

Physico-Chemical Properties and Anti-nutrient Contents of Unripe Banana and African Yam Bean Flour Blends

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Abstract: This study was carried out to determine the effect of substituting unripe banana (*Musa spp.*) flour with different levels of African yam bean (*Sphenostylis stenocarpa*) flour on the proximate composition, minerals, anti-nutrients and functional properties of the flour blends. Underutilized unripe banana cultivar ("mboro ukom") and African yam bean seeds (black variety) were separately processed into flours. The banana flour was supplemented with African yam bean flour at substitution levels of 0, 10, 20, 30, 40 and 50% to obtain the flour blends with 100% banana flour as the control sample. The results showed that substituting unripe banana flour with levels of African yam bean flour significantly ($p < 0.05$) increased the crude protein content from 4.39% for 100% banana flour to 14.05% for 50% yam bean flour substitution while the carbohydrate content decreased significantly ($p < 0.05$) from 90.92% for 100% banana flour to 80.12% for 50% yam bean flour substitution. The fat, ash and crude fibre contents increased with increase in African yam bean flour substitution from 0.58%, 2.80% and 1.31% for 100% banana flour to 0.98%, 3.06% and 1.79% for 50% African yam bean flour substitution, respectively. The 100% banana flour had the highest caloric value (386.46kcal/100g) while blend containing 50% African yam bean flour had the least value (385.84kcal/100g). The K, Ca and Mg decreased from 382.41mg/100g, 12.18mg/100g and 41.62mg/100g in the 100% banana flour to 345.96mg/100g, 8.93mg/100g and 33.12mg/100g in the 50% African yam bean flour blend, respectively. Conversely, the Na, Fe and Zn increased from 1.60mg/100g, 0.89mg/100g and 0.63mg/100g in 100% banana flour to 2.29mg/100g, 3.05mg/100g and 2.21mg/100g in the 50% African yam bean flour substituted blend, respectively. Oxalate, tannin, phytate and hydrogen cyanide contents increased with increase in African yam bean flour substitution. However, their values in the blended flours were low and would pose no threat to health. Blended flours exhibited higher water absorption, oil absorption, swelling and foaming capacities than the 100% banana flour. On the other hand, the bulk density decreased with African yam bean flour substitution. The study demonstrated that the nutritional quality and functional properties of unripe banana flour can be improved through supplementation with African yam bean flour.

Keywords: Unripe Banana Flour, African Yam Bean Flour, Supplementation, Physico-chemical Properties, Anti-nutrients

1. Introduction

Banana (*Musa spp.*) is one of the most popular fruits in the world and constitutes a major source of carbohydrate for millions of people in Africa, the Caribbeans, Latin America, Asia and pacific [1]. It is usually eaten either as supplementary food or as a whole meal. Bananas that are usually consumed fresh at full ripe stage are the most popular cultivars. The cooking types are usually referred to as plantain. In Nigeria, the unripe banana pulp is usually grated and used for the preparation of popular traditional complementary food called "oto mboro" for infants by the Efik and Ibibio ethnic groups. The green bananas are also boiled, fried or roasted and eaten

with palm oil, stew or vegetable soup. Processing of green bananas into flour is one of the means of post-harvest preservation of the crop. Nutritionally, banana pulp is rich in carbohydrate, vitamins A, B₆ and C, mineral elements such as potassium, magnesium, iron and phosphorus, but low in sodium and protein contents [2]. Green bananas contain a high amount of fibre and resistant starch fraction that cannot be digested in the small intestine [3]. Including food such as green banana that is high in resistant starch may reduce the risk of diabetes by aiding in blood sugar control. Green banana is a food of great value recommended for several pathological conditions especially for cases of gastrointestinal infection [1]. It is also recommended for salt free diets because of its low content of sodium chloride [4].

Protein-energy malnutrition in both children and adults is one of the major public health problems in most developing countries of the world [5]. This is sequel to the paucity of proteins from conventional animal sources such as milk, meat and egg which limits the low and medium income earners to carbohydrate based diets. Currently, increasing attention is focused on the utilization of the home grown legume crops with relatively high protein content as cheap sources of protein for the low income earners [6].

