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Development, physical, chemical and sensory attributes of cassava-based complementary food fortified with pigeon pea, tigernut and soybean isolate flour

Abstract

The study examined physical, chemical and sensory attributes of cassava-based complementary food fortified with pigeon pea, tigernut and soybean isolate flour. Four different samples were developed based on the composite flours ration added and coded as sample A - D. Standard analytical methods was used to determine their proximate composition, mineral profiles, functional property, antinutritional factors and sensory attributes. The study results revealed that there is significant improvement at alpha 0.05 % in proximate composition and mineral profiles of the formulated complementary food products while its antinutritional factors falls within tolerant level. Functional property of the complementary food shows good product development in terms of wettability, swelling capacity, swelling index and water absorption capacity. The gelling ability of the products indicated good interaction between its protein, carbohydrate and oils content with a percentage of less than 30 %. The study revealed that an accepted and nutrients dense complementary food could be produced from the combination of cassava tubers, pigeon pea, tigernut and soybean isolate flours because all the semi-trained panelists did not show total dislike for any of the complementary food samples produced. However, sample C is the most preferred and accepted followed by sample B.

Keywords: anti nutritional factors, composite flour, sensory attributes, soybean isolate, tigernut, wettability

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Introduction

Complementary food is the next phase from breast feeding to family foods in form of semi-liquid porridge and light solid food prepared from staple cereals and tubers such maize, sorghum, cocoyam cassava tubers, etc. In Nigeria complementary foods are given to infants and young children in addition to breast milk when breast milk nutrients become insufficient for their energy and growth needs[1] which often start within six months of exclusive breast feeding as advice by WHO, UNICEF and United Nations. Cassava is perhaps one of the most widely used as food source for both adults and children especially as staple food in developing countries. Nutritionally, cassava is a major source of energy for low income consumers in many parts of tropical Africa including east and southern Nigeria and stands out as a major diet for the Yoruba speaking ethnic because it can be processed into varieties of fermented stable foods including fufu, gari, pupuru, lafun among others.[2] Cassava flour had been used as a component of gluten-free composite with other cereals as major components and as hydrocolloids for several non-wheat-baked products and yoghurts.[3]

Pigeon peas a legume family can be used as a vegetable and cooked in curries or used to make relishes when mixed with cereal grains improve the protein content of its food products. Pigeon peas fresh seeds contain vitamins especially provitamin A and vitamin B complex while its dry seeds contain 7-10.3 g water, 14 - 30 g protein, 1 - 9 g fat, 36 - 65.8 g carbohydrates, 5 - 9.4 g fibre and 3.8 g ash with an energy value of 1325 - 1450 kJ/100 g.[4] Tigernut is a high dietary fibre tuber crop which could be utilized in the treatment and prevention of many disease including colon cancer, coronary heart diseases, obesity and gastro intestinal disorder as reported by[5] Its flour has been observed to be rich source of quality oil, vitamin E and some useful minerals such as iron and calcium which are essential for body growth and development[6] while soybean have been utilized both as grains and pulses in most African countries especially Nigeria. The pulse are usually used for food following minimal processing such as cooking, dehulling, grinding, steaming, fermenting, germinating, or frying. Other common food uses of soybean include processing to make akara (fried legume paste), moi-moi- (steamed legume paste), gbegiri (legume soup), soy-milk, fermented soybean for spicing soups and stews.[7]

It is therefore necessary to study how and ways of developing inexpensive but equally nutritious traditionally produced complementary food that may be within the reach of the under-privilege using locally available tubers, legumes with cottage technologies for its production. The formulation of quality complementary foods from local and readily available raw materials such as cassava, pigeon pea, tigernut and soybean isolate is expected to provide protein and micronutrients rich complementary foods that are of high quality and inexpensive. Therefore, the main objective of this study was to determine the physical, chemical and sensory attributes of developed cassava-based complementary food fortified with pigeon pea, tigernut and soybean isolate composite flour.

Materials and methods

Raw material and source of procurement

Freshly harvested samples of cassava tubers were sourced from a popular farm in Awe town, Oyo State, Nigeria while pigeon pea, soya beans and tiger nuts used for the study was purchased at a popular farmer market known as Ajegunle market, Oyo State, Nigeria.

