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Proximate, Vitamins, Minerals, and Antinutrients Composition of Breads Made from African Yam Bean (*Sphenostylis stenocarpa*) and Corn (*Zea mays*) Seeds Flour Blends

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ABSTRACT

Background: *Malnutrition is a big threat to the world's public health.*
Objectives: *This work evaluated the chemical composition of the breads made from African yam bean (Sphenostylis stenocarpa) and corn (Zea mays) seeds flour blends.*
Materials and Methods: *The seeds of African yam bean (AYB) roasted at 191^{0}C for 40 mins and corn oven-dried at 50^{0}C for 24 h were finely milled, and formulated into 5 flour samples in the ratios of AYB (70): Corn (30), AYB (50): Corn (50), AYB (30): Corn (70), AYB (100: 0), and Corn (100: 0) to yield one-third ($^1/_3$) of the daily dietary fiber requirement (12.7 g) of a reference man (70 kg). The samples and the control (wheat flour) provided 6 samples which were made into breads and evaluated for chemical composition using standard procedures. Data generated were analyzed using the IBM Statistical Product for Service Solution (version 21.0) and presented as means and standard deviations. Analysis of variance (ANOVA) was used to compare the means and significance was accepted at $p < 0.05$.*
Results: *The proximate range of the samples were 10.92 to 25.11g protein, 2.29 to 4.03g fat, 1.40 to 2.82g ash, 0.46 to 3.10g fibre, 50.23 to 66.50g carbohydrates, 8.29 to 9.41g moisture, 321.66 to 330.29kcal energy, and 80.60 to 81.71 dry matter; the vitamins: 3.12 to 32.67µg carotene, 0.14 to 1.55mg thiamin, 0.62 to 1.38g niacin and 4.76 to 41.76mg vitamin C. The mineral contents ranged from 13.23 to 72.30mg calcium 25.76 to 142.57mg magnesium, 73.81 to 208.13mg potassium, and 28.38 to 66.15mg sodium; the phytochemicals ranged from 0.94 to 11.36mg flavonoid, 0.02 to 0.41mg saponin, and the anti-nutrients contents ranged from 0.06 to 1.02mg tannin and 0.21 to 1.11 mg alkaloids.*
Conclusion: *The breads had decreased carbohydrates and energy contents and improved nutrient density. All bread samples could be used for varied meals.*

INTRODUCTION

Malnutrition constitutes a big threat to the world's public health. Its' unbearable burden on the health systems, socio-cultural and economic status of the society has already been reported [1]. It is a major public health problem in developing countries. Nigeria is one of the countries experiencing malnutrition crises with as much as 32% under-5 children, and 7% women of childbearing age malnourished; 2million children suffer severe acute malnutrition and the country had the 2nd highest burden of stunted children globally [2]. There are very high rates of stunting and wasting, 45% mortality from malnutrition, huge challenges for public health and development with economic losses of up to 11% in Gross Domestic Product [2]. In simple terms malnutrition crisis, translated to increased death, poor cognitive development, reduced performance in education and productivity with enormous economic losses. Its' etiology is linked with inadequate protein, energy, vitamins and minerals intake, poverty, inadequate food production, ignorance, uneven distribution of food, food restriction and taboo, poor sanitation, poor food preservation techniques, and improper preparation of foods [3]. Of especially prevalence is micronutrients deficiency and its' devastating impact, which is majorly due to prolonged inadequate intakes of dark green leafy vegetables, fruits, nuts, and fortified foods. The deficiencies in vitamins A and minerals like iron, and iodine, for instance, can cause innumerable maternal and childhood deaths, with millions of survivors in various states of nutritional disorders. Less severe deficiencies have been shown to impair intelligence and strength, reduce work capacity and productivity thus hindering economic development.

Most developing countries have staples as their main food source with inadequate animal proteins. These staples constitute essentially roots, tubers, cereals, and legumes providing mainly carbohydrates due to poor presentation in the local diets. These foods most often supply few or mono nutrients and are generally limited in nutrient variety. The situation is compounded by nutrition transition - the current adoption of highly refined and processed high-fat foods with little or no physical activity due to market globalization, industrialization, urbanization, and economic development. [5]. In addition, some cereals and legumes are gradually going into extinction because of non-consumption and/or poor perception. Certain individuals perceived cereals and legumes as a poor man's food, and subsequently saturate their daily diet with convenient foods like bread, which are widely and frequently consumed because of their availability. Bread is most often made from wheat which is imported into Nigeria involving a huge expenditure of foreign exchange, high cost of bread leading to inadequate consumption, and malnutrition of the dependent masses.

