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Original Research Article

Nutritional and Organoleptic Assessment of Composite Bread Containing Processed Conventional Mango and Wild Mango Kernels

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ABSRTACT

The study assessed the nutritional composition of composite bread formulations. Hence, wheat flour was substituted with either defatted or blanched conventional mango (*Mangifera indica*) or wild mango (*Irvingia gabonensis*) kernel powder at 50% and 75% levels. A reference wheat and composite bread samples were baked, and analysed using standard instrumental techniques for proximate, vitamin and mineral composition, fatty acid and amino acid profiles. The bread samples were organoleptically evaluated by randomly chosen panelists using a 9-point preference scale. Results indicated varied concentrations of nutrients and energy content, as significantly influenced by processing and levels of kernel substitution in bread formulations. Crude fibre, ash and protein concentrations of particularly *Irvingia*-based bread samples were highest followed by those of *Mangifera*, and 100% wheat in that order ($p < 0.05$). Essential amino acids concentrations were significantly higher in *Mangifera*-based bread than those of *Irvingia* and 100% wheat. The two composite bread-types at 50% substitution and the 100% wheat bread met the WHO/FAO standard of PUFA/SFA (> 0.4). The K/Na ratio also was enhanced by 200% through the blanching technique employed. The 75% substitution level increased Ca, Fe and vitamin concentrations. The level of kernel substitution in bread samples significantly influenced their sensory assessment as bread with 50% substitutions were rated next to the conventional 100% wheat bread in overall acceptability. Results have shown that the composite bread samples of 50% *Mangifera* and defatted *Irvingia* had better quality indices than the conventional wheat bread.

Keywords: Blanching, Defatting, *Irvingia gabonensis*, *Mangifera indica*, Organoleptic

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Introduction

Composite flour basically refers to a flour mixture of two or more plant sources "rich in either starch, protein or essential nutrients" with or without wheat flour for the production of some bakery products like leavened or unleavened breads, snacks and other food products or diets. The food products are fundamentally formulated either for the purpose of incorporating essential nutrients and phytochemicals for better nutritional and health benefits, or as a result of the scarcity of a particular flour due to seasonal availability, climatic or economic condition.[1] Composite flours containing essential, non-conventional food source have been reported to have preventive effects on the onset of degenerative diseases associated with modern lifestyle and eating habits. This is because some of these flours are significant sources of different minerals, vitamins, fibre and phenolic compounds.[2]

As a non-conventional source of food, mango kernel has drawn attention of researchers in recent years, due to its suitability to combat nutritional need of human beings when incorporated into composite flour.[3] The kernel was reported to be a useful source of protein, carbohydrate and fat except for the presence of anti-nutritional factors such as tannin.

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Assessment of the nutrients composition of processed kernel flour in percentage by weight revealed carbohydrate (69.8), protein (7.5), fat (11.5), crude fiber (2.2) and energy value of 421 kcal/100g. Appreciable equivalent levels (mg%) of macro minerals present were sodium (290), calcium (170), magnesium (210), potassium (368) while micro minerals were iron (12.4), copper (8.6) as well as zinc (5.6).[4] For these reasons, efforts have been made to promote the utilization of composite flour containing mango kernel in the production of food items. Some of these include the incorporation of defatted mango kernel flour into wheat flour for cookie production, [5] substitution of blanched mango kernel flour in refined wheat flour for the production of novel biscuit and other food items.[6,7,8,9]

In like manner, wild mango (*Irvingia gabonensis*) popularly called African mango, bush mango, dika nut or ogbono is of the *Irvingiacaea* family. It is found naturally in the tropical rainforest of West Africa countries. The kernel powder has culinary significance as soup-thickener.[10] *Irvingia gabonensis* is an oil kernel with valuable food properties. Proximate analysis revealed that the full-fat kernel, percentage by dry weight, contained fat (68.4), carbohydrate (18.7), protein (8.9), moisture (2.6) and ash (2.3) while the defatted kernel flour, in percentage, contained carbohydrate (62.2), protein (25.2), moisture (6.4) and ash (6.2). The fatty acid profile showed that it contained 97.6% saturation, 2.12% monounsaturation and 0.27% polyunsaturation.[11]

From the fore-going, both *Mangifera* and *Irvingia* fruits grow in similar climatic conditions, and have attracted consumers locally over decades for edible mesocarp of the *Mangifera* and use of the *Irvingia* kernel as soup-thickener.

High phenolic content of mango kernel, particularly the tannin content (6.4%) which made the raw kernel inedible[12] and the high saturated fatty acid content of *Irvingia* kernels (97. 6%) [11] are anti-nutritional factors affecting the consumption of these kernels. Processing techniques could reduce the phenolic and fat content of these kernels to a level that is

acceptable for consumption and with a preservative function. Hence, this study pioneers the formulation of composite bread samples substituted with processed *Mangifera indica* or *Irvingia gabonensis* kernel flour at 50 and 75% levels, and evaluating their nutritional and sensory attributes. *In-vivo* study is on-going in our laboratory on the physiological effects of the residual phenolics in the composite bread samples, using *wistar* rat.

Materials and Methods

Sample Collection: Mature conventional mango (*Mangifera indica*) fruits were plucked directly from several trees within Anyigba (7° 28' 51.39" N and 7° 11' 14.86 E) in April 2021 while dried wild mango (*Irvingia gabonensis*) kernels were procured from Anyigba market, Kogi State, Nigeria in May 2021. *Mangifera indica* and *Irvingia gabonensis* kernels were authenticated with voucher numbers (KSU-PT-B-201) and (KSU-PT-B-177), respectively at the Department of Plant Science and Biotechnology, Faculty of Natural Sciences, Kogi State University Anigba, Nigeria.

Refined Wheat (*Triticum aestivum*) flour, Golden Penny Classic flour (Flour Mills Nigeria Plc, 2 Old Dock Road, Apapa, Lagos State), were procured from a Golden Penny Mini Depot, Lokoja International Market, Kogi State, Nigeria. The nutritional composition of the flour in g /100g, according to the manufacturer include; Carbohydrate (73.3), Protein (11.2), Fat (0.4), Fibre (1.3) and Energy (1426. 7 kj). Other micro-nutrients in milligrams include; Zinc (50.0), Iron (40.0), Vitamin A (2.0), Vitamin B_1 (6.0), B_2 (5.0) and B_3 (45.0).

Kernel Preparation and Processing: *Irvingia gabonensis* kernels were sorted manually for wholesomeness. Mature *Mangifera indica* seeds were dissected using sterile stainless steel knife to obtain the kernel. For this study, the testa was scraped off, while the kernel was placed in sterilized water containing 730 mg/L of potassium metabisulphite in plastic container at ambient temperature (28° ± 2°C). Periodically, the coloured water was replaced with an equivalent amount of sulphited water until it remained colorless. The kernel was divided into two portions for the blanching and defatting process. The portion for blanching was used immediately while the portion for defatting was initially dried at ambient temperature (28° ± 2°C) to constant weight and milled into powdery form using Wily Laboratory Mill (Thomas Model: 4, Ramsey, USA). Milled powder was passed through standard sieves (Impact Laboratory Test Sieve, Crawley, England) to obtain flour with a particle size of ≤ 60 µm for the study.

Blanching of kernel: Blanching process was conducted using method of Arogba.[13] Each kernel-type (1 kg) in 450 ml sterilized water was blanched in a stainless-steel bowl for 33 min. Kernels were then drained on a nylon fabric (4 holes mm^{-2}), air dried at ambient temperature to constant weight and milled, similarly, into powdery form of particle size ≤ 60 µm.