Samples preparation

Preparation of cassava flour: Preparation of cassava flour was done according to the method described by Babalola et al.,[8] with little modification. About 5 kg of fresh roots of flesh cassava tubers free from any signs of infestation were thoroughly washed under running tap water to eliminate any adhering soil, dirt, or dust. Subsequently, the roots were peeled, washed, sliced into 5 % ppm ascorbic acid water for 2 mins and was dried in a Genlab drying cabinet (Model specification: DC 500 and Serial number;- 12B154) at temperature of 55±5 °C for 1½ days (36 hours). The dried chips were later milled into flour using hammer mill and sieved through a mesh sieve (200µm) to obtain a fine flour, and this was packed in a low density polyethene bag and stored at the room temperature of 28±2 °C prior to further applications

Production of pigeon pea flours: The method that was described by Nwosu et al.,[4] was adopted with a little modification. Pigeon peas of about 1 kg were first thoroughly cleaned by picking out the stones, spoilt seeds and foreign materials.

After washing, cleaning, and soaking in water for 12 hours at room temperature (28±2 oC), the pigeon pea seeds were dehulled and dried for 36 hours at 55±5 oC in a Genlab drying cabinet (Model: DC 500; Serial number: 12B154).Before being used again, the dried seeds were ground into flour using a hammer mill and sieved using a 200µm mesh sieve. The fine flour was then placed in a low density polyethene bag and kept at room temperature (28±2 oC).

Production of tigernut flours: Method described by Oke et al.,[9] was adopted with some modifications. Tigernut seeds of about 2 kg were first thoroughly cleaned by picking out the stones, spoilt seeds and foreign materials. The tigernut seeds were cleansed, cleaned, and dried for 36 hours at 55±5 °C in a Genlab drying cabinet (Model: DC 500; Serial number: 12B154). A hammer mill was used to grind the dry seeds into flour, which was then sieved through a 200µm mesh sieve to produce the fine flour. Before being used, each flour was stored at room temperature (28±2 °C) in a low density polyethene bag.

Preparation of soybean isolates flour samples: The procedure outlined by Akinsola et al.,[10] was used to determine the soybean isolate. One kilogram of soybean seeds was cleaned by sieving them through a plastic colander to get rid of the hull, shaft, and faulty seeds. The seeds were cleaned, boiled in 1:3 water (w/v) for 30 minutes, drained, cooled, soaked in 1:2 (w/v) clean water for 10 minutes, and manually dehulled. Their cotyledon was then dried in a Genlab drying cabinet (Model: DC 500; Serial number: 12B154) at 55±5°C for 36 hours, winnowed, milled, and sieved as previously mentioned for cassava flour. The resulting flour was soaked in 1:4 (w/v) ethanol and let to stand at room temperature for the entire night. After the mixture was filtered using filtration equipment, the solute—the soybean isolate flour utilised in the study—was spread out on a stainless laboratory tray and allowed to air dry for 36 hours at 55±5°C in a Genlab drying cabinet (Model: DC 500; Serial number: 12B154). Before being used again, the flour was stored at room temperature (28±2 oC) in a low density polyethene bag.

Cassava-based complementary flour samples formulation: Pre-processed raw material flours produced from cassava tubers (*Manihot esculenta*), pigeon peas (*Cajanus cajan*), tigernut (*Cyperus esculentus*) and soybean isolate (*Glycine max*) was blended at different rations as presented in Table 1 to obtain a cassava-based complementary food formulated. Each complementary food sample was prepared according to Table 1 below using a method as described by Akinsola et al.[11] However, with slight modification. Samples were blended using a Kenwood mixer (Model: HC 750D, Kenwood, UK) and coded samples A, B, C and D, respectively (Table 1).

Table 1 Cassava-based complementary food samples formulations

	Formulations (%)			
Ingredients	**A**	**B**	**C**	**D**
Fresh cassava tubers	45	50	55	60
Pigeon peas	35	30	25	20
Tigernut	15	15	15	15
Soybean isolate	05	05	05	05

Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05.

Production of cassava-based complementary food gruel samples: In a stainless pot on a gas cooker, two litres of water were brought to a boil. 200 g of each supplementary food flour made from cassava were combined with 200 ml of boiling water, and the mixture was constantly churned until a thick dough with a smooth consistency was achieved. To get the appropriate consistency, a little amount of hot water was added, vigorously mixed, and allowed to cool to room temperature (28±2 °C). The paste obtained is the formulated complementary food used for the sensory evaluation.

Method of analysis

Determination of proximate content

Proximate composition (moisture, protein, fat, fibre, ash) of each sample was carried out using Association of Official Analytical Chemistry.[12] The air oven method at 105 °C was used to determine the moisture content. The micro-Kjeldahl method was used to determine the sample's protein level. Petroleum ether was used as the extraction solvent in the Soxhlet extraction procedure to determine fat. Five grams of the burnt sample were weighed into a tarred porcelain crucible to test the ash content. It was burnt in an ash muffle furnace for six hours at 600 °C till ash was produced. Crude fibre was identified by thoroughly extracting soluble materials from a sample using a solution of H2SO4 and NaOH, ashing the residue, and recording the weight loss as crude fibre. While the gross energy value (KJ/100 g) of the samples was evaluated using the Famakin et al.,[13] technique, the carbohydrate content was determined by differences.

