 

# Proximate and Functional Properties of Bambara Groundnut, African Arrowroot Lily and Soybean Flour Blends

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**Abstract**
This study determined the proximate and functional properties of bambara groundnut, African arrowroot lily and soybean flour blends. The flour blends were prepared in the ratios 90:5:5, 80:10:10, 70:15:15, 60:20:20, 50:25:25, 40:30:30 of Bambara groundnut, African arrowroot lily and Soybean respectively. They were blended in a 2L blender operated for 10mins at speed 3. The flour blends were stored in airtight containers until required. Proximate composition of the flour blends showed significant differences with increase in protein (22.09% to 30.58%), fat (8.16% to 12.94%), moisture (7.04% to 7.65%) and ash (1.83% to 2.56%) content while carbohydrate decreases (58.92% to 45.20%). The functional properties include bulk density (0.71g/ml to 0.96g/ml), water absorption capacity (21.36% to 53.66%), oil absorption capacity (48.63% to 79.85%), swelling power (32.56% to 33.52%), foaming capacity (21.66% to 45.27%) and emulsion capacity (42.65% to 74.26%). There was an improvement in the proximate and functional properties of Bambara groundnut, African arrowroot lily and Soybean flour blends; therefore, the flours could be adopted in complementary feeding to alleviate malnutrition.
**Keywords:** Proximate, Functional, Flour blends, African arrowroot Lily, Bambara groundnut, soybean

## INTRODUCTION

Malnutrition has been a major health problem in developing countries (Muller and Krawinkel, 2005). However, various efforts have been made to solve this problem through the introduction of new food sources and development of methods to increase utilization of less popular foodstuffs (Luchio *et al*., 2013). Most of the traditional foods consumed in Nigeria are deficient in protein and need to be incorporated with protein food sources such as soybean (36.94%) and bambara groundnut (19.94%) (USDA, 2010; Onoja *et al*., 2014). Soybean and bambara groundnut are underutilized legumes of West African origin with great potential for addressing the protein-energy malnutrition problem in Nigeria (Klu *et al*., 2001). They are also valuable sources of edible oil, minerals and vitamins and hence, occupy very important place in human nutrition.

African arrowroot lily (*Tacca involucrata*), a tuber crop that is widely distributed in most parts of the forest and Savannah region of Nigeria has also remained un-mechanized and underutilized (Igbabul *et al*., 2013). Little information is available on its properties. However, Iwuoha, (2004) reported its starch contents to be highly digestible and its flour being used as thickener in soup. According to Padulosi *et al.* (2008), neglected and underutilized crops could play prominent roles in improving nutritional status and sustaining the impoverished rural African populations. Therefore, blends of these underutilized food sources can be used in alleviating malnutrition if well harnessed. Hence, proximate and functional properties of bambara groundnut, African arrowroot lily (*Tacca involucrata*), and soybean flour blends is being considered in this study.

## MATERIALS AND METHODS

### Source of Materials

Bambara groundnuts and soybeans were purchased from Modern market, Makurdi. African arrowroot lily tubers were harvested from a local farm in *Ihugh, Vandeikya* Local Government Area of Benue State. All the chemicals used were of analytical grade.

### Sample Preparation

#### Preparation of African Arrowroot Lily (*Tacca involucrata*) Flour

The method described by Igbabul *et al*. (2013) was used with a little modification (i.e. without wet milling of samples). African arrowroot lily (*Tacca involucrata*) tubers were peeled, rinsed, sliced into cubes and soaked in a closed container for fermentation to take place within 72 hours. The cubes were later drained and oven dried at 60$^o$C for 10 hours. The dried cubes were milled into flour using hammer mill, sieved through a 250µm mesh size and then packed in an air tight container.

#### Preparation of Bambara Groundnut Flour

The method of Okafor *et al*. (2014) was used. Bambara groundnut was manually sorted and winnowed to remove stones, debris and defective seeds. Thereafter, soaked for 24 hours to ease removal of the outer coat, oven dried the seed for 8 hours at 60$^o$C, milled using an attrition mill and sieved through a sieve 250 µm mesh, then packaged in an air tight container prior to use.

#### Preparation of Soybean Flour

The method of Fabiyi (2006) was adopted. Soybeans were soaked (1:5 w/v) for 12 hours, cleaned and washed to remove the testas. Thereafter, oven dried for 8 hours at 60$^oC$, milled using an attrition mill and sieved through a 250µm mesh, then packed in an air tight container prior to use.

