc (11.26-26.38 mg/100 g) and phosphorus (12.36-18.52 mg/100 g) were found to be the most abundant mineral elements while manganese (0.44-074 mg/100 g) was found to be the least mineral element in the composite flour and the control. Calcium contents ranged from 6.06 mg/100 g in CWF to 7.12 mg/100 g in WPRG-1. Essential mineral elements (magnesium, zinc, calcium and phosphorus) were significantly ($p \leq 0.005$) higher in the composite flour than the control. Magnesium, zinc and phosphorus are responsible for metabolism of carbohydrate, bone and haemoglobin formation [43]. Magnesium helps with the regulation of zinc level in the body. Hence, zinc and magnesium are reported as co-factors for management of diabetes through the initiation of insulin receptor [44]. Calcium is responsible for formation of bone, clotting of blood, control of heartbeat and contraction of muscle. It has also been reported with potential to prevent type-2 diabetes [45]. Zinc is an important mineral element during pregnancy for normal development [46]. Iron contents ranged from 1.32 to 1.64 mg/100 g. The iron contents obtained in this study is comparable with 1.06-1.48 g/100 g reported [24] for formulated composite flour from whole wheat, soycake, rice bran and oat bran. Iron is an essential mineral element for boosting immunity and prevention of anaemia [43].The sodium and potassium contents ranged from 0.52 to 1.44 mg/100g and 2.24 to 2.45 mg/100g, respectively. Potassium is a vital mineral element for the management of hypertension and it helped with the absorption of iron in the body [47]. Potassium and sodium were responsible for maintenance of body fluid, regulation of body pH, muscle and nerve signals [45]. Interestingly, the heavy metals, lead and selenium were not detected in the samples, which proven the formulated composite flour to not have adverse effect on the consumers [24].

The Na/K molar ratios (0.22-0.62) of the samples were within the recommended value (<1.0)of samples suitable for the management of hypertension [24]. The Ca/P molar ratios (0.38-0.52) of the samples were below the recommended value (>1). Hence, their application in food products would necessitate the addition of calcium supplement to prevent rickets and osteoporosis that were associated with calcium deficiency [48].

3.3 Amino acid profile and nutritional quality indices of whole wheat and sweet potato-based composite flour

The amino acid profile and nutritional quality indices of whole wheat and sweet potato-based composite flour is presented in Table 4a. Amino acidswere the building blocks of proteins with potential to regulate metabolic reactions [49]. Glutamic acid (11.27-17.36 g/100g protein) was the most abundant amino acids in the composite flour blends and the control. This corroborated the past study [24]that reported glutamic acid (14.81-21.93 g/100g protein) as the most abundant amino acids in whole wheat, soycake, oat bran and rice branflour blends.

Table 2 **Proximate composition and Energy value of whole wheat and sweet potato-based composite flour**

Sample	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)	Energy value (kcal/100g)
WPRG-1	5.38±0.07^{c}	21.98±0.06^{a}	3.05±0.06^{b}	10.25±0.01^{a}	3.01±0.01^{b}	56.33±0.09^{e}	340.69±2.05^{c}
WPRG-2	5.26±0.09^{c}	18.71±0.02^{b}	2.87±0.05^{c}	7.93±0.05^{b}	2.89±0.08^{c}	62.34±0.05^{c}	350.03±2.96^{b}
WPRG-3	5.39±0.09^{c}	15.81±0.03^{c}	3.38±0.03^{a}	10.82±0.03^{a}	2.75±0.02^{c}	61.85±0.07^{d}	341.06±1.09^{c}
WWF	7.30±0.01^{a}	11.33±0.03^{e}	3.32±0.05^{a}	7.35±0.05^{b}	4.41±0.02^{a}	66.29±0.06^{b}	340.36±1.88^{c}
CWF	6.33±0.03^{b}	13.69±0.05^{d}	1.93±0.06^{d}	1.86±0.06^{c}	1.49±0.01^{d}	74.70±0.06^{a}	370.93±3.14^{a}

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same column are significantly different ($p \leq 0.05$)

WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50% WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted Peanut; RB = Rice bran

Table 3: Mineral composition (mg/100g) of whole wheat and sweet potato-based composite flour