Gross energy = Carbohydrate x 16.7 + Lipid x 37.7 + Protein x 16.7 KJ/100 g (Dry matter)

Determination of mineral profiles

The mineral element (Ca, Fe, K, Mg, Na, P) determination was carried out as described by AOAC[12] method using an inductively-coupled plasma atomic emission spectrometer (ICPAES, USA, TL6000 Model). About 0.5 g of each sample was weighed into a 50 ml digestion tube. Approximate 2 ml of concentrate Nitric acid (HNO_3) was added and left overnight for a cold digestion (wet-ashing). Then, put into a digestion block at a temperature of 120 °C; as the liquid dries off, 2 ml concentrated HNO_3 was further added, when sample was still black indicating the presence of carbon, the temperature was increased to 150 °C. The last step was repeated until the sample no longer gave off reddish-brown fumes, or until the solution was clear. A solution of 50/50 (v/v) nitric acid and perchloric acid was added, and then the temperature was increased to 180 – 220 °C, while the tap for the washing of the exhaust was running. The heating continued until ash-like residue was obtained. Then, the digestion block was removed and allowed to cool to room temperature. The ash will be re-dissolved with 1ml of concentrated hydrochloric acid (HCl) and 10 ml 5 % nitric acid, vortexed and then transferred into plastic tubes or 15 ml centrifuge tubes. The sample ash solution was injected into the ICPAES to determine the mineral elements.

$$Mineral\ element\ (mg/100\ g) = \frac{Conc.\ (ppm)\ x\ Dilution\ Factor\ (11.0)}{Sample\ weight\ (g)}$$

Determination of functional properties of the cassava-based complementary food samples

Functional properties such as bulk density, water absorption capacity, solubility index, swelling power, dispersability, wettability, least gelatinization concentration of the complementary food samples were determined. Bulk density and water absorption capacity of the complementary food flours samples were determined as described by Pawase et al.,[14] method. Dispersability and wettability was determined using the method described by Akinyemi et al.,[15] while swelling power and solubility index was determined as described by Umar et al.[16] The method as described by Sandoval and Fernandez[17] was used to determine least gelation concentration of the samples.

Determination of anti-nutrients of the complementary food flour samples

Each blend was subjected to selected antinutrients analyses to determine the active constituents present in the complementary food samples. Selected anti-nutritional factors such as alkaloid, phytate, oxalate, tannins were determined using method described by Nwosu[4] while amylase and trypsin inhibitor contents were determined as described by Figueira et al.,[18] and Famakin et al.,[13] respectively.

Sensory evaluation of the complementary food gruel samples

The complementary food samples were coded with three random digits, prepared into gruel and presented to twenty semi-trained nursing mothers, lecturers and mothers in School of Secondary School, Vocational and Technical programmes, Federal College of Education (Special), Oyo. Each sample was evaluated for preference using the method as described by Akinsola et al. [19] Panelists were asked to score the complementary food samples for appearance, aroma, taste, texture and overall acceptability, respectively. Each panelist sat apart from one another for sensory evaluation. Water was provided to rinse mouth before and after tasting each of the samples. The panelists were presented with a score sheet using 9-point hedonic scale where 1 is disliked extremely and 9 liked extremely.

Statistical analysis

All experiments were conducted in triplicate. Statistical analysis was carried out using SPSS windows, version 17.0 (SPSS Inc., Chicago, IL) and its significance was established using a one-way analysis of variance (ANOVA). Data obtained was reported as mean values ± standard deviation (SD). Means were separated using Duncan Multiple range test (DMRT) while significant difference was established at $p \leq 0.05$.

Results

Proximate composition of the cassava-based supplemental food flour samples

Table 2 illustrates the proximate makeup of the cassava based supplementary flours. Ash percentage of the samples ranged from 2.78 % for sample D to 3.79 % for sample A. There were significant differences ($p < 0.05$) in the ash level of the supplemental foods. The carbohydrate value of the complementary food flour samples ranged from 59.15 % in sample A to 63.98 % in sample D while fat content of the complementary flour samples ranged from 4.86 % in sample C to 5.01 % in sample A, respectively. Crude fibre content of the complementary food flour samples ranged from 3.43 % in sample D to 4.32 % in sample A. According to the study's findings, the samples' moisture contents varied from 9.07 % in sample A to 9.61 % in sample B. The energy value of the complementary food samples varied from 1482.68 KJ/100g in sample A to 1509.42 KJ/100g in sample D, whereas the crude protein percentage of the complementary food flours varied from 15.32 % in sample D to 18.12 % in sample A. The cassava-based complementary food flours differs significantly in proximate composition as affected by the composite flours added. Carbohydrate content of the cassava-based flour accounts for the bulkiness of the flour and hence, contributes to fat production through Kreb's circle and spares proteins as an energy source for the body biochemical reactions.