Bulk fat extraction of kernel: Defatting process was conducted using solvent extraction technique. Each kernel-type powder (500 g) was extracted with 1.5 L of n-hexane (99% grade, Sigma-Aldrich, Gillingham, England) contained in a 2.0 L capacity round-bottom flask, which was placed on a Surgifriend Laboratory water-bath (SM 9082, Crawley, England) and refluxed at 65°C for 2 h. After prolonged cooling, the extract was decanted and filtered using Edwards's high vacuum pump (ES50, Crawley, England) into another empty round-bottom flask to obtain the residue. Fresh solvent (1.5 L) was added to residue and the entire process was repeated until solvent appeared colourless. The residual sample was air-dried at ambient temperature and stored for further analysis.

Bread formulation (kernel flour types, ratios, and treatments): Wheat flour was substituted with the processed kernel powder at different ratios for composite bread formulation, Table 1.

In the formulation of bread, a reference wheat bread was baked, while others contained 50% and 75% of a processed kernel-type (Table 1).

Determination of water absorption capacity (WAC): This was conducted using the method of Menon *et al*.,[3] to know the quantity of water to be added to the flour mix. Each flour-type (10 g) was weighed into 100 ml capacity beaker and distilled water was added gradually from a burette. The content was mixed with a glass rod until soft knead dough which was not sticky or stiff was formed. The volume of water used to form the dough was recorded.

Bread-baking: The basic recipe for bread-making included flour, yeast, salt, butter, sugar and water. The method of Menon *et al*.,[3] was adopted. The composition of the ingredients are shown in Table 2.

Each bread type was baked with the ingredients in Table 2 using the straight dough method as described by Bibiana *et al*.,[14]. All ingredients were mixed together for 9 min and the dough left in the bowl for a bulk fermentation period of 30 min. The dough was transferred into baking pan and gently placed in Electric Oven (DL-33, China) at 200°C for 30 to 40 min, depending on bread type. Baked bread samples (Figure 1) were cooled at ambient temperature and packaged in aluminium foil for analysis.

Proximate analysis of the bread samples: The proximate composition of moisture, ash, crude fibre, crude protein, crude fat, and carbohydrate contents were analysed using the standard methods of AOAC[15] reported by Al-Ansi *et al*.,[16] and Onyenweaku *et al*.[17]

However, carbohydrate content was calculated thus:

$$\%\ \text{Carbohydrate} = 100 - [\text{Crude fat} + \text{Crude Protein} + \text{Crude Fiber} + \text{Ash} + \text{Moisture conten}]\% \ldots . (1)$$

Estimation of calorific value (energy): The calorific (energy) value of the bread samples was calculated by the Atwater general factor method.[18,15] The value of the protein, carbohydrate and fat were multiplied by 4, 4 and 9 Kcal respectively, using the formula:

$$\text{Total energy (kcal/100g)} = [(4 \times \text{protein}) + (4 \times \text{carbohydrate}) + (9 \times \text{fat})]\% \ldots\ldots\ldots (2)\ .$$

Determination of fatty acid profile of the bread samples: The fatty acid profile was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) technique as reported by Ogunsina *et al*.[11] The oil extracted from the composite bread samples by soxhlet extraction method, were first converted to fatty acid methyl esters (FAMEs) and then analysed using Gas Chromatograph-Mass Spectrometer; Varian Star 3400 CX GC (Varian Inc. Alexandria, USA) with FID detector. The fatty acid concentration was expressed in% w/w sample.

Table 1: Flour substitution levels and treatment given for bread formulation

Treatment	Kernels	% Kernel flour : Wheat flour				
		75 : 25	75 : 25	50 : 50	50 : 50	0 : 100
Defatted	*M.indica*	✓	-	✓	-	-
	I. gabonensis	-	✓	-	✓	-
Blanched	*M.indica*	✓	-	✓	-	-
	I. gabonensis	-	✓	-	✓	-
Reference wheat flour						✓

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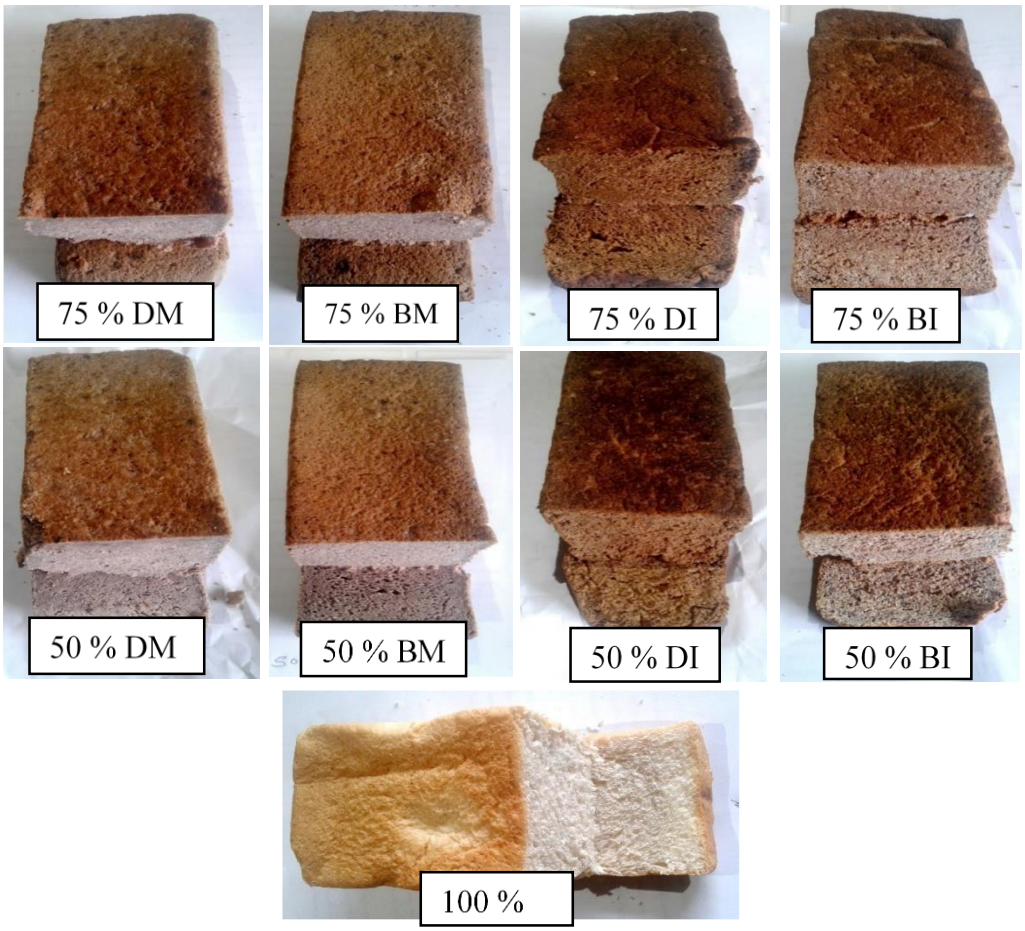

Figure 1: Composite and wheat bread samples.

Determination of amino acid profile of the bread samples: The amino acid profile was analysed using high performance liquid chromatograph (HPLC) technique, as described by AOAC[19] with modifications. Applied Biosystems Phenylthiohydratoin (PTH) Amino Acid Analyser 120A (Applied Biosystems Inc., Foster City, California, U.S.A) was used. It automatically analyses amino acids derived from Edman degradation of proteins and peptides. The concentration of the amino acid was expressed in g /100g protein.

