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Assessment of the mineral composition and vitamin content of blends of sorghum (*Sorghum bicolor* L.) and pigeon pea (*Cajanus cajan* L.) flours

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Abstract

This study was carried out to evaluate the mineral composition and vitamin content of sorghum and pigeon pea composite flours. Flours were produced from sorghum and pigeon pea seeds. The composite flours were mixed homogenously. Six different blends were formulated in the following ratios as 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 of sorghum and pigeon pea flours respectively, where 100% sorghum flour served as control. The mineral and vitamin composition of the blends were determined using standard methods. The mineral composition result showed significant ($p<0.05$) increase in potassium (315.10 – 635.0 mg/100 g), magnesium (90.01- 94.52 mg/100 g), calcium (20.10 – 52.11 mg/100 g), zinc (2.03 – 2.30 mg/100 g), iron (3.01 – 5.10 mg/100 g) and sodium (4.80 – 7.82 mg/100 g), and significant ($p<0.05$) reduction in phosphorus (300.20 - 264.15 mg/100 g), with the increased supplementation of pigeon pea flour to sorghum flour in the blends. The vitamin content result recorded significant ($p<0.05$) increase in niacin (2.60-2.91 mg/100 g), riboflavin (0.07-0.13 mg/100 g), thiamin (0.31-0.43 mg/100 g), ascorbic acid (29.31-34.56 mg/100 g), and decrease in pyridoxine (0.40-0.21 mg/100 g) and alpha-tocopherol (0.61-0.26 mg/100 g), with increased level of inclusion of pigeon pea flour to the blends. This study showed that supplementing sorghum flour with pigeon pea flour produced blends with improved micronutrients which can find use in ameliorating the prevalence of micronutrients deficiencies in developing countries.

Keywords: Mineral; Vitamin; Composite Flours; Sorghum; Pigeon Pea

1. Introduction

Micronutrient deficiencies are a significant public health problem in many developing countries such as Nigeria, with infants and pregnant women particularly at danger [1]. Ehile *et al.* [2] opined that micronutrient deficiency also known as hidden hunger, is the main source of health challenges, large casualty rate, and reduced economic productivity in tropical Africa. Nigeria alone loses over 1.5 billion US dollars annually on Gross Domestic Product (GDP) to mineral and vitamin deficiencies as many staple foods are low in essential micronutrients [3; 4]. According to Arukwe [5] pigeon pea is an important legume which can be used to check the diverse problems of protein-calorie malnutrition and micronutrient deficiencies in Nigeria. Micronutrients (minerals and vitamins) are required by the body to carry out a range of normal functions. Micronutrients are not produced by the body and must be derived from the food consumed. Welch *et al.* [6] noted that legumes are sources of dietary minerals that potentially furnish all the 15 essential minerals crucial for humanity. Sorghum contains minerals such as iron, zinc, phosphorus, calcium, potassium, manganese, sodium and magnesium [7; 8]. Studies have shown that pigeon pea contains potassium, phosphorus, calcium, magnesium, iron, zinc, copper, and manganese [9; 10].

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Composite flours have become the focus of many research work because of the requirement for the utilization of cheap and available local crops with ideal nutritional value and good processing qualities in place of wheat in the food industry. Cereals and legumes have been used by many people in developing countries to satisfy their protein, carbohydrate, minerals and vitamins requirements for centuries. Sorghum (*Sorghum bicolor*) is a cereal of the grass family Poaceae. It is also known as guinea corn in West Africa. It is resistant to drought and heat and can produce in marginal soil than other cereals and plays an important role for food security [11]. Sorghum was first cultivated in Africa (Ethiopia or Chad region) about 5000 years ago but has since spread to other parts of the world. Sorghum contains protein, carbohydrates, minerals and vitamins [12]. Pigeon pea (*Cajanus cajan*) is an important legume which belong to the family Fabaceae and its cultivation dates back to about 3000 years ago [13]. It can survive and produce under harsh climatic conditions. It is rich in protein, minerals and vitamins [10; 14]. According to Nwanekezi *et al*. [10], pigeon pea can be used to alleviate the problem of mineral deficiency in the diets. The mineral and vitamin contents of sorghum can be improved by complementing with that of pigeon pea.

The absence of sufficient information on the mineral and vitamin contents of some underutilized legumes such as pigeon pea and sorghum, have been one of the hindrances to their utilization. Knowledge of the micronutrient contents of the flour blends of sorghum and pigeon pea can be utilized to enhance the micronutrient intake of the people, thereby alleviating the problem of micronutrient deficiencies in the diets of the people. Also. Processing of sorghum and pigeon pea into composite flours with longer shelf life will curb post - harvest losses, and such flours can serve as raw materials in the bakery and confectionary industries, thereby increasing the economic value of these local crops. The aim of this study was to produce flours from blends of sorghum and pigeon pea and determine the mineral and vitamin contents of the blends.