African yam bean (*Sphenostylis stenocarpa*) is one of the lesser – known and underutilized legumes of the tropics and sub-tropical areas of the world which has been attracting research interest in recent time [7]. It is called “nsama” in Efik and Ibibio local dialects of Nigeria. The smooth hard testa varies in seed size and colour. The colour of the testa varies from whitish and unmarked to various shades of brown, black, grey with speckling or marbling [8]. The seeds have high protein content ranging from 15.5 to 34.7% [9], and a fairly good source of amino acids [5, 6]. Amino acid analysis indicated that lysine and methionine levels in the seed protein are equal to or better than those of soybean [9]. The seeds are also rich in mineral elements such as potassium, calcium, magnesium, iron, zinc and phosphorus, but low in sodium and copper contents [8, 9]. Despite the excellent nutritive composition of the African yam bean seeds, their potentials in food formulation have not been fully exploited. Harnessing African yam seed products to fortify carbohydrate based diets would contribute to solving the problem of protein-energy-malnutrition prevalent in most of our communities. This study was aimed at assessing the effect of substituting unripe banana flour with dehulled African yam bean flour on the nutrients, anti-nutrients and functional properties of the flour blends.

2. Materials and Methods

2.1. Procurement and Preparation of Unripe Banana Flour

Local Variety of unripe banana bunches (“mboro ukom”) purchased from Itam market in Uyo metropolis, Akwa Ibom State, Nigeria were processed into flour following the steps described by Adeyemi *et al.* [10]. The fruits were removed from the bunches, washed, steamed at 100°C for 10 minutes, cooled, peeled, sliced (0.50cm width) and placed in water to minimize browning. The water was drained off, slices dried in a conventional air oven (model P.P. 22 US, Genlab, England) at 50°C for 24h, milled with manual grinder, sieved to pass through 200µm mesh screen, packaged in plastic container and stored at 4°C for subsequent use.

2.2. Procurement and Preparation of African Yam Bean Flour

The African yam bean seeds (black variety) were purchased from Ikot Ekpene market in Akwa Ibom State, Nigeria. The bean seeds were sorted to remove immature and infected seeds as well as other foreign materials. The seeds (5kg) were washed in potable water, soaked in 2% unripe plantain peel

ash solution (1:3w/v) for 15h at room temperature (27±2°C), drained off the soaked solution and washed with potable water. While washing, the seeds were rubbed in between the palms to decorticate them. The decorticated cotyledons were dried in a conventional air oven (model p.p. 22 US, Genlab, England) at 50°C for 24 hr, milled with manual grinder, sieved to pass through 200µm mesh screen, packaged in plastic container and stored at 4°C for subsequent use.

2.3. Preparation of Banana-Yam Bean Composite Flours

The unripe banana flour was substituted with levels of African yam bean flour. The ratios of banana flour to African yam bean flour used for this study were 100:00, 90:10, 80:20, 70:30, 60:40 and 50:50. The 100% banana flour served as the control sample.

2.4. Methods of Analysis

The protein, fat, ash and crude fibre were determined following the methods described in AOAC [11]. Carbohydrate was calculated by difference [12]. The caloric value was calculated using the Atwater factor method [13]. Mineral elements (K, Ca, Na, Mg, Fe and Zn) were determined using atomic absorption spectrophotometer (UNICAM, Model 939, UK) as described in AOAC [11]. Hydrogen cyanide (HCN), tannin and oxalate contents were determined by AOAC [11] methods. The method described by oberleas [14] was followed for the determination of phytate. The methods described by Abbey and Ibeh [15] were followed for the determinations of Water absorption capacity, oil absorption capacity and swelling index. The method described by Okezie and Bello [16] was followed for the determination of bulk density of the samples.

2.5. Statistical Analysis

Data obtained were subjected to One Way Analysis of Variance (ANOVA) using SPSS version 18 statistical package (SPSS, Inc., USA) to determine variation between treatments. Means of data generated were separated using Duncans Multiple Range Test (DMRT). Results were expressed as means ± SD (standard deviation) of triplicate determinations. Significant variation was accepted at $p < 0.05$.

3. Results and Discussions

3.1. Proximate Composition

Table 1 shows the proximate composition of 100% unripe banana flour (control) and unripe banana flour blended with different levels of dehulled African yam bean flour. The result shows that unripe banana flour is a rich source of carbohydrate (90.92%), but a poor source of protein (4.37%). The protein content of the unripe banana flour obtained in this study was within the range (1.8-6.8%) reported by Ayo-Omogie *et al.* [17]. The protein content of the flour blends significantly ($p < 0.05$) increased with increasing levels of African yam bean flour substitution ranging from 5.07% for 10% African yam