Determination of mineral content of the bread samples: Spectroanalytical technique of AOAC [15] was used to determine the mineral content of the bread samples. Potassium and sodium content of the samples were evaluated using Flame Photometer (PFP7, Jenway Ltd, Dunmow Essex, UK) while calcium and iron were determined using Atomic Absorption Spectrophotometer (GBC 904AA, Kempen, Germany) as reported by Winiarska-Mieczan and Kwiecien (2011). For each sample type, 1.0 g was weighed into crucible, ashed in a muffle furnace at 500 °C for 6 h and dissolved in 5 mL of 20% (2M) hydrochloric acid. The solution was filtered, made up to 50 mL with distilled deionized water, and analysed. The mineral concentration was expressed in mg /100g sample.

Determination of vitamin content of the bread samples: The vitamin content of the bread samples was analysed using colorimetric assay techniques, [20, 21] based on the principles described below.

Vitamin C (ascorbic acid): Ascorbic acid reduces phosphotungstic acid in acidic medium to blue phosphotungstate chromogen, which has absorption maximum at 700 nm.

To each tube labelled test, standard and blank, 1.0 mL of sample (Ascorbate was extracted from 1 g of the sample using 4% TCA), Stock Standard ascorbic acid and distilled water were dispensed respectively. This was followed by the addition of 1.0 ml Phosphotungstic acid (colour developing reagent) to test and standard. The content of the tubes were mixed thoroughly and allowed to stand for 30 min at ambient temperature. Each tube was centrifuged at 3000 rpm for 10 min and the absorbance of the supernatant was measured against blank at 700 nm using UV/VIS Spectrophotometer (UV752, Shanghai, China). The concentration of ascorbic acid (mg/100g) was calculated using the formula:

$$\text{Ascorbic acid} = \left[\frac{A_{Sample}}{A_{Standard}} \times C_{Standard}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3).$$

Where; A = absorbance and C = concentration

Vitamin A (beta-carotene equivalent): The method is based on the extraction of β-carotene into light petroleum and measuring the intensity of the yellow extract at 460 nm.

Each sample type (0.5 g) was homogenized and saponified with 2.5 mL of 12% alcoholic potassium hydroxide in a water bath at 60 °C for 30 min. The saponified extract was transferred to a separating funnel containing 10 – 15 mL of petroleum ether and mixed properly. The lower aqueous layer was then transferred to another separating funnel and the upper petroleum ether layer containing the carotenoids was collected .The extraction was repeated until the aqueous layer became colourless. A small amount of anhydrous sodium sulphate was added to the petroleum ether extract to remove excess moisture. The final volume of the petroleum ether extract was noted and the absorbance of the yellow extract was measured against petroleum ether as blank, at 460 nm using UV/VIS Spectrophotometer (UV752, Shanghai, China).

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Table 2: Ingredients for bread samples from different treatments

Ingredient	Standard bread 100 %	*M. indica* bread 75 %	50%	*I. gabonensis* bread 75 %	50 %
Wheat flour (g)	250	65.5	125	65.5	125
[*M. indica* kernel powder (g) (defatted or blanched)]		187.5	125		
[*I. gabonensis* kernel powder (g) (defatted or blanched)]				187.5	125
Sugar (g)	25	25	25	25	25
Dried yeast (g)	10	10	10	10	10
Butter (g)	4	4	4	4	4
Salt (g)	3	3	3	3	3
Water (ml)	155				
Defatted WAC (ml)		243	205	228	200
Blanched WAC (ml)		240	205	150	153

The concentration of Vitamin A (IU/100g beta-carotene equivalent) was calculated using the formula: $\text{Vitamin A} = \left(\frac{A_{Sample}}{A_{Standard}}\right) \times C_{Standard} \times \left(\frac{\text{Volume of extraction solvent}}{\text{weight of sample}}\right) \ldots\ldots\ldots\ldots (4)$.

Vitamin E (tocopherol): This is based on the oxidation of tocopherol to tocopheryl quinine by ferric chloride and resultant ferrous ions is complexed with 2,2-dipyridyl to produce a red coloured compound.
Each sample type (0.5 g) was homogenized and saponified with 2.5 ml of 12% alcoholic potassium hydroxide in a water bath at 60 °C for 30 min. Saponified sample, standard, and distilled water (blank) (0.5 mL each) were dispensed into three different centrifuge tubes respectively. Xylene (0.5 mL) was added to all the tubes, stoppered, mixed and centrifuged. Xylene layer (1.0 mL) was carefully transferred into other tubes and α-Dipyridyl reagents (1.0 mL) was added to each tube, stoppered and mixed. Each mixture (1.5 mL) was pipetted into cuvettes and the absorbance of test and standard were measured against the blank at 460 nm. In turn beginning with the blank, 0.33 mL ferric chloride was added and the absorbance was taken again at 520 nm using UV/VIS Spectrophotometer (UV752, Shanghai, China).
The concentration of Vitamin E (mg/100g) was calculated using the formula:

$$\text{Vitamin E} = \left[\left(\frac{A_{Sample}\text{ at 520 nm} - A_{Sample}\text{ at460 nm}}{A_{Standard}\text{ at 460 nm}}\right) \times C_{Standard}\right] \times \left[\frac{\text{Voulume of solvent}}{\text{Weiht of sample}}\right] \ldots (5)$$

Sensory evaluation of the composite bread samples: The bread samples were numerically coded and organoleptically evaluated by randomly chosen panelists. The sensory attributes evaluated included colour, flavour, taste, texture, appearance and overall acceptability. The panelists were provided with water for mouth-rinse between each tasting. The attributes were scored using a 9-point preference scale, where nine (9) was scored for like extremely and one (1) for dislike extremely as reported by Ijabadeniyi *et al*.[22]

Data Analysis
This was conducted using Standard Error of Mean (SEM) on a calculator at *miniwebtool.com*. Results were expressed as mean ± SEM. Separation of Mean was conducted for test of significance at (p = 0.05). All measurements were taken in triplicate (n = 3).

Results and Discussion

Proximate composition and energy value of bread samples: In Table 3, the moisture content of the *Mangifera*-based bread samples was significantly higher ($p < 0.05$) than those with *Irvingia* at both levels of substitution, regardless of the treatment given. Crude fibre, ash and protein concentrations of particularly *Irvingia*-based bread samples were highest followed by those of *Mangifera*, and 100% wheat in that order. However, blanching or defatting had no significant effect on the carbohydrate content of *Mangifera* composite bread ($p > 0.05$) unlike the *Irvingia*-based bread.
The protein content of *Irvingia* bread samples increased with increase in kernel substitution ($p < 0.05$) while the reverse was observed in the *Mangifera* composite bread samples. The fat content of defatted *Irvingia* bread samples decreased ($p < 0.05$) at each level of substitution when compared with the blanched. Similar effect of defatting was observed in the energy content.
Proximate analysis is significant in evaluating the nutritional quality and chemical composition of formulated food products. It also serves as a basis for the overall acceptability of the food products.
The higher moisture content of *Mangifera* composite bread samples than the *Irvingia* samples at each level of kernel substitution could be attributed to their high water absorbing capacity at water activity a_w corresponding to their equilibrium moisture content (EMC), as well as composition. Unlike *Mangifera*, *Irvingia* kernel is an oil seed [11] of which the bread with calculated carbohydrate and residual crude fat contents were dependent on the influence of defatting process conducted in this study. In the formation of dough (Table 2), *Mangifera* composite flours absorbed more water than *Irvingia* and reference wheat flours, due to their high carbohydrate content.[4] The residual moisture content after baking could impact on physical, sensory and microbial properties of the bread. Furthermore, higher moisture content is associated with reduced shelf life, implying that the *Irvingia* and reference wheat bread samples could maintain longer acceptable quality at storage than the *Mangifera* bread samples.
The fibre-rich *Irvingia* kernel testa [23] and the defatting process could be responsible for the higher residual ash, fibre and protein contents of *Irvingia* bread compared with other bread samples. The defatting process also accounted principally for differences in parameters analysed with bread samples containing blanched kernels. The residual fat content of blanched *Irvingia* composite bread samples, therefore, could explain the high energy values obtained. Fat provides higher energy of about 9 kcal/g compared with protein or carbohydrate of 4 kcal/g.[18]
The proximate composition of the composite bread samples suggested that some of the bread samples, particularly those with higher energy and optimum protein content could be utilized in a dietary strategy to

boost the protein and energy intake of individual, and possibly avert protein-energy malnutrition in children and adults.