2. Material and methods

2.1. Raw Materials Procurement

Sorghum grains and pigeon pea seeds were procured from Ubani Main Market in Umuahia North Local Government Area, Abia State.

2.2. Sample Preparation

Two kilograms (2 kg) each of sorghum and pigeon pea seeds were sorted, cleaned and washed in water and the water drained. The seeds were soaked in water for about 12 h and the water drained.

2.2.1. Production of sorghum flours

The method described by Arukwe *et al*. [15] was used in production of boiled sorghum flour with slight modification. The soaked sorghum grains were boiled in water for 1 h at 100 °C. The water was drained and the grains dried in an oven at 60 °C for 7 h (Gallenkemp, 300 Plus, and England). The dried grains were milled into flour using disc attrition mill (Asiko A11, Addis Nigeria), sieved with standard sieve (1.0 mm mesh size) and packaged in polyethylene packs.

2.2.2. Production of pigeon pea flours

The method described by Arukwe *et al*. [15] was used in production of boiled pigeon pea flour with slight modification. The soaked pigeon pea grains were manually dehulled and boiled in water for 1 h at 100 °C. The water was drained and the grains dried in an oven at 60 °C for 7 h (Gallenkemp, 300 Plus, and England). The dried grains were milled into flour using disc attrition mill (Asiko A11, Addis Nigeria), sieved with standard sieve (1.0 mm mesh size) and packaged in polyethylene packs.

2.3. Blending of Sorghum and Pigeon Pea Flours

Table 1 depicts the blending ratios of sorghum flour and pigeon pea flour, where 100% sorghum flour served as control.

Table 1 Blending of sorghum and pigeon pea composite flours

Sample SGF:PPF	Sorghum flour	Pigeon pea flour	Total
100:0	100	0	100
90:10	90	10	100
80:20	80	20	100
70:30	70	30	100
60:40	60	40	100
50:50	50	50	100

2.4. Mineral Determination

The Onwuka [16] method was employed for the determination of minerals. The samples were ashed and digested and the digests were used for mineral element determination. The EDTA complexiometric titration method as described by Udoh and Ogunwale [17] was used to measure calcium and magnesium. The flame photometric method of AOAC [18] was used to analyze potassium and sodium. The zinc and iron were analyzed by atomic absorption spectrophotometer, model AAS, Hitachi 26100, and Tokyo Japan. The vonadomolybdate spectrometric method as described by James [19] was used to determine phosphorus.

2.5. Vitamin Determination

The photometric method as described by Okwu [20] was used to determine thiamin (vitamin B_1) and riboflavin (vitamin B_2) respectively. The photometric method of Onwuka [16] was employed to measure niacin (vitamin B_3). The Barakat titrimetric method as outlined by Okwu and Ndu [21] was adopted for ascorbic acid (vitamin C) determination. The method of Harold *et al*. [22] was used in the determination of pyridoxine (vitamin B_6). The HPLC method described by Klimes and Jedlicka [23] and McMurray *et al*. [24] was used to analyze the alpha-tocopherol (vitamin E) content.

2.6. Statistical Analysis

Results of all determinations were expressed as means of triplicate values. Data were subjected to One-way Analysis of Variance (ANOVA) and significant differences detected using Duncan multiple range test at 95% confidence level ($p<0.05$). An IBM SPSS Statistical package (version 22.0) was used for all statistical analyses.

3. Results and discussion

3.1. Mineral Composition of the Sorghum and Pigeon Pea Flour Blends

Mineral play an important role in the development of the human body. Table 2 shows the mineral composition of the blends of sorghum and pigeon pea composite flours. There were significant differences ($p<0.05$) in the potassium content of the samples which ranged from 315.10 – 635.0 mg/100 g. The lowest value of potassium was recorded for the 100% sorghum sample. The sample 50:50 (50% sorghum flour and 50% pigeon pea flour) recorded the highest value for potassium. The value for potassium significantly ($p<0.05$) increased with increased inclusion of pigeon pea flour to the blends. This indicates that pigeon pea flour is rich in potassium [10]. Potassium is required for proper fluid balance, nerve transmission and muscle contraction. It acts as a vasodilator, reduces blood constriction, and lowers blood pressure [25].