Table 2 Proximate composition of the cassava-based complementary food flour samples (DM), mg/100g

Parameter, %	Sample A	Sample B	Sample C	Sample D
Ash	3.79±0.01^{a}	3.42±0.04^{a}	3.19±0.21^{ab}	2.78±0.18^{b}
Carbohydrate	59.15±1.20^{c}	61.25±0.91^{b}	62.52±1.03^{b}	63.98±0.75^{a}
Crude fat	5.10±0.02^{a}	4.95±0.20^{a}	4.86±0.04^{a}	4.91±0.01^{a}
Crude fibre	4.32±0.31^{a}	4.04±0.33^{a}	3.82±022^{b}	3.43±0.03^{cb}
Moisture content	9.07±0.11^{b}	9.61±0.17^{a}	9.54±0.81^{a}	9.58±0.52^{a}
Protein content	18.12±0.19^{a}	16.73±0.51^{b}	16.07±0.27^{bc}	15.32±0.17^{c}
Energy, KJ	1482.68±1.83^{c}	1488.89±1.61^{bc}	1495.67±1.46^{b}	1509.42±0.85^{a}

All values are expressed as mean ± SD of three replicate determinations. Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05. Mean values in the same column with different superscript are significantly different @ $p< 0.05$.

Mineral profiles of the cassava-based complementary flour samples

Table 3 displays the mineral profiles of the complimentary samples made from cassava. All of the cassava-based supplementary samples exhibit substantial variances in their mineral profiles at alpha 0.05. Sample C's calcium concentration was 70.43 mg/100g, while sample A's was 84.38 mg/100g. The iron level of the samples varied significantly ($p \leq 0.05$), ranging from 17.07 mg/100g in sample C to 19.48 mg/100g in sample A. The samples' phosphorus level varied from 67.88 mg/100g in sample C to 144.83 mg/100g in sample A, and their magnesium content ranged from 54.54 mg/100g in sample C to 70.76 mg/100g in sample A. The potassium level of the complimentary flour samples made from cassava varied from 406.75 mg/100g for sample C to 631.40 mg/100g for sample A. According to the study's findings, the sodium level of the complimentary flour samples made from cassava varied between 80.49 and 94.06 mg/100g for samples C and A, respectively. Significant differences were observed at alpha 0.05 % for Ca/P values and there existed no significant differences for Na/K values of the cassava-based complementary flour samples. There values ranged from 0.55 – 1.04 and 0.15 – 0.20, respectively.

Table 3 Mineral profile of the cassava-based complementary food flour samples (DM), mg/100g

Parameter, %	Sample A	Sample B	Sample C	Sample D
Calcium, Ca	84.38±1.03[a]	75.76±1.18[b]	70.43±1.2[c]	71.86±1.17[c]
Iron, Fe	19.48±0.24[a]	19.03±0.63[a]	17.07±0.13[b]	17.50±0.09[b]
Magnesium, Mg	70.76±0.32[a]	68.48±0.21[b]	54.54±0.28[d]	58.72±0.19[c]
Phosphorus, P	144.83±0.95[a]	137.49±0.84[b]	67.88±0.62[d]	70.16±0.67[c]
Potassium, K	631.40±3.11[a]	595.34±1.57[b]	406.75±1.86[d]	438.50±1.88[c]
Sodium, Na	94.06±1.12[a]	91.83±0.93[b]	80.49±0.54[c]	81.34±0.33[c]
Ca/P	0.58±0.00	0.55±0.00	1.04±0.00	1.02±0.00
Na/K	0.15±0.00	0.15±.00	0.20±0.00	0.19±0.00

All values are expressed as mean ± SD of three replicate determinations. Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05. Mean values in the same column with different superscript are significantly different @ p< 0.05.

Functional properties of the cassava-based complementary food flour samples

Table 4 displays the functional characteristics of the complimentary flour samples made from cassava. The complementary food samples' bulk densities varied from 0.64 g/cm3 in sample D to 0.81 g/cm3 in sample A. The complementary food's bulk densities varied significantly ($p > 0.05$). Additionally, there was a significant difference ($p < 0.05$) in the swelling power and dispersibility of the complementary meal samples. The corresponding ranges were 11.88 to 13.46 g/100g and 4.36 to 5.32 g/100g. The supplemental foods' water absorption capacity and solubility index values differed considerably at alpha 0.05. Their respective ranges were 6.63–7.03 g/100g and 135.73–155.21 g/100g. The wettability and least gelatinization concentration of each supplemental food sample differed considerably ($p < 0.05$). There values ranged from 4.88 – 6.12 sec and 21.99 – 25.30 g/100g, respectively.