Fatty acid profile of bread samples: From Table 4a and 4b, except for the blanched *Irvingia*, its defatted form and both *Mangifera* bread types had similar UFA or SFA concentrations with the wheat bread ($p > 0.05$). However, the latter had relatively higher ratio of PUFA to SFA, as similarly observed with 75% kernel substitutions. Wheat contributed higher significant concentrations of palmitic, oleic, eicosenoic, and linoleic acids as *Mangifera* and *Irvingia* with stearic, arachidic, palmitolic, and α-linolenic acids to the profile of the composite bread samples ($p < 0.05$).

The ratio of unsaturation/saturation was significantly higher in the reference wheat bread than the composite bread samples. Furthermore, reference wheat and defatted *Irvingia* composite bread samples had the highest ratio of ω6/ω3 at 50% substitution level ($p < 0.05$).

Fatty acids constitute the main components of glycerolipids which are required in human nutrition as energy source, and also used for structural and metabolic activities. Over 80% of fatty acids commonly found in all bread samples were due to palmitic, stearic, oleic and linoleic acids. In *Irvingia* bread samples with blanched kernels, lauric (21%) and myristic (54%) acids were peculiarly and significantly major components of the profile, while others were below 8%. The semi-solid appearance of *Irvingia* oil-extract at ambient temperature was ascribed to myristic acid, [11] also could be additionally due to palmitic, stearic, and arachidic acids identified in this study.

On the contrary, the mango-based and wheat bread samples had higher concentrations of oleic acid possibly because *Mangifera* kernel oil is known to contain 48 and 44% of oleic acid [13] and [24] respectively. Oleic and linoleic acids appeared to have significantly influenced the ratio of unsaturation to saturation. These bread samples, therefore, could have favourable effects on cardiovascular system. The results for wheat, *Irvingia* and mango-based bread samples at 50% substitution met the WHO/FAO standard of PUFA/SFA of > (0.4).[25]

Linoleic (ω6) and α-linolenic (ω3) are essential fatty acids which serve as precursors of important biological molecules such as prostaglandins, membrane phospholipids and also involved in metabolic regulation of blood cholesterol. Dietary supplementation of these fatty acids and other unsaturated fatty acids have been reported to have anti-inflammatory effects, reduce risk of cardiovascular disease by lowering low density lipoprotein cholesterol and reducing the pathogenesis of other diseases such as cancer, type 2 diabetes and neurological disorders.[26]

Amino acid profile of bread samples: Tables 5a and 5b showed that the concentrations of essential amino acids in the *Mangifera* bread samples were significantly higher than those of *Irvingia* and 100% wheat bread types ($p < 0.05$). On the contrary, the concentrations of non-essential amino acids in the *Mangifera* bread samples were significantly lower. Among the two bread types, defatted composite samples had virtually lower or similar essential amino acid concentrations compared with the blanched type ($p > 0.05$).

Table 5c showed that the ratio of essential to non-essential amino acids in the composite bread samples increased with increased substitution of *Mangifera* kernel flour, irrespective of treatment. On the contrary, *Irvingia* kernel flour substitution had no such effect, even on comparing with the 100% wheat bread. *Mangifera* composite bread samples had increased essential amino acid compared with wheat bread by 20% at 50% substitution, and by 100 – 160% at 75% substitution. Defatting *Mangifera* kernel caused 23% loss of essential amino acid compared with the blanching process.At each level of substitution, defatted kernel substituted composite bread types had higher content of acidic and basic amino acid than blanched types ($p < 0.05$). The contrary was observed in respect of aromatic amino acid.

Amino acids are the structural and functional units of proteins, used by the body as intermediate substrates in the metabolic production of energy, and as building blocks of enzymes and structural proteins. As a result, proteins are considered as a multifunctional biomolecule due to the role of their amino acids.[27, 28] Tables 5(a and b) suggested that *Mangifera* kernel-based bread was richer in essential amino acids than those with *Irvingia* kernel and 100% wheat at both levels of substitution. Threonine, leucine, phenylalanine, valine and methionine were prominent. The observation was supported by the increase in the ratio of essential to non-essential amino acid in *Mangifera* composite bread samples at higher kernel substitution of 75%. On the contrary, *Irvingia* and wheat bread samples were richer in non-essential amino acids namely, glutamic acid, aspartic acid, glycine and tyrosine.

Table 5c showed that blanching caused significant reduction in acidic and basic amino acid contents, and aromatic amino acids by the defatted process, at similar levels of substitutions. The results depicted the solubility effects of the respective solvents employed.

Amino acids such as aspartic acid, arginine, glutamic acid and phenylalanine serve as precursors of gluconeogenesis to provide energy and also balance muscle protein turnover during starvation and stress condition.[27] In addition, amino acids have been reported to play a role in the treatment and prevention of metabolic diseases such as diabetes, obesity and cardiovascular disorders. For example, dietary supplementation of leucine, arginine, proline and glutamic acid reduce excess body fat, [29] and therefore, could be encouraged through the application of these processed kernels.

Mineral composition of bread samples: In Table 6, the sodium content of all the composite bread samples was significantly lower than the wheat bread ($p < 0.05$), but the potassium, calcium and iron concentrations of *Irvingia* and wheat bread samples were similar at 50% level ($p > 0.05$). Furthermore, the potassium content of composite bread samples was not less than twice the sodium concentration, regardless of substitution level and treatments given.