To improve the nutrient density of bread and ensure affordability to low-income earners who constitute the larger population of consumers, the need to avail of other food sources becomes pertinent. Many indigenous foods crops with good nutritional qualities are available. They include but are not limited to African yam bean (AYB), corn, pigeon pea, cassava, Bambara groundnut, cowpea, sorghum, millet, etc. These food crops could be made into flour and used in daily diets. Some of them like cassava, and corn have already been made into bread in combination with wheat flour [6], but the nutrient density is more of carbohydrates. The burden of malnutrition underscores the need to improve the nutrient density of bread through production from nutrient-rich composite flours.

Corn is one of the global cereals that are frequently and widely consumed by all age groups. It is an annual crop, very valuable as livestock feed, human food, and raw material for most industries [7]. It contains significant amounts of bioactive compounds in addition to basic nutrients such as carbohydrates, vitamins, and minerals, that are beneficial to humans. The whole grains have been linked to the reduced risk of chronic diseases including cardiovascular disease type 2diabetes, obesity, some cancers, improvement of digestive tract health, and health-promoting effects (phytochemicals antioxidant and anti-proliferative activities) [8 – 11]. All corn types are rich in dietary fiber, vitamins (A, B, E, and K), minerals (magnesium, potassium, and phosphorus), phenolic acids and flavonoids, plant sterols, and other phytochemicals (lignins and bound phytochemicals [12]. AYB is a legume known to improve the lives of subsistence farmers. In some Nigerian communities, the seed grains are boiled and eaten with other staples (yam, plantain, cassava, corn), some are roasted to produce snacks. The flavor of the cook seeds is superior to other pulses in local culinary dishes [13]. Its economic and nutritional value in terms of protein digestibility, amino acids availability, energy, fatty acids, vitamins, minerals, and fibre profile have been documented by various authors [13 – 17]. The challenge is its hard seed coat that requires overnight/long cooking; and its content of traces of anti-nutritional substances [18]. Some food processing measures (dehulling, soaking, soaking/cooking, and roasting) have been found to reduce significantly the contents of some of these anti-nutritional substances [19], thus making AYB more acceptable for human consumption. The nutritional composition of AYB has the potential to supplement most diets consumed in the third world that lack some essential nutrients.

Since most food products available to the world poor world's deficient in dietary nutrients, food crops with enormous nutritional potential such as AYB and corn will assist the fight against malnutrition if combined as in composite flour. Consequently, this study evaluated the proximate, vitamin, minerals, and anti-nutrients, composition breads made from corn, and AYB seeds flour blends.

MATERIALS AND METHODS

Study design: Experimental study design was used.

Collection and identification of raw materials

Corn grains and AYB seeds were purchased from Ubani Main Market in Umuahia North Local Government Area, Abia State. The raw materials were identified by an agronomist E. N. in the Department of Crop and Soil, Michael Okpara University of Agriculture, Umudike.

Raw material preparation

Processing of AYB and corn seeds into flour: The seeds of AYB and corn were sorted to remove extraneous materials, washed with tap water, and drained in a colander. AYB seeds were roasted at 191^{0}C on the medium gas mark for 40mins with continuous stirring, then finely milled into flour, packaged in polyethylene bags, and refrigerated. Corn seeds were oven-dried (Gallenkemp oven, 300 Plus, England) at 50 ºC for 24h, finely milled in an attrition mill (7hp China), and stored in an air-tight container inside the refrigerator until use.

Formulation of composite flour: The flour samples were formed into a composite in the ratio of 70(AYB): 30(Corn), 50(AYB): 50(Corn), 30(AYB): 70(Corn), 100(AYB), and 100 (Corn), measured in quantities of 70.85g (70% AYB:30% corn), 82.84g (50% AYB:50% corn), 94.81g (30% AYB:70% corn), 52.87g (100%AYB), 112.79g (100% corn) that will contribute 1/3 of the daily dietary fiber intake as described in [14]; and coded as 101, 102, 103, 104, and 105 respectively. Sample 106 the control measured 118.69g (the quantity of Wheat flour that will provide 12.7g dietary fibre) was calculated [20].