Table 4 Functional properties of the cassava-based complementary food flour samples (DM), g/100g

Parameter	Sample A	Sample B	Sample C	Sample D
Bulk density, g.cm^3	0.81±0.04[a]	0.73±0.12[b]	0.69±0.01[c]	0.64±0.04[c]
Dispersability, g/100g	5.32±0.13[a]	5.06±0.10[a]	4.78±0.05[ba]	4.36±0.09[b]
Swelling power, g/100g	13.46±0.22[a]	12.75±0.06[b]	12.27±0.25[cb]	11.88±0.23[c]
Solubility index, g/100g	7.03±0.17[a]	6.91±0.11[a]	6.88±0.07[a]	6.63±0.12[a]
Water absorption capacity, g/100g	155.21±2.33[a]	147.05±1.83[b]	140.04±0.92[b]	135.73±1.05[d]
Wettability index, sec	6.12±0.25[a]	5.85±0.05[b]	5.17±0.14[c]	4.88±0.16 [cd]
Least gelation concentrate, g/100g	21.99±1.67[c]	23.62±0.88[b]	25.16±1.15[a]	25.30±1.04[a]

All values are expressed as mean ± SD of three replicate determinations. Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05. Mean values in the same column with different superscript are significantly different @ p< 0.05.

Antinutritional factors of cassava-based complementary food flour samples

Table 5 shows the antinutritional factors content of the cassava-based complementary flour samples. Alkaloid content of the samples ranged from 3.52 – 4.81 mg/100g for sample A and D, respectively. Oxalate content of the complementary food samples ranged from 3.74 mg/100g in sample A to 5.08mg/100g in sample D, respectively. There are significant differences in the phytate content of the complementary food samples with sample A having the highest value (5.33 mg/100g) while sample D had the lowest value (4.28 mg/100g). The table revealed that tannin content ranged from 1.73 mg/100g to 3.15 mg/100g with sample A having the highest tannin content (3.15 mg/100g) while sample D had the lowest value of 1.73 mg/100g. Tannins have been shown to hasten the healing of wounds and prevention of decay. There are significant differences at alpha 0.05 % in amylase and trypsin inhibitor values of the cassava-based complementary flour samples. There values ranged from 2.36 – 3.47 mg/100g and 4.08 – 5.05 mg/100g, respectively.

Sensory attributes of cassava-based complementary food gruel samples

Table 6 presents the sensory attributes of the cassava based complementary foods. In term of appearance which has to do with visual quality of the product, sample B had the highest mean score (7.79) and was significantly preferred ($p \leq 0.05$) to other complementary food samples. Colour mean scores ranged from 7.03 to 7.50 with sample B having the highest value of preference while sample D had the lowest value (7.03). Colour is an important sensory attribute of any food because of its influence on preferences. Flavour mean scores ranged from 6.03 to 7.88. Sample C had the highest preferences for flavour while sample A had the lowest value of 6.03. Flavour has been shown to affects sensory judgment even before touching or tasting. There were significant differences ($p \leq 0.05$) in the taste attribute of the cassava-based complementary foods. There mean score ranged from 6.99 and 7.70 with sample C having the highest preferences. Texture of the cassava-based complementary foods ranged from 7.04 to 7.87 with sample A having the least mean score of preferences while sample B had the highest mean score of (7.87) preferences. Texture has to do with hand and mouth feel of the cassava based complementary foods to determine it degree of smoothness, roughness, coarse or softness. The sensory attributes data obtained showed that the cassava-based complementary food of sample C tastes better and had the highest mean score of 7.70 when compared with other complementary flours. In term of overall acceptability, the formulated complementary food sample C was highly preferred and accepted by the semi-trained panelists with mean score of 7.74 followed by sample B with 7.33.

Table 5 Antinutritional factors of cassava-based complementary food flour samples (DM), g/100g

Parameter, %	Sample A	Sample B	Sample C	Sample D
Alkaloid	3.52±0.01^{c}	3.97±0.00^{c}	4.40±0.06^{b}	4.81±0.00^{a}
Oxalate	3.74±0.00^{b}	4.10±0.06^{b}	4.73±0.16^{a}	5.08±0.13^{a}
Phytate	5.33±0.12^{a}	4.96±0.18^{a}	4.63±0.11^{b}	4.28±0.17^{b}
Tannin	3.15±0.12^{a}	2.62±0.00^{b}	2.26±0.03^{b}	1.73±0.08^{c}
Amylase inhibitor, AIU	3.33±0.07^{a}	3.47±0.12^{a}	3.32±0.00^{a}	2.36±0.09^{b}
Trypsin inhibitor, TIU	5.05±0.43^{a}	4.35±0.27^{b}	4.08±0.12^{b}	4.15±0.23^{b}

All values are expressed as mean ± SD of three replicate determinations. Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05. Mean values in the same column with different superscript are significantly different @ p< 0.05.