bean flour substitution to 14.05% for 50% yam bean flour substitution. On the other hand, carbohydrate content and caloric value decreased with increasing levels of African yam bean flour substitution in the blends. Similar decreases in the carbohydrate contents and caloric values of carbohydrate based foods fortified with legume flours have been reported by other authors [18-20]. The increased in crude protein content of the blends with increased levels of African yam bean flour substitution revealed high protein content of the African yam bean flour. The result suggests that significant

addition of African yam bean flour to unripe banana flour may be used to overcome protein-energy-malnutrition among the people. The fat and ash contents of the flour blends increased significantly ($p < 0.05$) while crude fibre increased marginally ($p > 0.05$) with increases in African yam bean flour substitution. Similar observations were reported for acha – cowpea flour blends [19, 21]. The low fat content of the 100% banana flour and blends of banana and African yam bean flour makes the product a good candidate for hypertensive patients and those that have fat related diseases like arteriosclerosis.

Table 1. Proximate composition of unripe banana and African yam bean flour blends (dry wt basis).

Blending Ratios (%) UBF : AYBF	Crude Protein (%)	Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)	Caloric Value (kcal/100g)
100 : 00	4.39 ^c ±0.03	0.58 ^b ±0.00	2.80 ^b ±0.10	1.31 ^a ±0.04	90.92 ^a ±0.20	386.46 ^a ±0.02
90 : 10	5.07 ^a ±0.11	0.66 ^b ±0.04	2.86 ^b ±0.00	1.38 ^a ±0.12	90.03 ^a ±0.01	386.34 ^a ±0.06
80 : 20	7.70 ^d ±0.00	0.74 ^b ±0.09	2.91 ^a ±0.05	1.46 ^a ±0.09	87.19 ^b ±0.14	386.22 ^a ±0.03
70 : 30	10.13 ^c ±0.03	0.87 ^a ±0.13	2.96 ^a ±0.08	1.61 ^a ±0.20	84.43 ^c ±0.07	386.07 ^a ±0.11
60 : 40	12.62 ^b ±0.06	0.92 ^a ±0.00	2.99 ^a ±0.05	1.70 ^a ±0.11	81.77 ^d ±0.00	385.84 ^a ±0.04
50 : 50	14.05 ^a ±0.12	0.98 ^a ±0.11	3.06 ^a ±0.02	1.79 ^a ±0.10	80.12 ^d ±0.03	385.50 ^a ±0.03

Values are Means ± SD (standard deviation) of triplicate determinations.

Means on the same column with different superscripts are significantly different at $p < 0.05$

UBF – unripe banana flour; AYBF = African yam bean flour.

3.2. Mineral Content

Table 2 depicts the effect of substituting unripe banana flour with levels of African yam bean flour on the mineral contents of the flour blends. The result shows that the two dominant minerals in 100% banana flour were potassium (382.41mg/100g) and magnesium (41.62mg/100g) while zinc content (0.63mg/100g) was the least in value. The values of K, Ca and Mg were significantly ($p < 0.05$) higher in the unripe banana flour than their values in the blended flours. The physiological roles of mineral elements in human diets have been documented ([12, 22]. The consistent reduction of K, Ca and Mg contents with increase levels of African yam bean flour substitution is an indication that African yam bean flour

had lower levels of these elements. Conversely, the Na, Fe and Zn contents in the blended flours were significantly ($p < 0.05$) higher than their values in the 100% banana flour. The values of Na, Fe and Zn contents in the blended flours consistently increased with increasing levels of African yam bean flour substitution. The sodium levels in the banana flour and the flour blends were low and ranged from 1.60mg/100g in 100% banana flour to 2.29mg/100g in 50% African yam bean flour substitution. Sodium intake needs to be monitored as it can become a major dietary culprit where high blood pressure problems are concerned. The low levels of sodium observed in the products make them suitable for use in sodium restricted diets.

Table 2. Mineral content of unripe banana and African yam bean flour blends (mg/100g).

Blending Ratios (%) UBF : AYBF	K	Ca	Na	Mg	Fe	Zn
100 : 00	382.41 ^a ±0.05	12.18 ^a ±0.01	1.60 ^b ±0.02	41.62 ^a ±0.06	0.89 ^d ±0.03	0.63 ^c ±0.00
90 : 10	369.52 ^b ±0.00	10.89 ^b ±0.04	1.94 ^b ±0.10	38.05 ^b ±0.00	1.45 ^c ±0.12	0.91 ^c ±0.16
80 : 20	361.19 ^b ±0.11	10.85 ^b ±0.00	2.08 ^a ±0.05	36.74 ^c ±0.00	1.72 ^c ±0.05	1.32 ^b ±0.10
70 : 30	356.03 ^c ±0.05	9.78 ^b ±0.00	2.13 ^a ±0.03	35.31 ^c ±0.11	2.26 ^b ±0.01	1.55 ^b ±0.11
60 : 40	350.27 ^c ±0.10	9.71 ^b ±0.05	2.20 ^a ±0.02	34.52 ^d ±0.04	2.83 ^b ±0.01	1.87 ^b ±0.05
50 : 50	345.96 ^d ±0.03	8.93 ^c ±0.11	2.29 ^a ±0.04	33.12 ^d ±0.11	3.05 ^a ±0.05	2.21 ^a ±0.12

Values are Means ± SD (standard deviation) of triplicate determinations.