Preparation of the bread samples: The blends formulated were baked using the straight dough method as in [21]. All the ingredients were mixed in a plastic bowl for 5minutes. The dough covered with damp clean muslin cloth was allowed to prove for 55mins at 29^{o}C, knocked back and molded into a loaf, placed in a loaf tin, further proved in a prolonged cabinet for 90mins at 85 relative humidity, and baked at 250^{o}c for 45 minutes. It was removed and placed in a rack, later packaged in transparent polythene, ready for chemical evaluation.

Chemical analyses: The proximate compositions of the bread samples were determined using standard procedures [22], total carbohydrate was obtained by difference and the energy values were calculated using the Atwater factors. The minerals (calcium, iron, magnesium, potassium, and sodium), vitamins (beta carotene, thiamin, niacin, and vitamin C), and phytochemicals (flavonoids and saponins) were determined as described by the Association of Official and Analytical Chemists [22]. Anti-nutrients (total tannins, and alkaloids) were determined using standard methods [22, 23].

Statistical analysis: Data generated from the study were reported as the mean of duplicate analyses. One-way analysis of variance (ANOVA) using the Statistical Product for Service Solution version (23.0) was used to compare between the mean values while treatment means were separated using Duncan multiple range test at 95% confidence level ($p<0.05$).

RESULTS

The proximate contents of the bread samples (Table 1) ranged from 321.66 to 330.00kcals (energy), 8.29 to 9.41% (moisture), 9.64 to 25.11g/100g (protein), 2.29 to 4.03g/100g (fat), 0.46 to 2.71g/100g (fiber), 50.23 to 66.50 g/100g (carbohydrates), and 80.60 to 81.71 (dry matter). Sample 101 had the lowest moisture content (8.29), highest fibre (3.10g/100g), ash (2.82g/100g), and dry matter (81.71) values. Sample 103 had the highest fat (4.03g/100g) content; the control sample 106 (100%wheat flour) had the highest energy (330.29kcals) and carbohydrates (66.50g/100g) but the lowest fibre (0.46g/100g) values; while sample 104 (100% AYB) had the highest protein (25.11g/100g) and lowest carbohydrates (50.23g/100g) values.

Table 1 Proximate composition of breads made from African yam bean and corn seeds flour blends

Sample	Energy (kcal)	Moisture content (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Carbohydrates (%)	Dry Matter
101	321.66^{c} ±0.75	8.29^{c} ±0.17	18.06^{b} ±0.01	3.70^{c} ±0.01	3.10^{a} ±0.01	2.82^{a} ±0.01	54.03^{e} ±0.17	81.71^{a} ±0.17
102	323.08^{c} ±0.42	8.68^{bc}±0.10	15.20^{c} ±0.01	3.92^{b} ±0.03	2.71^{b} ±0.01	2.74^{b} ±0.01	56.75^{d} ±0.06	81.32^{ab}±0.10
103	325.73^{b} ±0.52	8.48^{bc}±0.15	12.90^{d} ±0.01	4.03^{a} ±0.01	2.55^{c} ±0.01	2.58^{c} ±0.01	59.47^{c} ±0.15	81.53^{ab} ±0.15
104	322.42^{c} ±0.64	8.82^{b} ±0.17	25.11 ^{a}±0.01	2.34^{e} ±0.01	1.83^{d} ±0.01	1.67^{d} ±0.01	50.23^{f} ±0.11	81.18^{b} ±0.17
105	325.71^{b} ±0.74	9.41^{a} ±0.22	9.64^{f} ±0.03	3.21^{d} ±0.02	1.71^{e} ±0.01	1.47^{e} ±0.01	64.58^{b} ±0.21	80.60^{c} ±0.22
106	330.29^{a} ±0.49	8.43^{bc}±0.14	10.92^{e} ±0.01	2.29 ^{f}±0.01	0.46^{f} ±0.01	1.40^{f} ±0.01	66.50^{a} ±0.14	81.57^{ab} ±0.14