Table 3: Proximate composition and energy value of bread samples

Bread type	Moisture (%)	Ash (%)	Crude Fibre (%)	Crude Protein (%)	Crude Fat (%)	Carbohydrate (%)	Energy value (kcal/100g)
75 DM	25.0 ± 0.29^{d}	1.9 ± 0.21^{b}	1.8 ± 0.19^{c}	10.6 ± 0.17^{a}	5.3 ± 0.19^{a}	54.6 ± 1.04^{de}	309 ± 1.57^{a}
75 BM	24.1 ± 0.25^{d}	1.8 ± 0.10^{b}	1.7 ± 0.12^{bc}	11.2 ± 0.06^{ab}	10.9 ± 0.22^{b}	50.0 ± 1.16^{d}	343 ± 2.81^{b}
75 DI	20.1 ± 0.42^{c}	2.9 ± 0.23^{e}	3.3 ± 0.23^{e}	18.4 ± 0.12^{g}	10.1 ± 0.21^{b}	45.2 ± 0.20^{c}	345 ± 2.47^{b}
75 BI	15.2 ± 0.15^{ba}	2.1 ± 0.15^{c}	2.5 ± 0.18^{d}	15.7 ± 0.25^{e}	39.0 ± 0.27^{e}	25.7 ± 0.87^{a}	517 ± 4.20^{e}
50 DM	20.0 ± 0.23^{c}	1.9 ± 0.12^{b}	1.6 ± 0.17^{b}	13.4 ± 0.25^{c}	6.9 ± 0.23^{ab}	54.7 ± 1.60^{de}	344 ± 2.50^{b}
50 BM	19.2 ± 0.21^{c}	1.8 ± 0.10^{b}	1.6 ± 0.11^{b}	13.4 ± 0.10^{c}	9.0 ± 0.12^{ab}	55.9 ± 1.10^{e}	349 ± 1.95^{b}
50 DI	14.5 ± 0.09^{a}	2.3 ± 0.33^{d}	2.4 ± 0.15^{d}	17.0 ± 0.12^{f}	12.4 ± 0.12^{b}	51.4 ± 0.79^{d}	385 ± 1.43^{c}
50 BI	13.9 ± 0.12^{a}	2.1 ± 0.12^{c}	2.0 ± 0.12^{c}	14.3 ± 0.27^{d}	28.0 ± 0.35^{d}	39.8 ± 0.20^{b}	468 ± 3.84^{d}
100 W	16.1 ± 0.21^{b}	1.6 ± 0.07^{a}	1.2 ± 0.12^{a}	12.0 ± 0.09^{b}	9.3 ± 0.13^{b}	59.5 ± 1.05^{f}	369 ± 2.70^{c}
SEM	1.36	0.13	0.21	0.88	3.76	3.44	22.31

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts in the same column are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched I= Irvingia gabonensis, W = Wheat. SEM = Standard error of mean.

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Table 4a: Fatty acid profile of bread samples at 50 % kernel substitution

Fatty acid (% w/w)	50 DM	50 BM	50 DI	50 BI	100 W	SEM
Lauric (C_{12}:0)	4.1 ± 0.03^{a}	4.2 ± 0.05^{a}	2.9 ± 0.01^{a}	13.1 ± 0.40^{b}	2.6 ± 0.06^{a}	1.96
Myristic (C_{14}:0)	5.6 ± 0.11^{a}	4.6 ± 0.01^{a}	5.2 ± 0.03^{a}	38.3 ± 0.22^{b}	5.0 ± 0.05^{a}	6.64
Palmitic (C_{16}:0)	24.5 ± 1.24^{c}	15.8 ± 0.01^{b}	26.4 ± 0.23^{c}	12.3 ± 0.11^{a}	24.7 ± 0.20^{c}	2.81
Palmitolic (C_{16}:1)	3.3 ± 0.04^{b}	4.1± 0.03^{c}	2.4 ± 0.05^{a}	3.4 ± 0.02^{b}	2.3 ± 0.01^{a}	0.34
Stearic (C_{18}:0)	13.1 ± 1.03^{c}	19.9 ± 1.05^{d}	10.4 ± 0.08^{b}	7.2 ± 0.10^{a}	11.6 ± 0.01^{b}	2.10
Oleic (C_{18}:1)	24.8 ± 1.06^{b}	27.8 ± 1.01^{c}	24.6 ± 1.10^{b}	12.8 ± 0.91^{a}	25.4 ± 1.30^{b}	2.63
Linoleic (C_{18}:2)ω6	19.2 ± 0.88^{b}	17.2 ± 0.65^{b}	22.9 ± 1.01^{c}	7.6 ± 0.51^{a}	23.5 ± 2.00^{c}	2.87
α-linolenic C_{18}:3)ω3	1.7 ± 0.06^{b}	2.2 ± 0.07^{c}	1.5 ± 0.04^{a}	2.2 ± 0.05^{c}	1.7 ± 0.02^{b}	0.14
Arachidic (C_{20}:0)	0.5 ± 0.01^{ab}	1.7 ± 0.05^{c}	0.7± 0.01^{b}	0.9 ± 0.02^{b}	0.3 ± 0.01^{a}	0.24
Eicosenoic (C_{20}:1)	1.8 ± 0.23^{b}	1.6 ± 0.12^{ab}	1.7 ± 0.11^{ab}	1.1 ± 0.10^{a}	2.1 ± 0.40^{b}	0.63
ΣUFA	50.8^{b}	52.9^{b}	53.1^{b}	27.1^{a}	55.0^{b}	5.21
ΣSFA	47.8^{a}	46.2^{a}	45.6^{a}	71.8^{b}	44.2^{a}	5.20
ΣPUFA	20.9^{b}	19.4^{b}	24.4^{c}	9.8^{a}	25.2^{c}	2.75
Ratio (PUFA/SFA)	0.44^{b}	0.42^{b}	0.54^{c}	0.14^{a}	0.57^{c}	0.08
Ratio (ω6/ω3)	11.29^{c}	7.82^{b}	15.27^{d}	3.45^{a}	13.82^{d}	2.13

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts on the same row are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched I = Irvingia gabonensis, W = Wheat. ΣSFA = Sum of saturated fatty acids, ΣUFA = Sum of unsaturated fatty acids, PUFA = polyunsaturated fatty acids. SEM = Standard error of mean.

Table 4b: Fatty acid profile of bread samples at 75 % kernel substitution

Fatty acid (% w/w)	75 DM	75 BM	75 DI	75 BI	100 W	SEM
Lauric (C_{12}:0)	3.8 ± 0.02^{ab}	6.2 ± 0.04^{b}	3.3 ± 0.01^{a}	21.1 ± 1.32^{c}	2.6 ± 0.06^{a}	3.49
Myristic (C_{14}:0)	5.4 ± 0.04^{a}	3.7 ± 0.03^{a}	18.8 ± 0.21^{b}	54.3 ± 2.26^{c}	5.0 ± 0.05^{a}	9.62
Palmitic (C_{16}:0)	24.9 ± 1.67^{b}	7.8 ± 0.63^{a}	23.6 ± 1.03^{b}	6.7 ± 0.51^{a}	24.7 ± 0.20^{b}	4.21
Palmitolic (C_{16}:1)	3.4 ± 0.08^{b}	5.1 ± 0.21^{d}	3.1 ± 0.05^{b}	4.3 ± 0.21^{c}	2.3 ± 0.01^{a}	0.49
Stearic (C_{18}:0)	23.4± 1.42^{c}	29.9 ± 2.09^{d}	11.3 ± 0.91^{b}	1.3 ± 0.02^{a}	11.6 ± 0.01^{b}	5.02
Oleic (C_{18}:1)	24.4 ± 1.71^{b}	33.8 ± 2.03^{c}	24.7 ± 1.80^{b}	5.7 ± 0.04^{a}	25.4 ± 1.30^{b}	4.62
Linoleic (C_{18}:2)ω6	10.7 ± 0.92^{c}	6.2 ± 0.71^{b}	9.7 ± 0.42^{b}	1.8 ± 0.06^{a}	23.5 ± 2.00^{d}	3.63
α-linolenic (C_{18}:3)ω3	1.6 ± 0.02^{a}	2.7 ± 0.01^{c}	1.9 ± 0.02^{b}	2.6 ± 0.13^{c}	1.7 ± 0.02^{a}	0.23
Arachidic (C_{20}:0)	0.4 ± 0.01^{a}	2.2 ± 0.01^{c}	0.6 ± 0.01^{a}	1.3 ± 0.03^{b}	0.3 ± 0.01^{a}	0.59
Eicosenoic (C_{20}:1)	1.6 ± 0.02^{b}	1.3 ± 0.01^{b}	1.5 ± 0.04^{b}	0.3 ± 0.00^{a}	2.1 ± 0.40^{c}	0.30
ΣUFA	41.7^{b}	49.1^{bc}	40.9^{b}	11.7^{a}	55.0^{c}	8.89
ΣSFA	57.9^{b}	49.8^{a}	57.6^{b}	89.7^{c}	44.2^{a}	7.89
ΣPUFA	12.3^{c}	8.9^{b}	11.6^{bc}	4.4^{a}	25.2^{d}	3.24
Ratio (PUFA/SFA)	0.21^{b}	0.18^{b}	0.20^{b}	0.05^{a}	0.57^{c}	0.09
Ratio (ω6/ω3)	6.69^{c}	2.30^{b}	5.11^{c}	0.69^{a}	13.82^{d}	2.28

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts on the same row are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched I = Irvingia gabonensis, W = Wheat. ΣSFA = Sum of saturated fatty acids, ΣUFA = Sum of unsaturated fatty acids, PUFA = polyunsaturated fatty acids. SEM = Standard error of mean.