**Formulations of Flour Blends**

The flour blends were prepared in the ratios 90:5:5, 80:10:10, 70:15:15, 60:20:20, 50:25:25, 40:30:30 (Bambara groundnut:African arrowroot lily:Soybean). The flour blends were blended in a 2L blender (Philips Holland, model HR1702) operated for 10mins at speed 3 and stored in airtight containers until required.

**Table 1: Formulation of bambara groundnut, African arrowroot lily and soybean flour blends**

| | Composition (%) | | |
|---|---|---|---|
| Samples | Bambara groundnut flour | African arrowroot lily flour | Soybean flour |
| A | 100 | 0 | 0 |
| B | 90 | 5 | 5 |
| C | 80 | 10 | 10 |
| D | 70 | 15 | 15 |
| E | 60 | 20 | 20 |
| F | 50 | 25 | 25 |
| G | 40 | 30 | 30 |

**Proximate analyses of the flour blends**

Proximate composition including crude protein content, crude fiber, crude fat and ash were analyzed using the method described in AOAC (2010). Crude protein content was determined by estimating the nitrogen content using the Kjedahl method. Ash content was determined by incineration at 600$^oC$. Crude fat was determined by the Soxhlet method and the crude fiber was assayed by acid digestion and alkali digestion. Samples were analyzed in triplicate. Carbohydrate content was calculated by difference as shown below:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Protein} + \% \text{ Moisture} + \% \text{ Fat} + \% \text{ Fibre} + \% \text{ Ash}) \quad (1)$$

**Functional properties of the flour blends**

**Bulk density**

Bulk density was determined by the method described by Onwuka (2005). 10 mL capacity graduated measuring cylinder was filled gently with each sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level. Bulk density was calculated as shown below.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample after tapping (ml)}} \quad (2)$$

**Foaming capacity**

This was determined using the method described by Chandra and Samsher (2013). One gramme of flour sample was dispersed in distilled de-ionized water. The dispersed sample was whipped in with the aid of electric blending machine using a Braun Blender at 1600 rpm. The sample was whipped continuously for 8 minutes at ambient temperature. The foam volume was measured in 250ml measuring cylinder after the whipped sample was poured into it. The foam volume was expressed as a percentage of the volume occupied by the sample prior to whipping. The foaming capacity (FC) was calculated as:

$$\text{FC} = \frac{\text{Volume of foam after whipping} - \text{Volume of foam before whipping}}{\text{Foam Volume before whipping}} \text{ X } \frac{100}{1} \quad (3)$$

**Water absorption capacities**

This was determined using the method described by Onwuka (2005). One gramme of flour sample was weighed into 10ml of distilled water in a tared ml centrifuge tube and the tube capped. The capped tube was agitated on a wrist action shaker for 1 hour and centrifuged for 10 minutes ast 2,200 x g (approximately 7,500 rpm). The water was decanted and the tube tipped up to drain for 10 minutes. The centrifuge tube was weighed with the content and the amount of water held by the flour was determined by difference as:

$$\text{Water Binding Capacity } (\mathbf{WBC}) = \text{Gram bound water X } \frac{100}{1} \quad (4)$$

**Determination of Oil Absorption Capacity**

This was determined using the method described by Abu *et al.* (2006). One gramme of flour sample was mixed thoroughly by shaking with 5ml of grand soya oil in a conical flask. The mixture was allowed to stand for 30 minutes at room temperature (30 ± 2$^0C$) and then transferred into a graduated centrifuge tube. It was centrifuged at 500rpm for 30 minutes. The volume of oil absorbed (total volume-free volume) was multiplied by the density of the sample for conversion to gram. Absorption was expressed as grams of oil absorbed or retained per gram of sample. Oil absorbed = Total volume of oil - Free oil.

$$\text{OAC} = \frac{\text{Density of oil x Volume absorbed}}{\text{Weight of sample}} \quad (5)$$

**Determination of Emulsification Capacity**

This was determined using the method described by Chandra and Samsher (2013). One gramme of flour sample was blended with 10ml distilled water for 30 seconds in a Braun Blender at 1600 rpm. After complete dispersion, 10ml of grand soya oil was added from a burette and blending continued until there was separation into two layers-water and fat. Emulsifying capacity was expressed as ml of oil emulsified by 1g of flour.

$$\text{EC} = \frac{\text{Height of emulsified layer}}{\text{Height of whole solution in the centrifuge}} X \frac{100}{1} \quad (6)$$

**Statistical Analysis**

The mean and standard deviation of triplicate samples were determined. The data were subjected to the Analysis of Variance as prescribed by Abu *et al.* (2006), Means were significantly different were separated using the Duncan Multiple Range Test. Significance were accepted at $p < 0.05$.