Means on the same column with different superscripts are significantly different at $p < 0.05$

UBF – unripe banana flour; AYBF = African yam bean flour.

3.3. Anti-Nutritional Factors

The presence of anti-nutrients in foods could hinder the efficient utilization, absorption or digestion of some nutrients and thus, reduce their bioavailability [23]. The anti-nutrient contents in unripe banana flour (control) and composites of banana and African yam bean flour blends are shown in Table 3. The unripe banana flour had very low levels of oxalate

(0.64mg/100g), tannin (0.12mg/100g), phytate (trace amount) and hydrogen cyanide (trace amount). Similar low levels of tannin (0.28%), oxalate (0.51%), phytate ($4.5 \times 10^{-5}\%$) and cyanide ($8.0 \times 10^{-5}\%$) had been reported by Adeniji *et al.* [23] for BITA3 green banana hybrid. Substitution of unripe banana flour with different levels of African yam bean flour led to significant ($p < 0.05$) increases in the anti-nutrient contents

with increases in levels of African yam bean flour substitution. The levels of oxalate, tannin, phytate and hydrogen cyanide in the blended flours ranged from 1.13mg/100g, 0.54mg/100g, 0.39mg/100g and 0.16mg/100g for 10% African yam bean flour substitution to 3.17mg/100g, 1.54mg/100g, 2.37mg/100g and 0.73mg/100g for 50% African yam bean flour substitution, respectively. The consistent increase in oxalate, tannin, phytate and hydrogen cyanide contents in the

blended flours with increasing levels of African yam bean flour substitution could be attributed to the higher content of these anti-nutrients in the African yam bean flour [24] than in the 100% banana flour. However, the levels of these anti-nutrients in all the samples were relatively low and may not hinder the bioavailability of essential nutrients in the flours.

Table 3. Anti-nutrient content of unripe banana and African yam bean flour blends (mg/100g).

Blending Ratios (%) UBF : AYBF	Oxalate	Tannins	Phytate	Hydrogen Cyanide
100 : 00	0.64 ^c ±0.11	0.12 ^d ±0.04	ND	ND
90 : 10	1.13 ^d ±0.02	0.54 ^c ±0.13	0.39 ^d ±0.02	0.16 ^c ±0.04
80 : 20	1.68 ^e ±0.10	0.69 ^c ±0.01	0.83 ^d ±0.01	0.27 ^c ±0.06
70 : 30	2.20 ^b ±0.03	0.81 ^b ±0.06	1.36 ^c ±0.05	0.42 ^b ±0.11
60 : 40	2.74 ^a ±0.03	1.11 ^b ±0.11	1.94 ^b ±0.03	0.60 ^a ±0.05
50 : 50	3.17 ^a ±0.14	1.54 ^a ±0.02	2.37 ^a ±0.11	0.73 ^a ±0.02

Values are Means ± SD (standard deviation) of triplicate determinations.

Means on the same column with different superscripts are significantly different at $p < 0.05$. ND = not determined

UBF – unripe banana flour; AYBF = African yam bean flour.

Table 4. Functional properties of unripe banana and African yam bean flour blends.

Blending Ratios (%) UBF : AYBF	WAC (g/g)	OAC (g/g)	Bluk Density (g/cm ³)	Swelling Index (ml/g)	Foaming Capacity (%)
100 : 00	5.80 ^c ±0.28	7.02 ^a ±0.19	0.86 ^a ±0.04	0.96 ^a ±0.04	1.00 ^c ±0.00
90 : 10	5.95 ^{bc} ±0.21	7.15 ^a ±0.06	0.84 ^a ±0.07	0.98 ^a ±0.13	1.50 ^c ±0.17
80 : 20	6.05 ^{bc} ±0.21	7.21 ^a ±0.00	0.83 ^a ±0.08	1.00 ^a ±0.00	2.00 ^c ±0.21
70 : 30	6.35 ^{abc} ±0.07	7.29 ^a ±0.19	0.82 ^a ±0.11	1.04 ^a ±0.02	3.00 ^c ±0.15
60 : 40	6.40 ^{ab} ±0.21	7.38 ^a ±0.25	0.80 ^a ±0.09	1.10 ^a ±0.11	5.00 ^b ±0.04
50 : 50	6.85 ^a ±0.04	7.42 ^a ±0.19	0.79 ^a ±0.06	1.14 ^a ±0.05	8.00 ^a ±0.00

Values are Means ± SD (standard deviation) of triplicate determinations.