Element	WPRG-1	WPRG-2	WPRG-3	WWF	CWF
Fe	$1.35±0.01^{c}$	$1.64±0.02^{a}$	$1.32±0.03^{c}$	$1.44±0.04^{b}$	$1.36±0.05^{c}$
Mg	$55.70±0.14^{b}$	$56.20±0.13^{a}$	$56.50±0.15^{a}$	$53.80±0.15^{c}$	$50.63±0.05^{d}$
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	$7.12±0.02^{a}$	$7.02±0.03^{a}$	$6.99±0.02^{ab}$	$6.87±0.05^{b}$	$6.06±0.02^{c}$
P	$17.30±0.60^{b}$	$18.25±0.76^{a}$	$18.52±0.70^{a}$	$13.20±0.15^{c}$	$12.36±0.01^{d}$
Na	$1.20±0.03^{b}$	$0.52±0.01^{c}$	$1.23±0.02^{b}$	$1.21±0.01^{b}$	$1.44±0.04^{a}$
K	$2.24±0.02^{c}$	$2.36±0.08^{ab}$	$2.45±0.02^{a}$	$2.26±0.31^{c}$	$2.34±0.07^{b}$
Mn	$0.62±0.02^{b}$	$0.44±0.36^{d}$	$0.61±0.01^{b}$	$0.54±0.03^{c}$	$0.74±0.02^{a}$
Cu	$0.03±0.01^{d}$	$0.04±0.01^{c}$	$0.06±0.02^{b}$	$0.07±0.01^{a}$	$0.07±0.02^{a}$
Se	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND
Na/K	$0.54±0.01^{b}$	$0.22±0.02^{d}$	$0.50±0.04^{c}$	$0.54±0.03^{b}$	$0.62±0.01^{a}$
Ca/P	$0.41±0.01^{c}$	$0.38±0.01^{d}$	$0.38±0.01^{d}$	$0.52±0.01^{a}$	$0.49±0.01^{b}$

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same row are significantly different ($p \leq 0.05$)

ND = Not Detected; WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

Glutamic acid is responsible for maintenance of acid-base balance, prevention of memory loss and control of body weight [50].The tryptophan (0.87-1.32 g/100g protein), phenylalanine (2.28-5.98 g/100g protein) and tyrosine (3.03-4.31 g/100g protein) are aromatic amino acids reported to improve insulin secretion with positive effect on people suffering from type-2 diabetes [50]. The leucine of the composite flour blends ranged from 3.95 g/100g protein in WPRG-1 to 5.31 g/100g protein in WPRG-3. Leucine is a branched-chain amino acid as well as essential amino acid linked with the regulation of serum glucose [51]. Hence, the formulated composite flour would be a potential tool for the management of diabetes.The total essential amino acids (26.73-34.27 g/100g protein) were significantly ($p \leq 0.05$) higher in the flour blends than WWF (26.60 g/100g protein) and CWF (25.79 g/100g protein). This may be attributed to the inclusion of defatted peanut flour in the composite flour blends. The essential amino acids could not be synthesized by the body but must be supplied to the body through foods ingested. Moreso, the consumption of food rich in essential amino acids helped to improve growth and cognitive development in children [24].The nutritional quality indices of the whole wheat and sweet potato-based composite flour and the control are presented in Table 4b. The essential amino acid components of food and its digestibility indicate the nutritional value of food protein [13]. The branched chain amino acids (BCAA), Arg/Lysine, EAAI, PER, BV and fischer ratio of the samples ranged from 10.77-13.64 g/100g protein, 0.55-0.76, 76.85-102.13%, 0.96-1.49 g/100g protein, 72.07-99.62% and 1.03-1.80, respectively. BCAAs have been reported to demonstrate healing effect on liver disease [52] and possessed potential effect against oxidative stress and diabetes [24]. A high Fischer ratio helped to improve protein synthesis and this is beneficial for those suffering from liver disease [52]. The fact that the EAAI and BV of composite flour were higher than that of WWF and CWF is worthy of note, whichwere greater than the recommended value (70%)of most legume-based food products [53]. Thus, the improved nutritional quality observed in this study may be linked to the multiple food crops used in the formulation of the composite flour [54].