There were significant differences ($p<0.05$) in the phosphorus content of the samples which ranged from 264.15 – 300.20 mg/100 g. The highest value of phosphorus was recorded for the 100% sorghum sample, while sample 50:50 (50% sorghum flour and 50% pigeon pea flour) recorded the lowest value for phosphorus. The value for phosphorus significantly ($p<0.05$) reduced with the increased inclusion of pigeon pea flour to the blends. This result suggests that sorghum flour had more phosphorus than pigeon pea flour. Phosphorus is found in every cell; important for healthy bones and teeth, and part of the system that maintains acid-base balance.

Table 2 Mineral composition of Blends of Sorghum and Pigeon Pea Flours

Sample SGF:PPF	Potassium Mg/100g	Phosphorus Mg/100g	Magnesium Mg/100g	Calcium Mg/100g	Zinc Mg/100g	Iron Mg/100g	Sodium Mg/100g
100:0	$315.10^{f}\pm0.01$	$300.20^{a}\pm0.02$	$90.01^{f}\pm0.0$	$20.10^{f}\pm0.0$	$2.03^{f}\pm0.01$	$3.01^{f}\pm0.0$	$4.80^{f}\pm0.02$
90:10	$384.20^{e}\pm0.0$	$294.0^{b}\pm0.0$	$90.85^{e}\pm0.0$	$25.23^{e}\pm0.01$	$2.08^{e}\pm0.0$	$3.43^{e}\pm0.01$	$5.35^{e}\pm0.0$
80:20	$455.0^{d}\pm0.02$	$287.05^{c}\pm0.0$	$91.60^{d}\pm0.02$	$30.50^{d}\pm0.0$	$2.14^{d}\pm0.0$	$3.80^{d}\pm0.02$	$6.01^{d}\pm0.01$
70:30	$502.10^{c}\pm0.01$	$281.0^{d}\pm0.01$	$92.33^{c}\pm0.01$	$38.78^{c}\pm0.01$	$2.20^{c}\pm0.01$	$4.12^{c}\pm0.0$	$6.50^{c}\pm0.0$
60:40	$567.05^{b}\pm0.0$	$273.20^{e}\pm0.01$	$93.0^{b}\pm0.0$	$44.50^{b}\pm0.02$	$2.25^{b}\pm0.01$	$4.60^{b}\pm0.0$	$7.10^{b}\pm0.0$
50:50	$635.0^{a}\pm0.0$	$264.15^{f}\pm0.02$	$94.52^{a}\pm0.0$	$52.11^{a}\pm0.01$	$2.30^{a}\pm0.0$	$5.10^{a}\pm0.01$	$7.82^{a}\pm0.01$

*means with the same superscripts down the column are not significantly different (p<0.05); Key: 100:0 = 100% sorghum flour, 90:10 = 90% sorghum and 10% pigeon pea flour, 80:20 = 80% sorghum flour and 20% pigeon pea flour, 70:30 = 70% sorghum flour and 30% pigeon pea flour, 60:40 = 60% sorghum flour and 40% pigeon pea flour and 50:50 = 50% sorghum flour and 50% pigeon pea flour.

There were significant differences (p<0.05) in the magnesium content of the sorghum and pigeon pea composite flours. The magnesium content of the blends ranged from 90.01 – 94.52 mg/100 g. The 100 % sorghum flour sample had the lowest value (90.01 mg/100 g) and sample 50:50 (50 % sorghum flour and 50 % pigeon pea flour) recorded the highest value for magnesium. The magnesium content of the blends recorded increase with increased addition of pigeon pea flour in the blends. This implies that pigeon pea flour possesses higher magnesium than sorghum flour. Magnesium is found in bones, and is required for production of protein, muscle contraction, nerve transmission, and immune system health.

There were significant differences (p<0.05) in the calcium content of the sorghum and pigeon pea composite flours which ranged between 20.10 mg/100 g and 52.11 mg/100 g. The least value (20.10 mg/100 g) was recorded for the 100 % sorghum flour sample, while sample 50:50 (50 % sorghum flour and 50% pigeon pea flour) recorded the highest value for calcium. The calcium content of the blends recorded increment with increase in the inclusion of pigeon pea flour in the blends. Pigeon pea flour has been reported to be moderately rich in calcium [9; 10]. Calcium is the mineral that helps to build and maintain strong bones and teeth, aids relaxation and contraction of muscles, important in nerve functioning, blood clotting, blood pressure regulation [26], and immune system health.