Values are mean ± standard deviation of duplicate samples. $^{a-f}$ Means with similar superscripts within the same column are not significantly different (p>0.05)

Key: 101– (30% African yam bean: 70% corn flour)
102– (50% African yam bean: 50% corn flour)
103– (70% African yam bean: 30% corn flour)
104– (100% African yam bean)
105– (100% Corn flour)
106– Control (100% Wheat flour)

Table 2 shows that the vitamins composition of breads made from AYB and corn seeds flour blends ranged from 3.12 to 32.67 µ g/g (pro vitamin A), 0.14 to 1.55mg/100g (thiamin), 0.62 to 1.38mg/100g (niacin), and 4.76 to 41.76mg/100g (vitamin C). Sample 101 ((30% AYB: 70% corn flour) had the pro-vitamin A (32.67 g/g) and vitamin C (41.76mg/100g) values. Sample 103 (70% AYB: 30% corn flour) had highest thiamin (1.55mg/100g) and niacin (1.38mg/100g) values; while the control 106 (100% wheat flour) and 104 (100% whole corn flour) had the lowest thiamin (0.14mg/100) and niacin (0.62mg/100g) values.

Table 2: Vitamin composition of breads made from African yam bean and corn seeds flour blends

Sample	Pro VitaPro-Vitamin)	Thiamin (mg/100g)	Niacin (mg/100g)	Vit. C (mg/100g)
101	32.67^{a} ±0.18	1.15^{d} ±0.03	1.34^{ab} ±0.01	41.76^{a} ±0.02
102	28.64^{b} ±0.01	1.22^{c} ±0.01	1.33^{ab} ±0.01	31.52^{b} ±0.03
103	20.31^{c} ±0.01	1.55^{a} ±0.01	1.38^{a} ±0.01	29.41^{c} ±0.03
104	10.96^{d} ±0.01	0.15^{e} ±0.02	0.62^{d} ±0.03	11.19^{d} ±0.01
105	7.30^{e} ±0.01	1.43^{b} ±0.01	1.32^{b} ±0.03	4.76^{f} ±0.01
106	3.12^{f} ±0.01	0.14^{e} ±0.01	1.10^{c} ±0.01	7.89^{e} ±0.01

Values are mean ± standard deviation of duplicate samples. $^{a-f}$ Means with similar superscripts within the same column are not significantly different (p>0.05)

Key: 101– (30% AYB: 70% corn flour)
102– (50% AYB: 50% corn flour)
103– (70% AYB: 30% corn flour)
104– (100% AYB)
105– (100% Corn flour)
106– Control (100% Wheat flour)

Table 3 presents the mineral composition of breads made from AYB and corn seeds flour blends. The minerals ranged from 13.23 to 70.31mg/100 calcium, 25.76 to 142.57mg/100g magnesium, 73.81 to 208.13mg/100g potassium and 28.38 to 66.15mg/100g sodium. The control sample 106 (100% wheat flour) had the lowest calcium (13.23mg/100g), magnesium (25.76mg/100g), and sodium (28.38mg/100g) values compared to the samples; sample 101 (30% AYB: 70% corn flour) had the highest potassium (208.13mg/100) value, sample 103 (70% AYB: 30% corn flour), had the highest calcium (72.30mg/100g), and magnesium (142.57mg/100g), while sample 104 (100% AYB) had the highest sodium (66.15mg/100) values.

Table 3: Mineral composition of breads made from African yam bean and corn seeds flour blends

Sample	Calcium (mg/100g)	Magnesium (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)
101	65.52^{c} ±0.01	80.21^{c} ±0.03	208.13^{a} ±0.03	57.71^{ab} ±0.01
102	70.31^{b} ±0.01	74.63^{d} ±0.01	168.96^{d} ±0.01	58.51^{ab} ±0.01
103	72.30^{a} ±0.01	142.57^{a} ±0.01	190.28^{c} ±0.01	54.95^{ab} ±0.01
104	40.45^{e} ±0.01	51.61^{e} ±0.01	207.82^{b} ±0.01	66.15^{a} ±35.37
105	65.42^{d} ±0.01	139.20^{b} ±0.01	73.81^{f} ±0.01	55.16^{ab} ±0.01
106	13.23^{f} ±0.01	25.76^{f} ±0.01	159.83^{e} ±0.03	28.38^{b} ±0.01