3.4 Phytochemicals of whole wheat and sweet potato-based composite flour

The phytochemical composition of whole wheat and sweet potato-based composite flour and the control is presented in Table 5. The flavonoid, saponin, tannin, phenol, oxalate and phytate contents ranged from 40.36-110.50, 15.41-28.63, 4.21-5.52, 113.27-220.68, 20.24-30.89 and 3.03-5.34 mg/100g, respectively. Theywere plant nutrients that prevented the uptake of essential nutrients in the body [24]. The health importance of phytochemicals is linked to its antioxidant activity, which helped to prevent the formation of free radicals that were responsible for various diet-related diseases [55]. They (especially the flavonoid, phenol andsaponin) possessedantioxidant properties and thus, their consumption at low concentration has been encouragedfor the management of obesity, diabetes, gastrointestinal and other cardiovascular diseases [53]. The concentrations of phytochemicals observed in this study were lower compared to those previously reported [24] and this could be due to the different processing methods involved in the production of the current flour blends.

3.5 Functional properties of whole wheat and sweet potato-based composite flour

The functional properties of the whole wheat and sweet potato-based composite flour are presented in Table 6. The bulk density ranged from 3.92 g/ml in WPRG-2 to 4.43 g/ml in WWF. Bulk density is a function of particle size and it determined the required packaging, material handling and varying utilization in food industry [56]. Bulk densities (3.92-4.43 g/ml) observed in this study were lower than the 0.63-0.79 g/ ml reported for wheat, sweet potato and African yam bean composite flour[57].The low bulk densities observed in study could be attributed to the loose structure of the starch polymer as opined by past study [21].

Table 4a: Amino acid profile (g/100g protein) and nutritional quality of whole wheat and sweet potato-based composite flour

Amino acid	WPRG-1	WPRG-2	WPRG-3	WWF	CWF	FAO/WHO	Egg protein
Valine	4.64[b]	4.12[d]	5.64[a]	4.11[d]	4.28[c]	3.5	4.3
Threonine	3.23[a]	2.92[b]	3.23[a]	2.73[c]	2.53[d]	3.4	2.9
Isoleucine	2.69[a]	2.70[a]	2.69[a]	2.59[c]	2.67[b]	2.8	4.0
Leucine	4.62[c]	3.95[e]	5.31[a]	4.84[b]	4.44[d]	6.6	5.3
Methionine	2.91[a]	2.62[b]	2.91[a]	2.18[c]	2.14[d]	2.2	3.2
Phenylalanine	5.98[a]	2.42[c]	3.98[b]	2.28[e]	2.32[d]	2.8	5.1
Lysine	4.72[a]	3.70[c]	4.72[a]	3.78[b]	3.12[d]	5.8	3.7
Histidine	4.13[b]	3.39[c]	4.49[a]	3.22[e]	3.31[d]	1.9	2.4
Tryptophan	1.32[a]	0.91[d]	1.30[b]	0.87[e]	0.98[c]	1.1	1.8
Alanine	3.18[a]	2.52[d]	3.18[a]	2.73[b]	2.58[c]		
Aspartic acid	13.13[a]	11.43[b]	11.42[b]	9.27[c]	8.27[d]		
Glutamic acid	17.36[a]	13.78[c]	15.41[b]	11.96[d]	11.27[e]		
Serine	4.85[a]	4.21[b]	4.85[a]	3.56[c]	3.34[d]		
Glycine	3.28[c]	3.78[b]	3.81[a]	3.16[e]	3.22[d]		
Proline	2.04[e]	2.81[a]	2.41[b]	2.32[c]	2.19[d]		
Arginine	3.61[a]	2.48[d]	2.61[b]	2.54[c]	2.24[e]		
Tyrosine	4.31[a]	3.49[b]	4.31[a]	3.41[c]	3.03[d]		
Cystine	1.51[a]	0.91[e]	1.49[b]	1.43[c]	1.31[d]		

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same row are significantly different ($p \leq 0.05$). WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

Table 4b: Nutritional quality indicesof whole wheat and sweet potato-based composite flour