## RESULTS AND DISCUSSION

**Results**

The proximate composition of Bambara groundnut, African arrow lily and Soybean flour blends are presented below (Table 2).

The moisture contents ranged from 4.52% to 12.31% where sample I had the lowest value and sample H had the highest value respectively. There was significant differences ($p<0.05$) among samples. Crude protein content ranged from 0.37% to 37.41% with sample H having the lowest value and sample I the highest value respectively. There were significant differences ($p<0.05$) among samples. Crude fat contents of the flour blends ranged from 1.44% to 18.06% with sample I having the highest value while sample H had the lowest value. There were significant differences ($p<0.05$) among samples. Ash content ranged from 0.12% to 4.18% where sample H had the lowest value and sample I had the highest value respectively while Crude fibre content range from 0.10% to 2.95% where sample H had the lowest value and sample I had the highest value respectively but there were no significant differences ($p>0.05$) among the samples. Carbohydrate content ranged from 32.89% to 85.66% with sample H having the highest value while sample I the lowest value respectively. The values showed significant differences ($p<0.05$) among the samples.

The functional properties of the flour blends are presented in Table 3. The various ranges for the parameters includes bulk density (0.71g/ml to 1.04g/ml), water absorption capacity (21.36% to 83.26%), oil absorption capacity (48.63% to 78.96%), swelling power (32.56% to 50.31%), foaming capacity (21.66% to 81.24%) and emulsion capacity (19.34% to 74.26%) for samples A to I respectively. There were significant differences ($p<0.05$) among the samples for all the parameters.

**Discussion**

The moisture contents of the flour blends decreased with increasing level of African arrowroot lily flour and soybean flour. The differences could be due to variations in drying kinetics between bambara groundnut, African arrowroot lily and soybean. The low moisture content of the flour blends would enhance its keeping quality. Similar observations were reported by Zaku *et al*. (2009). The increase in protein content may be attributed to the high protein content of soybean flour which was reported to be within the range of 35% – 48% (Enwere, 1998). The flour blends would be a good source of protein to children suffering from protein deficiency malnutrition. The increase in fat content may be due to incorporation of un-defatted soybean. Soybean being an oil seed plant has fat content of about 19g/100g (USDA, 2010). This would in turn increase the energy density of the flour blend and could retain in the stomach when consumed in product form for longer periods. Fat contents of the samples were similar to those reported by Ojimelukwe and Ayernor (1992) and Zaku *et al.* (2009). The ash content of a given food provides some insight to its mineral content and could also be employed as an index of fibrous contamination in flour products (Adewuyi and Abu, 2014). The increase in ash content might be indicative of increases in mineral content. This could also be an unintended additional benefit of African arrowroot lily to enhance the mineral content of food products. The carbohydrate content of 100% bambara groundnut flour showed the highest. Similar observation was reported by Yusuf *et al.* (2008) for bambara nut flour. However, the decrease observed could be the consequent result of increasing substitution level of soybean in the flour blends. Ukpabi *et al*. (2009) noted similar observation.