Table 6 Sensory attributes of cassava-based complementary food gruel samples (DM), g/100g

Parameter, %	Sample A	Sample B	Sample C	Sample D
Appearance	7.59±0.00^{b}	7.79±0.15^{a}	7.70±0.13^{a}	7.40±0.01^{b}
Colour	7.32±0.04^{a}	7.50±0.08^{a}	7.14±0.00^{a}	7.03±0.00^{b}
Flavour	6.03±0.01^{c}	7.26±0.05^{bc}	7.88±0.00^{a}	7.30±0.16^{b}
Taste	7.36±0.00^{b}	7.48±0.00^{b}	7.70±0.13^{a}	6.99±0.16^{c}
Texture	7.04±0.13^{c}	7.87±0.13^{a}	7.67±0.11^{b}	7.55±0.00^{b}
Overall acceptability	6.48±0.13^{c}	7.33±0.11^{b}	7.74±0.05^{a}	6.41±0.02^{c}

Samples were in ration of cassava, pigeon pea, tigernut and soybean isolate flour, respectively. Sample A: 45,35,15,05; Sample B: 50,30,15,05; Sample C: 55,25,15,05; Sample D: 60,20,15,05. Mean scores in the same column with different superscript are significantly different @ p< 0.05.

Discussions

Proximate composition of the cassava-based complementary food flour samples

Ash content, which is the organic residue left over after organic matter has been burnt off, provides an indirect indication of the sample's mineral composition. The total ash level of the complementary meal samples, particularly examples A–D, differs significantly ($p \leq 0.05$) when protein addition rises, but it is still within the Codex Standard's suggested range of ≤ 5 %.[20] All their food samples analyzed can provide targeted consumers with enough energy per 100 g. This will allow protein to be useful for its primary work. Carbohydrate, according to Sushma et al.,[21] contributes effectively to muscles coordination, blood and Kreb's circle activities and also acts as mild laxative. All of the samples' fat content is insufficient to supply roughly 28.43 % of the energy value, which is less than the FAO/WHO recommended value.[22] The crude fibre levels were comparable to the cowpea values reported by Idowu et al.[7] According to Agbon et al.,[23] the complementary meal sample's low crude fibre level will improve nutritional availability and absorption, particularly for kids. The crude fibre and carbohydrate content of the complementary food samples did not significantly increase ($p < 0.05$). The food's or processed product's moisture content provides information about its nutritional value and shelf life. Longer storage capacity requires a low moisture level.[24] The dry matter content and, thus, the crop yield are correlated with the moisture content of the study samples. The study's protein values exceed Anigo et al.,[25] suggested range of 13–14 g/100g. With the exception of sample A, none of the complementary food samples in this investigation could provide the necessary amount of 13 % (energy from fat) for elderly infants and young children. According to FAO/WHO,[22] the Codex Alimentarius guidelines for prepared complementary foods for older infants and young children suggested that the complementary food's crude fat should account for at least 13 % of its total calories. Crude fat from the supplemental foods had an energy value ranging from 12.25 to 12.97 %. Therefore, it is necessary to add additional supplements to the complementary food.

Mineral profiles of the cassava-based complementary food flour samples

Calcium is necessary for supporting bone formation and growth, muscle contraction and maintenance of healthy blood pressure.[19] Idowu et al.,[7] reported that calcium is a micronutrient essential to health and wellbeing, which performs diverse biological function in the human body. It serves as a second messenger for nearly every biological process, stabilizes many protein and in deficient amounts is associated with a large number of diseases. Akinyemi et al.[15] recommended a dietary allowance of 360 mg/day and 1200 mg/day calcium for infants and young adults. A deficiency in calcium could lead to rickets or osteoporosis as reported by several workers.[27] Iron has several functions in the human body which includes; being a constituent of the hemoglobin molecule – 70 %, myoglobin stored in muscles, an activating molecule of several enzymes and found in storage molecules such as ferritin and hemosiderin.[28] Iron assists with transmission of nerve signals and absorption of glucose/other