Samples/ Parameters	WPRG-1	WPRG-2	WPRG-3	WWF	CWF
HAA	30.66	25.83	31.23	25.08	24.82
AAA	11.61	6.82	9.59	6.56	6.33
NCAA	30.49	25.21	26.83	21.23	19.54
BCAA	11.95	10.77	13.64	11.54	11.39
TEAA	34.24[b]	26.73[c]	34.27[a]	26.60[d]	25.79[e]
TNEAA	53.27[a]	45.41[c]	49.49[b]	40.38[d]	37.45[e]
TAA	87.51[a]	72.14[c]	83.76[b]	66.98[d]	63.24[e]
Arg/Lysine	0.76	0.67	0.55	0.67	0.72
EAAI (%)	102.13	80.03	102.08	78.04	76.85
PER (g/100g)	1.18	0.96	1.49	1.37	1.23
BV (%)	99.62	75.53	99.57	73.36	72.07
Fischer ratio	1.03	1.58	1.42	1.76	1.80

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same row are significantly different ($p \leq 0.05$). WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

TEAA = Total essential amino acids; TNEAA = Total non-essential amino acids; TAA = Total amino acids; HAA – Hydrophobic amino acids; AAA – Aromatic amino acids; NCAA – Negatively charged amino acids; BCAA - Branched chain amino acids; EAAI – Essential amino acid index; PER – Protein efficiency ratio; BV – Biological value

Table 5: Phytochemical composition (mg/100g) of whole wheat and sweet potato-based composite flour

Parameter	WPRG-1	WPRG-2	WPRG-3	WWF	CWF
Flavonoid	80.42±2.40[c]	90.41±3.00[b]	110.50±5.10[a]	60.35±2.03[d]	40.36±1.80[e]
Saponin	25.12±1.00[b]	23.51±0.79[d]	28.63±1.00[a]	15.41±0.90[e]	24.12±1.00[c]
Tannin	4.79±0.03[c]	4.87±0.04[c]	5.29±0.11[b]	5.52±0.12[a]	4.21±0.03[d]
Phenol	113.27±3.62[d]	220.68±7.67[a]	173.19±4.68[b]	130.31±0.00[c]	114.99±2.44[d]
Oxalate	24.64±1.04[b]	30.18±2.07[a]	30.89±2.05[a]	20.24±1.03[c]	20.24±1.02[c]
Phytate	3.12±0.05[d]	3.36±0.02[c]	5.34±0.06[a]	4.89±0.40[b]	3.03±0.05[e]

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same row are significantly different ($p \leq 0.05$)

WPRG-1 = 56.25% WW:18.75% SP:5% Rice bran:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

Table 6: **Functional properties of whole wheat and sweet potato-based composite flour**

Sample	BD (g/ml)	WAC (%)	OAC (%)	SI (%)	LGC (%)	SC (ml)
WPRG-1	4.02±0.02^{c}	59.59±0.44^{a}	32.83±0.09^{c}	18.53±0.47^{c}	3.00±0.22^{b}	6.20±0.20^{a}
WPRG-2	3.92±0.48^{d}	57.29±0.15^{c}	32.36±0.02^{c}	19.00±0.10^{c}	3.04±0.20^{b}	6.26±0.05^{a}
WPRG-3	4.12±0.02^{b}	57.70±0.20^{c}	32.17±0.05^{c}	12.86±0.49^{d}	3.10±0.21^{b}	6.08±0.25^{a}
WWF	4.43±0.02^{a}	58.66±0.06^{b}	33.34±0.06^{b}	20.05±0.13^{b}	3.20±0.21^{b}	5.47±0.05^{b}
CWF	4.10±0.01^{b}	59.08±0.10^{a}	34.17±0.05^{a}	21.04±1.00^{a}	4.61±0.20^{a}	5.85±0.05^{b}

Values are mean ± standard deviation (n=3). Values with different superscripts (a,b,c,d) within the same column are significantly different ($p \leq 0.05$)

WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50% WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted Peanut; RB = Rice bran

BD = Bulk density, WAC = Water absorption capacity, OAC = Oil absoption capacity, SI = Solubility index, LGC = Least gelation concentration, SC = Swelling capacity

Table 7: Pasting properties of whole wheat and sweet potato-based composite flour