Functional properties are the physical and chemical characteristics of a product influencing its behaviour in food system during processing, storage, cooking and consumption. Bulk density is an important factor in determining the packaging requirement, handling and utilization during wet processing in food industry (Abioye, 2011). It also influences the amount and strength of packaging material; texture and mouth feel (Wilhelm *et al.* 2004). The decrease observed in bulk density of the flour blends is a desirable attribute for preparation of *akpekpa* which would enhance its paste thickness and ease dispersibility. This could be as a result of the reduced particle size of the flour blends. This is similar to the observation of Danbaba *et al.* (2014) where increasing level of cassava flour substitution in 100% rice flour decreases its bulk density. Therefore, low bulk density is advantageous in complementary feeding (Adebowale *et al.* 2008). Hence, the flour blends could be adopted for preparation of complementary foods. Water absorption capacity is the ability of the flour particles to entrap large amount of water such that exudation is prevented (Ezeocha *et al.*2011). It could also be an index of protein ability to absorb or retain water (Chima *et al.* 2009). The high water absorption capacity of the flour blends indicates higher polar amino acid residue of protein having an affinity for water molecules. The major chemical compositions that enhance the water absorption capacity of flours are proteins and carbohydrates, since these constituents contain hydrophilic parts, such as polar or charged side chains. Protein has both hydrophilic and hydrophobic properties thereby can interact with both water and oil in foods. Furthermore, exposure of the water binding site on the side chain groups of protein units previously blocked in a lipophilic environment might have as well led to the increase in water absorption capacity of the flour blends (Uwaegbute *et al.*2000). High water absorption capacity indicates better reconstitution ability of flour product. Oil absorption capacity is the ability of dry starch to physically bind fat by capillary attraction. The decrease observed could be due to the lipophilic characteristics of root starch. In addition, the increased fat content of the flour blends might have also resulted to its inability to absorb or retain more oil in its structure. Forming capacity of flour depends on the surface active properties of its proteins. The decrease in forming capacity might be due to increase in surface tension of the air and water interface leading to in-absorption of soluble protein molecules thereby limiting hydrophobic interactions. Similarly, it could be related to increase in the flour blends fat content. Lipids are known to destabilized foams by displacing proteins from the air-water interface (Kunze, 2005). Okpala *et al.* (2013) explained decrease in forming capacity on the basis of presence of globular proteins which makes denaturing of the surface difficult. Emulsion capacity indicates the amount of oil that can be emulsified by protein dispersion. Therefore, it depends on oil content and protein concentration of a product. The increase observed indicate high interaction between protein and fat content of the flour blends. Sikorski (2002) further explained that protein can emulsify and stabilize by decreasing surface tension of the oil droplet, providing electrostatic repulsion on the surface of the oil droplet. Swelling power is the spontaneous uptake of water by protein or starch matrix and the ability to hold the water in its structures before and during gelatinization (Whistler and Daniel, 1985). It further indicates the water binding capacity of the starch or mixture in a product; correlates with final product quality and as well provides an indication of the viscous load likely to be encountered by a mixing cooker (Ingbian and Adegoke, 2007). The increase in swelling power could be ascribed to high level interaction between water molecules and amylopectin fraction of the root starch granules resulting to high gel strength and elasticity of the flour blends.

**Conclusion**
The proximate and functional properties of the flour blends had an improvement over the unblended African arrowroot lily, soybean and bambara groundnut flour. Therefore, this flour blends could be adopted in complementary feeding and alleviating malnutrition in Nigeria. Also, food products such as confectioneries, baked products and breakfast meal like *Akpekpa* can be prepared from this blend. Therefore, this study has demonstrated that blends of underutilized crops can be used to produce good nutritional and functional flour product.

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**TABLE 2: Proximate Composition and free fatty acid content of bambara groundnut, African arrowroot lily and Soybean four blends**

| Parameters | A | B | C | Composition (%) D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| Moisture | 7.04$^{e}$ ±0.01 | 7.65$^{b}$ ±0.02 | 7.54$^{c}$ ±0.01 | 7.50$^{c}$ ±0.01 | 7.46$^{c}$±0.02 | 7.35$^{c}$±0.01 | 7.21$^{d}$±0.02 | 12.31$^{a}$±0.02 | 4.52$^{f}$±0.02 |
| Protein | 22.09$^{h}$±0.02 | 25.98$^{g}$±0.02 | 26.39$^{f}$±0.02 | 27.30$^{e}$±0.26 | 28.59$^{d}$±0.02 | 29.73$^{c}$±0.02 | 30.58$^{b}$±0.02 | 0.37$^{i}$±0.02 | 37.41$^{a}$±0.02 |
| Fat | 8.16$^{f}$±0.02 | 8.57$^{f}$±0.02 | 8.88$^{f}$±0.02 | 9.84$^{e}$±0.02 | 10.05$^{d}$±0.02 | 11.06$^{c}$±0.12 | 12.94$^{b}$±0.02 | 1.44$^{g}$±0.02 | 18.06$^{a}$±0.02 |
| Ash | 1.83$^{d}$±0.02 | 2.12$^{c}$±0.02 | 2.14$^{c}$±0.02 | 2.19$^{c}$±0.02 | 2.25$^{bc}$±0.02 | 2.54$^{b}$±0.02 | 2.56$^{b}$±0.02 | 0.12$^{e}$±0.02 | 4.18$^{a}$±0.02 |
| Crude fiber | 1.23$^{b}$±0.02 | 1.25$^{b}$±0.02 | 1.30$^{b}$±0.02 | 1.37$^{b}$±0.19 | 1.42$^{b}$±0.02 | 1.44$^{b}$±0.02 | 1.53$^{b}$±0.02 | 0.10$^{c}$±0.02 | 2.95$^{a}$±0.02 |
| Carbohydrate | 58.92$^{b}$±0.02 | 54.72$^{c}$±0.02 | 53.77$^{c}$±0.02 | 51.85$^{d}$±0.02 | 50.29$^{e}$±0.02 | 48.17$^{f}$±0.02 | 45.20$^{g}$±0.02 | 85.66$^{a}$±0.02 | 32.89$^{h}$±0.02 |

Values are means ± SD of triplicate determinations. Means with the same superscript within a row were not significantly different ($p > 0.05$).