Values are mean ± standard deviation of duplicate samples. $^{a-f}$ Means with similar superscripts within the same column are not significantly different (p>0.05)

Key: 101– (30% AYB: 70% corn flour)
102– (50% AYB: 50% corn flour)
103– (70% AYB: 30% corn flour)
104– (100% AYB)
105– (100% Corn flour)
106– Control (100% Wheat flour)

The phytochemicals in the bread samples made from AYB and corn seeds flour blends (Table 4) ranged from 0.94 to 11.36mg/100g flavonoids, and 0.08 to 0.41mg/100g saponin. The anti-nutrients ranged from 0.03 to 1.02mg/100g tannin, and 0.18 to 1.11mg/100g alkaloids. Sample 102 had the highest saponin value (0.41mg/100g), 103 had the highest alkaloids (1.11mg/100g), while the control sample 106 had the lowest flavonoids (0.94mg/100g), and 104 had the lowest tannin (0.03mg/100g) and alkaloids (0.18mg/100g).

Table 4: Phytochemicals and anti-nutrient composition of breads made from African yam bean and corn seeds flour blends

Sample	Flavonoid (mg/100g)	Saponin (mg/100g)	Tannin (mg/100g)	Alkaloid (mg/100g)
101	1.42^{c} ±0.01	0.20^{b} ±0.01	0.16^{c} ±0.01	0.23^{c} ±0.01
102	1.28 ^{d} ±0.01	0.41^{a} ±0.01	0.22^{b} ±0.01	0.29^{b} ±0.01
103	1.52^{b} ±0.01	0.17^{b} ±0.01	1.02^{a} ±0.01	1.11^{a} ±0.01
104	11.36^{a} ±0.01	0.02^{e} ±0.01	0.03^{f} ±0.01	0.18^{d} ±0.01
105	1.11^{e} ±0.01	0.12^{c} ±0.01	0.12^{d} ±0.01	0.32^{b} ±0.01
106	0.94^{f} ±0.01	0.08^{d} ±0.01	0.06^{e} ±0.01	0.21^{d} ±0.01

Values are mean ± standard deviation of duplicate samples. $^{a-f}$ Means with similar superscripts within the same column are not significantly different (p>0.05)

Key: 101– (30% AYB: 70% corn flour)
102– (50% AYB: 50% corn flour)
103– (70% AYB: 30% corn flour)
104– (100% AYB)
105– (100% Corn flour)
106– Control (100% Wheat flour)

DISCUSSION

The proximate composition of breads produced from AYB and corn seeds flour blends (Table 1) showed that the study samples had significantly high (321.66 to 330.91kcal) energy values and could be good sources of energy. This result is in agreement with the work of Dogo *et al.* [24] where bread samples made from wheat and AYB flour blends had improved energy value. However, the study samples had significantly lower energy values compared to the control sample 106 (100% wheat flour), this lower energy value of these flour samples is an indication that they could be used for individuals on a reduced calories diet. The moisture content of sample 105 (100% Corn flour) 9.41 % was significantly higher (P<0.05) than other bread samples and 1.33 to 3.08% and 3.11 to 5.15% reported in Okafor and Ugwu [25] and Ojinnaka and Agubolum, [26] baked ready-to-eat snacks and cashew nut-wheat cookies respectively; but similar to that in wheat and defatted cashew nut bread samples [24] and in wheat flour with yam, vanilla flour and groundnut [27, 28] respectively.