Sample	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temp (^{o}C)
WPRG 1	$334.00±3.5^{c}$	$301.00±1.5^{c}$	$33.00±0.5^{b}$	$692.00±5.0^{d}$	$391.00±3.0^{d}$	$7.00±0.5^{a}$	$94.35±2.5^{a}$
WPRG 2	$504.00±4.8^{a}$	$473.00±3.8^{a}$	$31.00±0.0^{c}$	$1001.00±8.5^{a}$	$526.00±3.5^{a}$	$7.00±0.0^{a}$	$88.85±2.3^{c}$
WPRG 3	$356.00±2.4^{b}$	$330.00±4.6^{b}$	$26.00±0.4^{d}$	$740.00±4.0^{b}$	$410.00±2.5^{c}$	$7.00±0.5^{a}$	$92.85±1.8^{b}$
WWF	$323.00±1.8^{d}$	$293.00±2.0^{d}$	$30.00±0.0^{c}$	$719.00±3.5^{c}$	$426.00±2.8^{b}$	$7.00±0.5^{a}$	$94.50±1.5^{a}$
CWF	$145.54±1.4^{e}$	$84.54±1.2^{e}$	$61.00±1.0^{a}$	$170.13±1.8^{e}$	$85.59±0.8^{e}$	$5.95±0.8^{b}$	$61.95±1.4^{d}$

Values are mean ± standard deviation (n=3). Values with different superscripts within the same column are significantly different ($p≤0.05$)

RVU = Rapid Visco-Analyser Unit

WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

Hence, these composite flour samples could be useful in the formulation of complementary foods [58]. The water absorption capacity (WAC) of the samples ranged from 57.29% in WPRG-2 to 59.59% in WPRG-1. The WAC (57.29-59.59%) obtained in this study is higher than 12.00-12.95 g/ml reported [24] for formulated composite flour from wheat, soycake. Rice bran and oat bran. The WAC is a function of the hydrophilic nature of the food sample and it showed the tendency of protein to be applicable in aqueous food formulation such as dough making [59]. However, the oil absorption capacity (OAC) of the sample ranged from 32.17% in WPRG-3 to 34.17% in CWF. Research finding has shown that the flour samples with high OAC could be employed in the baking production [53]. This is because the high OAC indicated the high ratio of hydrophobic groups to hydrophilic groups on the protein molecule surface [18]. The least gelation concentration (LGC) of the samples ranged from 3.00% in WPRG-1 to 4.61% in CWF. The LGC indicated the ability of flour to form gel and differences in LGC of flours may be due to proportion of its components as well as the interaction between the components [18]. Swelling capacity of the samples ranged from 5.47 ml in WWF to 6.26 ml in WPRG-2. The rate at which a flour sample exhibited an increase in volume when soaked in water is determined by its swelling capacity [18]. It is also an indication of the extent of associative forces within the starch granules. Moreso, the swelling capacity is an important measure in baked products. The variation observed in the swelling capacity of the flour may be attributed to the ratio of amylose to amylopectin propertiesin the flour samples [60].

3.6 Pasting properties of whole wheat and sweet potato-based composite flour

The pasting properties of the whole wheat and sweet potato-based composite flour are presented in Table 7. Food quality and aesthetic value were being determined by the pasting properties as it affected the texture, digestibility and application of starch-based raw materials in food products [21]. The peak viscosity significantly ($p \leq 0.05$) increased from 145.54 RVU in CWF to 504.00 RVU in WPRG-2. Peak viscosity is an indication of the ability of starch-based food to swell freely before their physical breakdown [61].However, the reduced peak viscosity could be attributed to reduced starch and relationship between the food components [62]. The trough ranged from 84.54 RVU in CWF to 473.00 RVU in WPRG-2. Trough determined the ability of the paste to resist breakdown prior to cooling [21]. The breakdown viscosities of the composite flour blends and WWF (26.00-33.00 RVU) were significantly ($p \leq 0.05$) lower than that of CWF (61.00). Hence, a higher capacity of the composite flour blends to resist heating and shearing during cooking than the control [58]. The final viscosity ranged from 170.13 RVU in CWF to 1001.00 RVU in WPRG-2. It is known that the final viscosity defined the quality of starch and stability of its cooked paste. Therefore, the low final viscosity signified the reduced ability to form viscous pastes. Interestingly, the setback ranged from 85.59 RVU in CWF to 526.00 RVU in WPRG-2. Notably, the setback is the ability of the gelatinized starch to retrograde on cooling as a result of high amylose content of the starch [58]. The result (Table 7) further showed that the composite flour technology might have influenced the setback capacities of the composite flour blends. It was observed from the current result that the setback value of the control sample (85.59 RVU) is lower than those (391-526 RVU) of the composite flour blends. Meanwhile, the peak time of the different whole wheat and sweet potato-based composite flour blends, which is the time required for cooking, ranged from 5.95 RVU in CWF to 7.00 RVU in the composite flour blends and WWF. On the other hand, the pasting temperature ranged from 61.95 RVU in CWF to 94.50 RVU in WWF. A research finding has described the pasting temperature of the flour pastes as the least temperature needed for stable granules in the sample to swell [58].