The zinc content of the blends ranged between 2.03 mg/100 g and 2.30 mg/100 g. There were significant differences (p<0.05) in the zinc content of the blends. The lowest value of zinc (2.03 mg/100 g) was recorded for the 100% sorghum flour and the highest value 2.30 mg/100 g was recorded for sample 50:50 (50 % sorghum flour and 50% pigeon pea flour). The zinc content of the blends increased with increasing supplementation of pigeon pea flour to sorghum flour. This depicts that pigeon pea flour contains more zinc than sorghum flour. Zinc is part of many enzymes; required for production of protein and genetic material, for taste perception, wound healing, normal fetal development, making of sperm, normal growth, sexual maturation, and immune system health [27].

There were significant differences (p<0.05) in the iron content of the blends. The iron content ranged from 3.01 – 5.10 mg/100 g. The lowest value (3.01 mg/100 g) for iron was recorded for the 100% sorghum flour while the highest value (5.10 mg/100 g) was recorded for sample 50:50 (50% sorghum flour and 50% pigeon pea flour). The iron content recorded consistent increase with increase in inclusion of pigeon pea flour in the blends. This indicates that pigeon pea flour had more iron content than sorghum flour. The values for iron content obtained in this study are lower than the values (10.10-10.33 mg/100 g) reported for African yam bean [28]. Iron is part of a molecule (hemoglobin) found in red blood cells that carries oxygen in the body, and is required for energy metabolism, immune defense and thyroid function.

The sodium content of the sorghum and pigeon pea flour blends ranged between 4.80 mg/100 g and 7.82 mg/100 g. There were significant differences (p<0.05) in the sodium content of the blends. The lowest value (4.80 mg/100 g) for sodium was recorded for the 100% sorghum flour while sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the highest value (7.82 mg/100 g). There were significant (p<0.05) increase in sodium content with increased addition of pigeon pea flour to sorghum flour. The values obtained in this study for sodium are below the value (≤140 mg/100 g of sodium) considered as low sodium foods [29]. Sodium is important for proper fluid balance, nerve transmission, and muscular contraction. Low sodium in the diets causes decrease in blood pressure, stroke and cardiovascular diseases [30].

3.2. Vitamin Content of the Sorghum and Pigeon Pea Flour Blends

Vitamins are organic substances crucial for normal cell function, growth and development [31]. Table 3 presents the vitamin content of the sorghum and pigeon pea flour blends. The pyridoxine (vitamin B6) content of the blends ranged between 0.21 mg/100 g and 0.40 mg/100 g. There were significant differences (p<0.05) in the pyridoxine content of the blends. The control sample (100 %) sorghum flour recorded the highest value (0.40 mg/100 g) of pyridoxine while the least value (0.21 mg/100 g) was recorded for sample 50:50 (50% sorghum flour and 50% pigeon pea flour). The flour blends of sorghum and pigeon pea recorded decreased values as the addition of pigeon pea flour increased. This implies that sorghum flour had more pyridoxine than pigeon pea flour. Pyridoxine helps to form red blood cells and maintain brain function. It plays important role in transamination, decarboxylation, transsulphuration, glycogenolysis, absorption of amino acids and making of arachidonic acid from linoleic acid [32].

Table 3 Vitamin content of Blends of Sorghum and Pigeon Pea Flours (mg/100g)

Sample SGF:PPF	Pyridoxine (B6)	Niacin (B3)	Riboflavin (B2)	Thiamin (B1)	Ascorbic acid (C)	Alpha-tocopherol (E)
100:0	$0.40^{a}\pm0.00$	$2.60^{f}\pm0.01$	$0.07^{f}\pm0.01$	$0.31^{f}\pm0.02$	$29.31^{f}\pm0.0$	$0.61^{a}\pm0.01$
90:10	$0.37^{b}\pm0.02$	$2.66^{e}\pm0.0$	$0.08^{e}\pm0.02$	$0.33^{e}\pm0.0$	$29.86^{e}\pm0.02$	$0.55^{b}\pm0.0$
80:20	$0.33^{c}\pm0.01$	$2.72^{d}\pm0.0$	$0.09^{d}\pm0.00$	$0.35^{d}\pm0.01$	$30.65^{d}\pm0.01$	$0.51^{c}\pm0.01$
70:30	$0.29^{d}\pm0.02$	$2.78^{c}\pm0.01$	$0.10^{c}\pm0.10$	$0.38^{c}\pm0.0$	$31.50^{c}\pm0.0$	$0.42^{d}\pm0.0$
60:40	$0.25^{e}\pm0.00$	$2.84^{b}\pm0.0$	$0.11^{b}\pm0.00$	$0.40^{b}\pm0.01$	$32.20^{b}\pm0.01$	$0.34^{e}\pm0.02$
50:50	$0.21^{f}\pm0.01$	$2.91^{a}\pm0.01$	$0.13^{a}\pm0.04$	$0.43^{a}\pm0.02$	$34.56^{a}\pm0.0$	$0.26^{f}\pm0.01$