This could be attributed to crop types, processing methods employed, and end products. Moisture content is an important indicator for the shelf life of the flour [29]. Low water contents allow long-term storage by inhibiting the proliferation of microorganisms that can alter the product [30]. The low moisture values of the breads, therefore, implied better shelf-life as the values were less than the 14% moisture limit for storage stability [31]. There was a significant difference in protein contents of all the bread samples in this study. The protein contents of the bread samples were significantly higher (P<0.05) than breads made from 100% wheat flour (the control sample 106) and 100% whole cornflour (sample 105). The increase in the protein content of the products could be attributed to the blending of whole AYB and Whole corn seeds which are high in protein contents [32]. This study protein range (9.64 to 25.11%) was higher than 7.76 to 11.84% protein contents reported in Ojinnaka and Agubolum [26] AYB and wheat flour cookies; and 13.88 to 15.90% in Okafor and Ugwu, [25] extruded ready-to-eat baked products. This could be due to differences in crop types, products types, and blending formulas. Igbabul *et al*. [33] reported similar results with bread made from wheat, plantain, and soy. The protein contents (10.92 to 25.11%) of the study samples excluding sample 105 (100% whole corn flour) are of significant value since they are higher than the acceptable range (10.5% to 14%) recommended for bread flour [34]. The fat content of the bread samples showed significant differences from each other. All the study samples had higher fat contents compared to the control sample 106 (100% wheat flour), but lower than 13.37 to 21.50% and 16.41 to 29.81% reported in [25, 26] for baked ready-to-eat snacks and AYB-wheat cookies. This could be attributed to the composition of the study blends (whole AYB and Whole corn seeds flour) with high-fat contents than wheat flour, differences in product type, ingredients used, and method of processing/production. The fat values are indicative of increased nutrient density. The increase in the fat content of the breads is comparable to the finding of [35. 36] which showed that the substitution of wheat flour by African yam bean seed and Cornflour respectively, increased the lipid contents of composite breads. However, despite this increase, the lipid content of the breads was below the recommended values (10- 25%) [37] which could be beneficial for the individual on reduced-fat diets.

All the study samples had significantly higher fibre values compared with the control (100% wheat flour) at p < 0.05. The increase in the fiber content of breads was due to the incorporation of whole AYB and whole corn flours rich in fiber. These values were significantly higher than 0.46 to 1.22% and 0.52 to 1.47% in [26, 25] AYB-wheat cookies and baked ready-to-eat snacks. The result is in agreement with the work of Dogo *et al*., [24] in the production of bread with blends of wheat and cornflour. Increased fibre contents are beneficial to good health, recommended for a healthy heart and gastrointestinal tract. These high fibre bread samples could reduce the risk of constipation associated with the consumption of wheat flour breads [38]. The fiber contents of the breads although improved is within the recommended values of less than 5% fibers for breads [37].

The ash content of a food product is an indication of the mineral values. All the bread samples had significantly (P<0.05) higher ash content compared with the control 106 (100% wheat flour). By implication more mineral contents than the control (100% wheat flour). The ash contents of the bread samples are within the recommended values of less than 3% ash [37]. The ash values of the study breads (1.40 to 2.82%) were relatively higher than 1.97 to 2.05% in baked ready-to-eat snacks [25] and 0.46 to 1.22% in AYB-wheat cookies [26].

The carbohydrates contents of the bread samples were significantly (p <0.05) lower (50.23 to 64.58%) than 66.50% in 100% wheat flour bread (sample 106), but comparable to 62.27 to 66.49% and 34.30 to 68.00% in baked ready-to-eat snacks and AYB-wheat cookies [25], and [26] respectively. Carbohydrates contents in the study breads decreased with the increased substitution of AYB. The lower carbohydrate contents of the bread samples could be explained by the higher values of the other proximate parameters since carbohydrates were determined by difference. Similar trends have been reported [39], in the fortification of wheat flour with defatted soy flour, and bread made from wheat and Cornflour [24]. Despite the lower carbohydrates, the values (66.50% to 50.23%) of this study, were moderate and relatively close to the recommended value of 68% carbohydrates [37].

Dry matter contents of the study samples showed that sample 101 (30% AYB: 70% corn flour) had significantly higher (P<0.05) dry matter content (81.71%), than the other samples. The least dry matter content was observed in sample 105 (100% Corn flour) with the value (80.60%) lower than other samples 106 Control (100% Wheat flour) 81.57%. This result aligns with bread samples made from AYB and wheat flour blends [24].