Table 8: **Colour properties of whole wheat and sweet potato-based composite flour**

Sample	*L**	*a**	*b**	*C**	*h*(°)
WPRG-1	72.35±0.82^{b}	3.12±0.00^{c}	9.34±0.00^{b}	9.85±1.05^{b}	69.34±1.20^{b}
WPRG-2	72.03±0.65^{b}	3.25±0.01^{c}	9.71±0.00^{b}	10.24±0.89^{b}	64.71±0.80^{e}
WPRG-3	80.19±1.42^{a}	2.15±0.01^{d}	5.24±0.04^{c}	5.66±0.14^{d}	65.24±1.04^{d}
WWF	7.28±0.52^{d}	5.43±0.02^{a}	10.37±0.01^{a}	11.71±0.91^{a}	67.37±2.01^{c}
CWF	49.02±1.52^{c}	3.87±0.01^{b}	5.29±0.01^{c}	6.55±0.62^{c}	70.29±3.24^{a}

Values are mean (n=3). Values with different superscripts (a,b,c,d) within the same column are significantly different (p≤0.05)

WPRG-1 = 56.25% WW:18.75% SP:5% RB:20% DPN; WPRG-2 = 37.50%WW:37.50% SP:5% RB:20% DPN; WPRG-3 = 18.75% WW:56.25% SP:5% RB:20% DPN; WWF = 100% Whole wheat flour; CWF = 100% Commercial wheat flour (Control); WW = Whole wheat; SP = Sweet potato; DPN = Defatted peanut; RB = Rice bran

3.7 Colour properties of whole wheat and sweet potato-based composite flour

The colour parameters of the samples are presented in Table 8. Colour is an essential physical parameter that influenced the consumer's acceptability of a product and marketing [38]. The *L** value showed the lightness or darkness of the flour. The *L** values for the composite flour blends (72.03-80.19) were significantly ($p \leq 0.05$) higher than that of CWF (49.02) and WWF (7.28). The a* value, which is an indication of the degree of red-green colour ranged from 2.15 in WPRG-3 to 5.43 in WWF, with a higher positive *a** value (WWF) indicating more red. The b* value, which is an indication of the degree of the yellow-blue colour ranged from 5.24 in WPRG-3 to 10.37 in WWF, with a higher positive *b** value (WWF) indicating more yellow [63]. The composite flour exhibited lower *a** when compared with WWF and CWF. This corroborated the past study [64]that reported a decrease in *a** for composite flour of wheat and orange-fleshed sweet potato as a result of loss of beta carotene. The chroma (*C**) ranged from 5.66 in WPRG-3 to 11.71 in WWF while the hue angle (*h**) ranged from 64.71° in WPRG-2 to 70.29° in WWF. Hue is the colour characteristic observed as either red, green, blue, yellow, orange, purple or intermediate between adjacent pairs observed in a closed ring while chroma is the colour characteristic indicating the extent of colour saturation [38]. Actually, the variations observed in the colour parameters of the samples may be attributed to the variation in the pigments of the different raw materials used [15].

4 Conclusion

This study established that composite flour with improved protein, fibre and essential amino acids could be formulated from blends of whole wheat, sweet potato, defatted peanut and rice bran. The limiting amino acids in cereals (lysine and threonine) and legumes (methionine) were observably improved in the composite flour. The composite flour blends exhibited the potential to partially replace wheat flour in application of flours for health-promoting food formulation due to their reported phytochemical properties. The pasting properties of the composite flour blends gave an indication of their ability to withstand excess heating and shear stress during baking and confectioneries production. Besides, utilization of these locally available food crops for production of baked products would reduce the production costs of diverse baked products and ensured food security in many households.

Availability of data and materials

The data presented in the study are included in the article and additional material.

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