For any kernel type and percentage substitution, the respective sodium, potassium, calcium and iron contents were similar regardless of treatment given ($p > 0.05$). Except for sodium, potassium, calcium and iron concentrations increased with level of substitution for *Mangifera* kernel-substituted bread samples ($p < 0.05$).

Minerals are inorganic nutrients, which are needed by the body in small quantities, less than 1 to 2500 mg per day. They are involved in the transport of molecules, muscle contractions, structural components of body tissues, maintenance of acid-base balance, enzymes activities and regulate body fluids. Information on mineral content of foods is essential to ensure adequate dietary intake of minerals.[30] Table 6 showed that *Mangifera* and *Irvingia* kernel bread samples had lower sodium content than the wheat bread. This observation was similar to a report on mineral content of bread samples.[31] On the contrary, K, Ca and Fe content of the *Mangifera* composite bread samples increased with increase in the substitution. *Mangifera* kernel possibly absorbed more potassium from potassium metabisulphite solution used in soaking the kernels during processing, as evidenced in the defatted *Mangifera* bread samples. At 50% substitutions, K/Na ratio was twice greater and even increased at higher level of substitution, with attendant beneficial effect on the cardiovascular system. Blanching treatment,

generally, leached insignificant concentrations of all the minerals at both substitution levels ($p > 0.05$).

Potassium and sodium are the respective principal intracellular and extracellular cations. They function in acid-base balance, regulate osmotic pressure, transmit nerve impulse, involved in Na^+/K^+-ATPase activity. Calcium plays significant role in bones and teeth formation and activates the conversion of prothrombin to thrombin in blood coagulation. Iron functions as component of haemoglobin in the transport of oxygen.[30] The results, therefore, illustrated the potential and more positive effects of consuming these composite bread samples, than the conventional wheat bread.

Vitamin composition of bread samples: Table 7 showed that the 50 and 75% substitutions of the kernel types contributed significantly to the vitamin content of the bread samples ($p < 0.05$). At each level of substitution, defatted kernel substituted composite bread had higher concentration of vitamin C compared with blanched kernel substituted bread ($p < 0.05$). The contrary was observed in the concentrations of vitamin A and vitamin E contained in the blanched kernel types.

Table 5a: Amino acid profile of bread samples at 50 % kernel substitution

Amino acid (g /100g protein)	50 DM	50 BM	50 DI	50 BI	100 W	SEM
Essential amino acids (EAA)						
Histidine (+)	3.5 ± 0.01^{c}	2.5 ± 0.00^{a}	3.4 ± 0.01^{c}	2.7 ± 0.02^{ab}	2.9 ± 0.02^{b}	0.20
Threonine	7.5 ± 0.06^{d}	6.2 ± 0.03^{c}	4.9 ± 0.01^{b}	4.3 ± 0.02^{ab}	4.0 ± 0.01^{a}	0.65
Leucine	11.2 ± 0.11^{c}	11.5 ± 0.22^{c}	8.4 ± 0.16^{a}	10.0 ± 0.31^{b}	10.0 ± 0.14^{b}	0.55
Valine	7.1 ± 0.21^{c}	8.1 ± 0.13^{d}	4.6 ± 0.02^{a}	5.1 ± 0.01^{a}	6.2 ± 0.04^{b}	0.64
Isoleucine	4.5 ± 0.01^{b}	6.1 ± 0.03^{d}	4.3 ± 0.06^{ab}	5.2 ± 0.02^{c}	4.0 ± 0.01^{a}	0.38
Phenylalanine (*)	8.3 ± 0.11^{c}	9.5 ± 0.05^{d}	5.5 ± 0.03^{a}	6.8 ± 0.12^{b}	6.2 ± 0.09^{ab}	0.73
Methionine	2.3 ± 0.01^{a}	4.2 ± 0.03^{b}	2.0 ± 0.01^{a}	1.8 ± 0.03^{a}	2.3 ± 0.01^{a}	0.43
Tryptophan (*)	1.9 ± 0.02^{a}	1.9 ± 0.01^{a}	1.2 ± 0.04^{b}	1.1 ± 0.01^{ab}	1.2 ± 0.02^{b}	0.19
Lysine (+)	4.5 ± 0.10^{b}	3.2 ± 0.03^{a}	5.5 ± 0.02^{c}	5.4 ± 0.07^{c}	6.6 ± 0.06^{d}	0.57
Total EAA	50.8^{c}	53.2^{c}	39.8^{a}	42.5^{b}	43.4^{b}	2.57
Non-essential amino acids (NAA)						
Arginine (+)	6.5 ± 0.00^{b}	4.0 ± 0.33^{a}	9.1 ± 0.27^{d}	8.6 ± 0.50^{cd}	7.7 ± 0.10^{c}	0.91
Aspartic acid (-)	7.8 ± 0.18^{b}	5.5 ± 0.44^{a}	12.0 ± 0.23^{d}	9.5 ± 0.52^{c}	9.4 ± 0.31^{c}	1.07
Cysteine	2.2 ± 0.02^{c}	1.4 ± 0.00^{a}	1.6 ± 0.01^{b}	1.3 ± 0.02^{a}	1.3 ± 0.03^{a}	0.17
Glutamic acid (-)	10.6 ± 0.10^{b}	5.7 ± 0.33^{a}	15.0 ± 0.56^{d}	12.3 ± 0.50^{c}	13.9 ± 0.16^{c}	1.63
Serine	6.1 ± 0.00^{d}	6.6 ± 0.03^{e}	4.9 ± 0.11^{b}	4.5 ± 0.01^{a}	5.6 ± 0.02^{c}	0.32
Alanine	2.7 ± 0.04^{b}	4.0 ± 0.12^{c}	4.4 ± 0.07^{c}	6.4 ± 0.04^{d}	1.7 ± 0.02^{a}	0.80
Glycine	2.5 ± 0.02^{a}	6.6 ± 0.05^{c}	4.9 ± 0.01^{b}	5.2 ± 0.03^{b}	6.2 ± 0.03^{c}	0.72
Proline	4.3 ± 0.02^{a}	6.6 ± 0.00^{c}	4.3 ± 0.07^{a}	5.5 ± 0.05^{b}	6.0 ± 0.04^{bc}	0.56
Tyrosine (*)	6.5 ± 0.00^{c}	6.3 ± 0.04^{c}	4.0 ± 0.06^{a}	4.1 ± 0.01^{a}	4.8 ± 0.03^{b}	0.53
Total NAA	49.2^{a}	46.8^{a}	60.2^{c}	57.4^{b}	56.6^{b}	2.57

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts on the same row are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched, I = Irvingia gabonensis, (-) = Acidic amino acid, (+) =Basic amino acid, (*) = Aromatic amino acid. SEM = Standard error of mean.