*means with the same superscripts down the column are not significantly different (p<0.05); Key: 100:0 = 100% sorghum flour, 90:10 = 90% sorghum and 10% pigeon pea flour, 80:20 = 80% sorghum flour and 20% pigeon pea flour, 70:30 = 70% sorghum flour and 30% pigeon pea flour, 60:40 = 60% sorghum flour and 40% pigeon pea flour and 50:50 = 50% sorghum flour and 50% pigeon pea flour.

The niacin (vitamin B3) content of the sorghum and pigeon pea flour blends ranged from 2.60 – 2.91 mg/100 g. There were significant differences (p<0.05) in the niacin content of the composite flours with the control sample recording the lowest value (2.60 mg/100 g) and sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the highest value (2.91 mg/100 g). The niacin content increased with rise in percent pigeon pea flour in the blends. This could be attributed to addition effect, and shows that pigeon pea flour contained more niacin than sorghum flour. Niacin enhances carbohydrate metabolism, prevent fat storage and boost energy levels [33].

There were significant differences (p<0.05) in the riboflavin (vitamin B2) content of the flour blends. The riboflavin content of the samples ranged from 0.07 – 0.13 mg/100 g. The control, 100% sorghum flour sample had the least value, while sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the highest value. The riboflavin content recorded increment with increased inclusion of pigeon pea flour in the blends. This can be attributed to the high riboflavin content of pigeon pea flour [14]. Arukwe and Onyeneke [34] reported similar trend of increase in riboflavin during the production of ogiri from melon and groundnut seeds. Riboflavin in the diet helps to promote growth and the production of red blood cells.

The thiamin (vitamin B1) content of the samples ranged between 0.31 mg/100 g and 0.43 mg/100 g. The thiamin content of the samples recorded significant differences (p<0.05) with control sample (100 % sorghum flour) having the least value (0.31 mg/100 g) and sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the highest value (0.43 mg/100 g). The values for thiamin increased for the composite blends with increase in level of addition of pigeon pea flour. This justifies the need for this research to combine sorghum and pigeon pea for more benefits. Thiamin helps the body cells change carbohydrates into energy. It is also essential for heart function and healthy nerves cells [35].

There were significant differences (p<0.05) in the ascorbic acid (vitamin C) content of the flour blends which ranged from 29.31 – 34.56 mg/100 g. The control, 100% sorghum flour had the lowest ascorbic acid content value (29.31 mg/100 g) while sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the highest value (34.56 mg/100 g). The ascorbic acid content of the blends recorded increment with increase in addition of pigeon pea flour. This suggests that pigeon pea flour has more ascorbic acid content than sorghum flour. Ascorbic acid increases the production of white blood cells, and acts as an antioxidant that promotes overall wellness as well as strong immunity.

The alpha-tocopherol (vitamin E) content of the flour blends ranged between 0.26 mg/100 g and 0.61 mg/100 g. There were significant differences ($p<0.05$) in the alpha-tocopherol content of the flour blends. The 100 % sorghum flour sample recorded the highest alpha-tocopherol content value (0.61 mg/100 g) while sample 50:50 (50% sorghum flour and 50% pigeon pea flour) had the least value (0.26 mg/100 g). The alpha-tocopherol content significantly ($p<0.05$) reduced with the increased inclusion of pigeon pea flour in the blends. This could be attributed to dilution effect, and indicates that sorghum flour has higher content of alpha-tocopherol than pigeon pea flour. Alpha-tocopherol is an antioxidant that helps the body form red blood cells and use vitamin K.

These results indicate that consumption of diets containing blends of sorghum and pigeon pea flours will likely improve the mineral and vitamin intake of the people.

4. Conclusion

This study has shown that the flours of sorghum and pigeon pea blends have improved mineral and vitamin contents. Increasing levels of pigeon pea flour substitution to sorghum flour resulted to increase in potassium, magnesium, calcium, zinc, iron, and sodium. There were also increases in thiamin, riboflavin, niacin, ascorbic acid, with increased addition of pigeon pea flour to sorghum flour in the blends. These blends can be useful in mitigating the prevalence of micronutrient deficiencies in developing countries.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors hereby state that there is no conflict of interest.

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