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nutrients, and aids muscle contraction.[19] Iron deficiency anemia which is characterized by small red cells (microcytosis) with low haemoglobin (hypochromia). The values obtained in this study for samples A and B are more than the recommended daily allowance of 18 mg reported by Ikpeme-Emmanuel et al.[29] Thus, consumption of the cassava-based complementary food flours could be recommended in diets to improve iron status and help to prevent anemia. It is worth noting that anemia constitute a major problem of human health that affects more than 40 % of preschool children in Africa. It caused many health consequences including poor pregnancy outcomes, impaired physical and cognitive development, reducing of work productivity and morbidity.[19] Magnesium is essential for all biosynthetic processes including glycolysis, formation of cyclic AMP, energy dependent membrane transport and transmission of the genetic code, greater than 300 enzymes are known to be activated by magnesium ion.[15] It is important to notice that magnesium is an essential mineral element which is involved in interaction with calcium metabolism in bone and circulatory diseases as ischemic heart disease.[8] Potassium has a beneficial effect on sodium balance. A high intake of potassium has been reported to protect against increasing blood pressure and other cardiovascular risks.[19] The range of values for phosphorus and potassium showed no definite trend but varied significantly ($p \leq 0.05$) among the flour sample. Phosphorus plays an important role in multiple biological processes such as maintenance of cell membrane integrity and nucleic acids, generation of ATP, maintenance of acid-base homeostasis, among others.[26] Calcium and phosphorus play an important role in human diet. Both are associated in the growth and maintenance of bones, teeth and muscles. The values of the molar ratios Ca/P ranged from 0.41 to 0.77. About this ratio, Akinsola et al.,[30] indicated that it is a good predictor of calcium availability. According to the authors, molar ratios of Ca/P which are greater than 1, suggests a good absorption of calcium, while values less than 0.5 indicates a poor calcium uptake. In the present study, the ratios Ca / P were higher than 1; this may constitute a great advantageous and indicated a good intestinal absorption of calcium. Low Na as reported by many workers[31] could be used in special diet for kidney disease patients. A Na/K molar ratio less than one is recommended in the diets of people who are prone to high blood pressure.[30] Na/K molar ration of the study ranged from 0.15 - 0.20 for sample A, B and C, respectively. The implication of this is that consumers could also benefit from this diet especially those that have issues with high blood pressure because sodium to potassium (Na/K) ratio in the body is of great concern for the prevention of high blood pressure.

Functional properties of the cassava-based complementary food flour samples

Bulk density is influenced by particle size and the density of the flour and is important in determining the packaging requirement and material handling. For infants and early children, low bulk density food products have been shown to give nutrient-dense meals since more of the goods can be consumed, giving the baby a high nutritional intake per meal.[32] Bulk density reflects the complimentary flours' particle size distribution and may also be influenced by moisture content. The dispersibility and wettability results are consistent with the earlier findings of Ezeocha & Onwuka,[33] who studied complementary foods based on cereals and legumes (maize-soybean) and found that the processing method had a significant impact on the wettability and dispersibility of the soybean-based complementary foods. The ease of dispersing flour samples in water determines their wettability, and the sample with the lowest wettability dissolves in water the quickest. The wettability time indicates how long it takes to wet a sample of flour. It demonstrates the food sample's hydrophilic potential and how easily flour disperses in water.

The ability of starch or flour to absorb water and swell for better consistency and texture is known as water absorption capacity, or WAC. The large percentage of hydrophilic groups and amino acids in the protein molecule causes water absorption, and the increase could be caused by the protein's ability to bind to the flour.[34] According to Oke et al,[5] variations in protein content and structural conformation may have contributed to the rise in WAC of heat-processed cowpea flour. According to Pawase et al.,[14] who studied the functional characteristics of various pearl millet cultivars, the low viscosity patterns and weak internal organization caused by starch granules are likely connected to the water absorption capacity (WAC) found in this study. The composite flour starch affects swelling, retains less water, and has a lower viscosity while increasing the nutritional and energy densities per unit volume of the blended flour, may have contributed to the samples' low level of swelling power. The strength and nature of the granules' micellar network have a significant impact on the swelling index.[24] The swelling power is an indication of presence of amylase which influences the quantity of amylose and amylopectin present in the complementary food flour. Olorode et al.,[1] reported that the swelling power of flour granules is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch-based flour during heating. According to Akinsola et al.,[11] the lowest protein concentration at which gel stays in the inverted tubes is known as the "least gelation capacity" (LGC). Composite flours added during product formulation may be the cause of the samples' increased LGC. These findings are consistent with Mbaeyi and Onweluzo's[35] research on breakfast blends made with sorghum and pigeon pea flake. According to Akinyemi et al.,[15] the relative ratios of protein, carbs, and lipids as well as the interactions between these components are responsible for the gelling characteristics of the complementary meal samples.