The vitamin composition of the breads made from AYB and corn seeds flour blends (Table 2) shows that the bread samples had significantly higher (P<0.05) pro-vitamin A contents than bread made with 100% wheat flour (sample 106). The composite blends (101– 30% AYB: 70% corn flour, 102– 50% AYB: 50% corn flour, 103– 70% AYB: 30% corn flour) had higher values compared with the pure samples (104– 100% AYB, 105– 100% cornflour, 106– Control 100% Wheat flour). These pro-vitamin A values were significantly higher than 2.42 to 6.01µ**g/g** in [25] ready-to-eat baked snacks and could be attributed to the value addition of AYB and corn seeds flour. The role of pro-vitamin A in vision, bone growth, reproduction, cell division, and cell differentiation had already been documented [40]. All the study breads had significantly higher(P<0.05) Vitamin B1 (thiamine) content compared to 0.15mg/100g sample 105 (100% whole corn) and 0.14mg/100g sample 106

(100% wheat flour bread). These values were comparable to the increase in thiamin contents (0.13 to 0.42mg) in ready-to-eat snacks made from blends of breadfruit, AYB, and coconut [25]. The blending of AYB and corn seeds flours in the bread samples is a value addition strategy that improved the thiamin contents of the study samples. Thiamine is involved in energy release during carbohydrate and fat metabolism [41]. Surprisingly, sample 104 (100% AYB) had significantly low (P<0.05) niacin content (0.62 mg/100g) compared to the other bread samples. The bread samples that had whole corn flour had improved niacin content, this could be because whole corn contains an appreciable amount of niacin. Okafor and Ugwu [25] had relatively lower 0.16 to 0.48mg niacin values. The importance of niacin in energy transfer reactions in the metabolism of glucose, fat, and alcohol has been reported [42]. Sample 101 (30% AYB: 70% corn flour) had the highest vitamin C content (41.76mg/100g), while sample 105 (100% corn) had the lowest (4.76 mg/100g) vitamin C content. The increased content of vitamin C in the composite samples could be the result of the addition of African yam beans which had an appreciable vitamin C in the whole seeds. Vitamin C is known to protect the immune system, improve prenatal health, eye, and skin status as well as regulate body processes [43].

The mineral composition of the bread samples shown in Table 3 revealed that the study samples had significantly higher minerals (calcium, magnesium, potassium, and sodium) contents (P< 0.05) than the control sample 106 (100% wheat flour) except for sample 105 which had a lower potassium content than 100% wheat flour. These values were comparable to bread made from wheat and corn flour blends [24]. All samples with AYB, a legume had high potassium density. Calcium and magnesium contents increased with increased substitution with corn. The importance of minerals is in human health has already been underscored [33, 44 – 46]. Potassium is involved in the metabolism of carbohydrates and protein, the regulation of heartbeat, and the reduction in risk of hypertension and stroke [43]. The sodium and potassium contents of the bread samples constitute valuable information for hypertensive patients.

All study bread samples had higher flavonoid content than the control samples 106 (100% wheat flour). Flavonoids have been associated with anti-allergic, anti-oxidant, anti-inflammatory, anti-cancer, and anti-viral effects [47], and can enhance good flavor and limit the generation of off-flavors. The saponin contents of the blends are comparable to the range (0.07 to 0.11mg) reported in [26]. High saponin contents can reduce uptake of certain nutrients including glucose and cholesterol [48]. The tannin content of the study samples was slightly higher than 0.09 to 0.21 in AYB-wheat cookies [26]. Although tannin is known to interfere with mineral absorption, and protein digestibility [49], the bread samples contained trace amounts, considerably lower than 80mg/g of anti-nutritional factors that are detrimental to health [50].

CONCLUSION

This work is a response to the need to promote the utilization of low-cost indigenous foods to improve consumers' nutrition status and health benefits. The study samples had higher protein, fat, fiber, moisture, and ash but lower energy and carbohydrates compared to the control sample 106 (100% wheat flour). This implies that the study samples had higher proximate density compared to conventional wheat bread. The higher values of protein, fat, ash, fibre, vitamins, and minerals as shown in the study samples are value addition results for an improved nutrient intake. The high nutrient content of the African yam bean and cornflour blends made the bread an excellent naturally available supplement for low nutrient-dense diets. The lower energy and carbohydrates values of these bread have health implications for individuals on low energy and carbohydrates diets. The trace amounts of anti-nutrients found are within the safe level for human consumption. Study bread can contribute to improved nutrients intake, varied meals, increase the cultivation of under-utilized local crops, and reduce of importation of wheat flour for better economic growth.

Conflict of interest

None

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