A = 100% Bambara groundnut flour
B = 90% Bambara groundnut flour, 5% African arrowroot lily flour and 5% Soybean flour
C = 80% Bambara groundnut flour, 10% African arrowroot lily flour and 10% Soybean flour
D = 70% Bambara groundnut flour, 15% African arrowroot lily flour and 15% Soybean flour
E = 60% Bambara groundnut flour, 20% African arrowroot lily flour and 20% Soybean flour
F = 50% Bambara groundnut flour, 25% African arrowroot lily flour and 25% Soybean flour
G = 40% Bambara groundnut flour, 30% African arrowroot lily flour and 30% Soybean flour
H = 100% African arrowroot lily flour
I = 100% Soybean flour

**TABLE 3: Functional Properties of Bambara Groundnut, African Arrowroot Lily and Soybean flour blends**

| Parameters | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| BD (g/ml) | 0.71$^{b}$±0.02 | 0.99$^{a}$±0.02 | 0.98$^{a}$±0.02 | 0.98$^{a}$±0.02 | 0.97$^{a}$±0.03 | 0.97$^{a}$±0.02 | 0.96$^{a}$±0.02 | 1.04±0.02 | 1.04±0.02 |
| WAC (%) | 21.36$^{h}$±0.02 | 29.58$^{g}$±0.02 | 41.05$^{f}$±0.02 | 47.35$^{e}$±0.02 | 49.88$^{d}$±0.02 | 53.42$^{c}$±0.02 | 53.66$^{c}$±0.02 | 76.95±0.02 | 83.26±0.02 |
| OAC (%) | 79.85$^{a}$±0.02 | 48.63$^{d}$±0.03 | 44.25$^{e}$±0.02 | 39.78$^{f}$±0.02 | 36.24$^{g}$±0.02 | 34.26$^{h}$±0.02 | 30.58$^{g}$±0.02 | 66.75±0.02 | 78.96±0.02 |
| FC (%) | 21.66$^{g}$±0.02 | 45.27$^{c}$±0.02 | 36.04$^{d}$±0.02 | 29.34$^{e}$±0.02 | 26.51$^{f}$±0.03 | 21.54$^{g}$±0.02 | 16.54$^{h}$±0.02 | 78.56±0.02 | 81.24±0.02 |
| EC (%) | 74.26$^{a}$±0.02 | 21.43$^{g}$±0.03 | 26.54$^{f}$±0.02 | 29.77$^{e}$±0.02 | 34.97$^{d}$±0.03 | 38.22$^{c}$±0.02 | 42.65$^{b}$±0.02 | 19.34±0.02 | 21.05±0.02 |
| SP (%) | 32.56$^{d}$±0.02 | 15.36$^{g}$±0.02 | 18.76$^{h}$±0.02 | 21.45$^{g}$±0.02 | 24.85$^{f}$±0.02 | 27.66$^{e}$±0.02 | 33.52$^{c}$±0.02 | 43.62±0.02 | 50.31±0.02 |

Values are means ± SD of triplicate determinations. Means with the same superscript within a row were not significantly different ($p > 0.05$).

A = 100% Bambara groundnut flour
B = 90% Bambara groundnut flour, 5% African arrowroot lily flour and 5% Soybean flour
C = 80% Bambara groundnut flour, 10% African arrowroot lily flour and 10% Soybean flour
D = 70% Bambara groundnut flour, 15% African arrowroot lily flour and 15% Soybean flour
E = 60% Bambara groundnut flour, 20% African arrowroot lily flour and 20% Soybean flour
F = 50% Bambara groundnut flour, 25% African arrowroot lily flour and 25% Soybean flour
G = 40% Bambara groundnut flour, 30% African arrowroot lily flour and 30% Soybean flour
H = 100% African arrowroot lily flour
I = 100% Soybean flour

BD: Bulk density WAC: Water absorption capacity OAC: Oil absorption capacity FC: Foaming capacity
EC: Emulsion capacity SP: Swelling Power