Means on the same column with different superscripts are significantly different at $p < 0.05$

WAC = Water absorption capacity; OAC = oil absorption capacity

3.4. Functional Properties

Table 4 depicts the effect of substituting unripe banana flour with levels of African yam bean flour on some functional properties of the flour blends. The blended flours exhibited higher water absorption, oil absorption, swelling and foaming capacities than that of the 100% unripe banana flour (control). The aforementioned functional properties increased with increasing levels of yam bean flour in the blends. Similar trends have been reported for maize-cowpea “kokoro” blends [25]. The increases in water absorption and oil absorption capacities of the flour blends ranged from 5.95g/g and 7.15g/g for 10% yam bean flour substitution to 6.85g/g and 7.42g/g for 50% yam bean flour substitution, respectively. The values for 100% banana flour were 5.80g/g for water absorption capacity and 7.02g/g for oil absorption capacity. The increases in water absorption and oil absorption capacities could be attributed to increase in protein content of the flour blends with increased in the level of yam bean flour substitution (Table 1). Henshaw and Sobowale [26] noted that the water absorption and oil absorption capacities are believed to be influenced by the nature and behaviour of seed macromolecules especially, protein. Nature of starch has also been found to have varying effects on water absorption capacity [27]. Adebawale *et al.*

[28] and Oladipo and Nwokocha [29] attributed high water absorption capacity to loose structure of starch polymers while low value indicates compactness of the structure. The high water absorption capacity of the flour blends is an indication that the flours will perform useful function in baked products during dough making stage. Iwe and Onadipe [30] reported that the ability of flour to absorb water improved dough making potentials. Fat improves flavour and increase the mouth feel of foods [31, 32] and this is a significant factor in food formulation.

There was no significant difference ($p > 0.05$) in the swelling capacity of the flour blends. Similar result was reported by Abegunde [25] for maize-cowpea “kokoro” blends. Finney [27] reported that swelling capacity affects the temperature at which product forms gel. Both water absorption and swelling capacities contribute to dough formation and stability [21]. High swelling capacity has been reported as part of the criteria for good quality product [33]. Both the 100% banana flour and the flour blends had low foaming capacity ranging from 1.00% for 100% banana flour to 8.00% for 50% African yam bean flour substitution. Foamability is related to the rate of decrease in the surface tension of the air-water interface caused by absorption of protein molecules [31, 34]. The bulk density of

the 100% banana flour was 0.86g/cm³. The bulk density marginally decreased ($p>0.05$) with increase in the levels of African yam bean flour substitution ranging from 0.84g/cm³ for 10% yam bean flour substitution to 0.79g/cm³ for 50% yam bean flour substitution. Bulk density is an indication of the porosity of a product which influences packages design and could be used to determine the type of packaging material required for the product. The observed decrease in bulk density with increase in yam bean flour substitution could be due to decreased in carbohydrate in the blends with increase in yam flour substitution (Table 1). Bhattacharya and Prakash [35] reported that bulk density of flour increased with starch content. The lower bulk density of the flour blends with increases in the levels of yam bean flour substitution would be an advantage in the use of the flour blends to formulate complementary food [30].

4. Conclusion

The findings of this study indicate that substituting unripe banana flour with levels of African yam bean flour (0-50%) had varying effects on the proximate composition, mineral contents, anti-nutrients and functional properties of the blended flours. The crude protein, fat, ash, crude fibre, Na, Fe, Zn, anti-nutrients, water absorption capacity, oil absorption capacity, swelling index and foaming capacity increased with increasing levels of African yam bean flour substitution. On the other hand, the carbohydrate, K, Ca, Mg, bulk density and calorific value decreased with increasing levels of African yam bean flour substitution. The levels of oxalate, tannin, phytate and hydrogen cyanide in all the samples were low and may not hinder the bioavailability of essential nutrients in the flours. The results revealed that the nutritional quality and functional properties of unripe banana flour could be enhanced through supplementation with African yam bean flour.

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