Antinutritional content of the cassava-based complementary food flour samples

Significant differences ($p \leq 0.05$) were observed in the selected antinutritional factors investigated among the samples. Antinutritional factors are well known to associate with a decrease in bioavailability of many nutrients and minerals. These organic substances can bind essential minerals to form insoluble or indigestible complexes in the lumen of intestinal tracts, thereby impairing their absorption. Hence, in order to predict the bioavailability of divalent minerals such as Ca, Fe, Mg and P in human diet were evaluated. Alkaloids are essential to medicine and make up the majority of beneficial medications. According to Nwosu et al.,[4] they have a significant physiological impact on animals. When comparing this study to that of Nwosu et al.,[4] there is a modest conformity of alkaloids, which are lower than the values given for the complementary food samples in this study. Phytate reduces the intestinal absorption of mineral ions such as Ca, Fe, Mg, and Zn by forming stable complexes with them.[36] However, the Phytate/Ca molar ratios (0.05 – 0.06) calculated for all of the investigated cassava-based complementary food flours were below the critical level of 0.24 regarded to have an effect on calcium bioavailability.[15] It is the same case about iron because Phytates/Fe ratios (0.24 – 0.27) below 0.4 which is the critical ratio. These ratios might have been considerably reduced as a result of different flour blends during product formulation. However, these results are in line with the reports of Idowu et al.,[26] and Akinyemi et al.[15] Oxalic acid and its salts have been found to have deleterious effects on human nutrition and health, particularly by decreasing calcium absorption and aiding the formation of kidney stones.[30]

Research has shown that alkaloids can cause gastrointestinal and neuronal disorders.[37] Oxalate, according to Akinsola et al.,[30] prevents the body absorption of Ca++ by forming insoluble calcium-oxalate complex. However, the level of oxalate in these complementary food flours is not a concern for normal healthy person, as toxic level for humans was set as 2 - 5 g.[19] Oxalate/Ca (0.04 – 0.07) in all the studied cassava-based complementary food flours was lower than critical level of 2.5.[30] This situation shows good calcium bioavailability in the body. Tannins lower the biological properties of proteins by forming insoluble complexes with them.[38] According to Phillips and McWatters,[39] the presence of antinutritional factors in soybeans, such as trypsin and chymotrypsin inhibitors, reduces the digestibility of soybean protein, gives soybeans an unpleasant or bitter taste, and hinders the intestinal absorption of divalent metal ions. These antinutrients prevent the absorption of divalent ions like Fe++ and Zn++ by forming insoluble complexes with them. The amylase and trypsin inhibitors reported in these flour samples are significantly not different due to pre-processing method and composite flours blends to produce the cassava-based complementary food. Amylase inhibitor inhibits the action of pancreatic and salivary amylases thereby increasing the amount of undigested starch in the feaces and subsequently decreasing the availability of carbohydrate /starch in the foodstuffs. Akinsola et al.,[10] revealed that the lethal doses of several specific antinutritional factors were 50–60 mg/kg for phytate, 30 mg/kg for tannin, 2–5 g/kg for oxalate, and 2.50 g/kg for trypsin inhibitor. Alkaloids (3.52–4.81 g/100g), phytate (4.28–5.33 g/100g), oxalate (3.74–5.08 g/100g), tannins (2.77–4.15 g/100g), and trypsin inhibitor (8.58–9.55 TIU) were the factors whose antinutritional values varied. According to Akinsola et al.,[10] all of the values found in this investigation were far lower than those lethal dosages, indicating that the body would be able to absorb all of the minerals and micronutrients from the sample flour.

Sensory attributes of the cassava-based complementary food flour samples

When it comes to the texture of the supplemental food samples made from cassava, Sample C is the most favoured of all the samples. Their choice of Sample C as the most favoured supplemental food formulation may have been influenced by its flavour and taste. Sushma et al.,[21] state that consumers and end users of food product materials have been proven to be influenced by taste and flavour in their preference for such food. According to their mean score, which is greater than 6 out of 10, none of the semi-trained panelists expressed complete distaste for any of the complementary food samples.

Conclusions

The study results of proximate composition, mineral profile, functional property, antinutrients factors and sensory attributes indicates that fortification of cassava-based complementary food flour with pigeon pea, tigernut flours and soybean isolate flour for complementary food formulation improves its macro and micro nutrients bioavailability for it end-users/consumers. The study shows that an acceptable and nutrient dense complementary food could be produced from the combination of cassava, pigeon peas, tigernut and soybean isolate. This suggests that they could suitably be promoted through different sectors of the food chain in order to improve food security among rural people and less privileges citizen. There is necessity for further studies on its pasting, vitamins content, amino acids profiles, in-vivo, and antioxidant properties before commercialization. Because of its improved nutrition and micronutrients, the cassava-based complementary food samples have the potential to prevent and manage protein-energy-malnutrition, particularly in rural regions and among low-wage earners.

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Conflict of interest

The authors declare no conflict of interest.

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