Table 5b: Amino acid profile of bread samples at 75 % kernel substitution

Amino acid (g /100g protein)	75 DM	75 BM	75 DI	75 BI	100 W	SEM
Essential amino acids (EAA)						
Histidine (+)	9.2 ± 0.02^{c}	5.0 ± 0.01^{b}	4.6 ± 0.10^{b}	2.4 ± 0.01^{a}	2.9 ± 0.02^{a}	1.20
Threonine	13.1 ± 0.03^{d}	8.1 ± 0.01^{c}	5.8 ± 0.04^{b}	3.4 ± 0.02^{a}	4.0 ± 0.01^{a}	1.76
Leucine	7.4 ± 0.20^{ab}	15.0 ± 0.19^{d}	6.7 ± 0.15^{a}	8.8 ± 0.20^{b}	10.0 ± 0.14^{c}	1.45
Valine	7.9 ± 0.13^{c}	9.4 ± 0.10^{d}	4.2 ± 0.06^{a}	7.7 ± 0.40^{c}	6.2 ± 0.04^{b}	0.88
Isoleucine	6.5 ± 0.12^{b}	9.2 ± 0.04^{c}	3.7 ± 0.02^{a}	6.5 ± 0.07^{b}	4.0 ± 0.01^{a}	1.00
Phenylalanine (*)	7.6 ± 0.33^{c}	11.2 ± 0.17^{d}	4.5 ± 0.08^{a}	7.5 ± 0.24^{c}	6.2 ± 0.09^{b}	1.10
Methionine	3.3 ± 0.02^{c}	5.2 ± 0.01^{d}	3.8 ± 0.10^{c}	1.5 ± 0.00^{a}	2.3 ± 0.01^{b}	0.64
Tryptophan (*)	2.5 ± 0.01^{c}	2.3 ± 0.00^{c}	1.7 ± 0.02^{b}	1.1 ± 0.00^{a}	1.2 ± 0.02^{a}	0.28
Lysine (+)	4.3 ± 0.05^{b}	2.4 ± 0.01^{a}	6.3 ± 0.2^{c}	4.8 ± 0.13^{b}	6.6 ± 0.06^{c}	0.76
Total EAA	62.0^{b}	67.8^{c}	41.3^{a}	43.8^{a}	43.4^{a}	5.50

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Non-essential amino acids (NAA)						
Arginine (+)	5.9 ± 0.30[b]	2.7 ± 0.15[a]	10.3 ± 0.71[d]	9.1 ± 0.00[d]	7.7 ± 0.10[c]	1.33
Aspartic acid (-)	6.5 ± 0.6[b]	3.1 ± 0.14[a]	11.2 ± 0.70[d]	10.3 ± 0.42[d]	9.4 ± 0.31[c]	1.48
Cysteine	2.8 ± 0.01[d]	1.0 ± 0.03[a]	2.1 ± 0.04[c]	1.3 ± 0.00[a]	1.3 ± 0.03[a]	0.33
Glutamic acid (-)	9.8 ± 0.35[b]	7.5 ± 0.23[a]	13.0 ± 0.60[c]	10.1 ± 0.31[b]	13.9 ± 0.16[c]	1.16
Serine	2.2 ± 0.05[a]	1.7 ± 0.01[a]	5.4 ± 0.16[c]	4.1 ± 0.11[b]	5.6 ± 0.02[c]	0.80
Alanine	3.2 ± 0.30[b]	5.4 ± 0.05[d]	4.3 ± 0.02[c]	6.6 ± 0.07[e]	1.7 ± 0.02[a]	0.85
Glycine	2.6 ± 0.04[a]	3.7 ± 0.0[b]	4.3 ± 0.12[b]	5.5 ± 0.07[c]	6.2 ± 0.03[d]	0.64
Proline	2.0 ± 0.03[a]	3.1 ± 0.06[b]	3.9 ± 0.10[b]	5.7 ± 0.09[c]	6.0 ± 0.04[c]	0.76
Tyrosine (*)	3.0 ± 0.01[a]	4.0 ± 0.01[c]	4.2 ± 0.15[c]	3.5 ± 0.07[b]	4.8 ± 0.03[d]	0.31
Total NAA	38.0[b]	32.2[a]	58.8[c]	56.2[c]	56.6[c]	5.51

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts on the same row are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched, I = Irvingia gabonensis, (-) = Acidic amino acid, (+) = Basic amino acid, (*) = Aromatic amino acid. SEM = Standard error of mean

Table 5c: Types of amino acids in bread samples derived from Tables 3(a,b)

Bread type	Essential: Non-essential	Acidic	Basic	Aromatic	Acidic: basic: aromatic
		(g/100g protein)			
75 DM	1.6: 1.0	16.3[b]	19.4[e]	13.1[c]	1.2: 1.5: 1.0
75 BM	2.1: 1.0	10.6[a]	10.1[a]	17.5[de]	0.6: 0.6: 1.0
75 DI	0.7: 1.0	24.3[f]	21.2[f]	10.4[a]	2.3: 2.0: 1.0
75 BI	0.8: 1.0	20.4[d]	16.3[c]	12.1[b]	1.7: 1.4: 1.0
50 DM	1.0: 1.0	18.4[c]	14.5[b]	16.7[d]	1.1: 0.9: 1.0
50 BM	1.0: 1.0	11.2[a]	9.7[a]	17.8[e]	0.6: 0.5: 1.0
50 DI	0.7: 1.0	27.0[g]	18.0[d]	10.7[a]	2.5: 1.7: 1.0
50 BI	0.7: 1.0	21.8[e]	16.7[c]	12.0[b]	1.8: 1.4: 1.0
100 W	0.8: 1.0	23.3[e]	17.2[cd]	12.2[bc]	1.9: 1.4: 1.0
SEM		1.90	1.30	0.97	

Values with the same superscripts in the same column are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched, I = Irvingia gabonensis, W = Wheat. SEM = Standard error of mean

Vitamins are micro-nutrients for the metabolism and regulation of key biological activities. Vitamin C prevents scurvy, vitamin A enhances better vision, and E strengthens immune system and possesses anti-inflammatory function. As exogenous antioxidants, vitamins C and E function as chain-breaking antioxidants by inhibiting the propagation phase of free radical reactions and reduce oxidation of LDL, which is linked to atherosclerosis and cardiovascular disease.[32]

Table 7 showed that increase in kernels substitutions enhanced the vitamin content of the bread samples, and to possibly improve shelf-stability due to the antioxidant properties of the kernels. *Mangifera* and *Irvingia* kernels were reported to have significant antioxidant activity due to their high phenolic content, [33] and appreciable amount of antioxidant vitamins.[34] Blanching treatment given to the kernels could be responsible for the low content of vitamin C in the blanched composite bread samples compared with defatted types at similar level of kernel substitutions, due to effects of solvents employed. In all instances, the processed kernels boosted the vitamin content and antioxidant potential of bread samples compared with 100% wheat bread.

Sensory attributes of bread samples scored on 9-point preference scale: Bread samples are shown in Figure 1. From Table 8, the scores of the sensory parameters significantly decreased ($p < 0.05$) with increased substitution of *Mangifera* in composite bread samples and treatments had virtually no effect ($p > 0.05$) at the same level of substitution. Colour, taste and flavour were rated higher ($p < 0.05$) in defatted *Irvingia* bread samples than the blanched at each level of substitution except for texture and appearance. Overall, wheat bread was most acceptable while 75% *Mangifera* bread samples were least acceptable ($p < 0.05$). Among the composite bread samples, the 50% substituted kernels of *Mangifera* (mango) and the defatted *Irvingia* (wild mango) were rated 78% compared with the 100% wheat bread.

The 100% wheat bread was rated highest for all parameters assessed, possibly for familiarity of panelists with conventional bread. However, the 50% composite bread samples were rated next. The least acceptability at 75% inclusion of kernels could be attributed to bitter taste from residual tannin content and poor texture due to low available gluten content of the wheat flour portion for efficient dough formation. High tannin content (6.4% w/w) of raw *Mangifera* kernel was earlier reported.[12]

The effects of blanching and defatting were not as significant on parameters of colour, taste, flavour, texture and appearance at 50% compared with 75% substitutions. It could, therefore, explain the ranking of 50% bread samples next to the conventional wheat bread.

Conclusion

This study revealed that incorporation of processed 50 % *Mangifera indica* or *Irvingia gabonensis* kernel in regular human dietary preparations would improve nutrition in respect of fibre, K, Ca, Fe, PUFA/SFA ratio, and essential amino acids. The 50 % kernel-based bread samples were rated high organoleptically among the composite bread samples.

The residual water- and fat-soluble phenolic and antioxidant vitamin contents of the composite bread sample compared with 100 % wheat

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bread illustrated their possible nutraceutical potential. Therefore, *Mangifera* kernel should be processed preferably by blanching, and *Irvingia* by defatting to reduce cost of processing *Mangifera* kernel and improve overall acceptability of products derived from *Irvingia* kernel respectively. Mass production of kernel from these natural sources would be encouraged at cottage level.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Table 6: Mineral composition (mg/100 g) of bread samples

Bread type	Na	K	Ca	Fe
75 DM	78.2 ± 1.40^{bc}	635.4 ± 3.25^{e}	161.6 ±1.05^{e}	4.47 ± 0.13^{c}
75 BM	71.2 ± 1.22^{b}	304.2 ± 1.31^{c}	148.1 ± 1.11^{e}	4.11 ± 0.11^{c}
75 DI	52.6 ± 0.91^{a}	170.8 ± 1.00^{a}	73.4 ± 0.23^{c}	0.86 ± 0.04^{a}
75 BI	44.1 ± 1.02^{a}	156.4 ± 1.65^{a}	66.8 ± 0.55^{bc}	0.80 ± 0.01^{a}
50 DM	134.1 ± 2.11^{d}	542.3 ± 2.10^{d}	94.4 ± 0.48^{d}	2.26 ± 0.07^{b}
50 BM	121.6 ± 2.09^{d}	248.2 ± 2.79^{b}	80.8 ± 0.50^{d}	1.96 ± 0.08^{b}
50 DI	103.2 ± 1.73^{c}	204.3 ± 1.33^{a}	57.8 ± 0.26^{ab}	0.66 ± 0.05^{a}
50 BI	96.4 ± 1.10^{c}	178.1 ± 0.76^{a}	55.3 ± 0.61^{ab}	0.57 ± 0.02^{a}
100 W	273.4 ± 0.54^{e}	146.4 ± 1.14^{a}	47.7 ± 0.24^{a}	0.46 ± 0.02^{a}
SEM	22.91	60.61	13.64	0.516

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts in the same column are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched I = Irvingia gabonensis, W = Wheat. SEM = Standard error of mean.

Table 7: Vitamin composition of bread samples

Bread type	Vitamin C (mg/100g)	Vitamin A (IU/100g)	Vitamin E (mg/100g)
75 DM	18.0 ± 0.20^{f}	4.2 ± 0.07^{b}	0.6 ± 0.02^{c}
75 BM	13.7 ± 0.06^{e}	5.6 ± 0.06^{d}	0.9 ± 0.04^{f}
75 DI	12.1 ± 0.41^{d}	5.1 ± 0.04^{c}	0.6 ± 0.02^{c}
75 BI	10.7 ± 0.14^{c}	7.0 ± 0.85^{f}	0.8 ± 0.01^{e}
50 DM	9.8 ± 0.25^{bc}	3.3 ± 0.03^{a}	0.4 ± 0.02^{b}
50 BM	5.3 ± 0.04^{a}	4.2 ± 0.00^{b}	0.7 ± 0.03^{d}
50 DI	9.5 ± 0.08^{bc}	4.3 ± 0.00^{b}	0.4 ± 0.04^{b}
50 BI	8.9 ± 0.08^{b}	6.2 ± 0.14^{e}	0.7 ± 0.06^{d}
100 W	4.4 ± 0.02^{a}	3.0 ± 0.10^{a}	0.3 ± 0.06^{a}
SEM	1.39	0.44	0.07

Values are expressed as mean ± SEM (where n=3). Values with the same superscripts in the same column are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched I = Irvingia gabonensis, W = Wheat. SEM = Standard error of mean.

Table 8: Mean sensory scores of bread samples based on 9-point preference scale

Bread type	Crust Colour	Taste	Flavour	Texture	Appearance	Overall acceptability
75 DM	6.0 ± 0.24^{b}	2.0 ± 0.61^{a}	4.0 ± 0.47^{a}	5.0 ± 0.58^{b}	5.0 ± 0.21^{a}	2.0 ± 0.76^{a}
75 BM	6.0 ± 0.13^{b}	3.0 ± 0.40^{b}	4.0 ± 0.26^{a}	5.0 ± 0.77^{b}	5.0 ± 0.47^{a}	2.0 ± 0.85^{a}
75 DI	6.0 ± 0.31^{b}	7.0 ± 0.38^{e}	8.0 ± 0.80^{d}	4.0 ± 0.25^{a}	5.0 ± 0.38^{a}	7.0 ± 0.18^{d}
75 BI	5.0 ± 0.22^{a}	6.0 ± 0.04^{d}	7.0 ± 0.24^{c}	4.0 ± 0.69^{a}	5.0 ± 0.55^{a}	5.0 ± 0.43^{b}
50 DM	7.0 ± 0.09^{c}	5.0 ± 0.62^{c}	6.0 ± 0.71^{b}	7.0 ± 0.06^{c}	6.0 ± 0.38^{c}	7.0 ± 0.22^{d}
50 BM	7.0 ± 0.18^{c}	5.0 ± 0.33^{c}	6.0 ± 0.57^{b}	7.0 ± 0.78^{c}	6.0 ± 0.29^{c}	7.0 ± 0.15^{d}
50 DI	7.0 ± 0.07^{c}	7.0 ± 0.27^{e}	8.0 ± 0.63^{d}	5.0 ± 0.17^{b}	7.0 ± 0.26^{d}	7.0 ± 0.31^{d}
50 BI	5.0 ± 0.16^{a}	6.0 ± 0.90^{d}	7.0 ± 0.55^{c}	5.0 ± 0.35^{b}	5.0 ± 0.64^{a}	6.0 ± 0.24^{c}
100 W	7.0 ± 0.52^{c}	9.0 ± 0.02^{f}	7.0 ± 0.25^{c}	8.0 ± 0.18^{d}	8.0 ± 0.22^{e}	9.0 ± 0.01^{e}
SEM	0.31	0.71	0.50	0.40	0.41	0.74

Values are expressed as mean ± SEM (where n=15). Values with the same superscripts in the same column are not significantly different at ($p > 0.05$). D = defatted, M = Mangifera indica, B = blanched, I = Irvingia gabonensis, W = Wheat, SEM = Standard error of mean

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