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Comparative Analysis of the Proximate Composition, Amylose Content, Functional and Pasting Properties of Three Underutilized Legumes

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***Abstract*—This study was conducted in order to compare the proximate composition, amylose content, functional properties, swelling power and pasting properties of whole pigeon pea, lima bean and African yam bean flours using standard analytical methods. The proximate composition of the legume flours showed that the amount of moisture ranged from 6.43-7.24%; crude protein, 23.6-28.5%; crude fat, 1.42-2.48%; ash, 3.35-3.74%; crude fibre, 3.48-4.93%; and carbohydrate, 55.6-59.9%. The amylose contents of the legume samples were significantly different. African yam bean flour had the highest amylose content with 16.9±0.3%, while pigeon pea flour had the lowest value (14.8±0.0 %).Results showed that the mineral composition of the three legume flours differed significantly. Pigeon pea flour had the highest amount of most of the minerals analyzed (Na, K, Mg, Ca, P, Fe, Zn, Mn and Cu) ($P<0.05$) followed by lima bean flour. Except for sodium and manganese, African yam bean flour had the lowest mineral values of all the elements analyzed.Regarding functional properties, lima bean flour had the highest water absorption capacity (240±6%), while pigeon pea flour had the least (120±0%). There was no significant difference in the emulsion capacity value of the three samples. The least gelation concentration of the legume flours ranged from 6-10 with pigeon pea flour having the lowest value. Lima bean flour had the highest swelling power at 60, 70 and 95^{o}C while pigeon pea flour had the lowest swelling power at each temperature studied.Results of the pasting properties revealed that lima bean flour had the highest peak and final viscosity values (139±7 and 198±4 RVU), followed by African yam bean flour (128±2 and176±4 RVU) and pigeon pea flour (99.8±3 and 114±4RVU). The pasting temperatures of the three legume flours were not significantly different. The results obtained in the study showed that these legume flours could be used as functional ingredients in food systems.**

***Index Terms*—amylose,flour,legume, pasting properties, proximate composition,**

I. Introduction

Grain legumes are plants belonging to the family Fabaceae which are grown primarily for their edible seeds. These food legumes also known as pulses constitute an important foodstuff in tropical and subtropical countries [1] and have long played a key role in the traditional diets of people throughout the world. They are an excellent source of protein, dietary fiber, starch, micronutrients, and phytochemicals with low fat content[2]. Based on plant value and economy, grain legumes are classified into major and minor species. Major legumes are widespread and common in well-established cultivation, domestication and usage while minor legumes are less known, neglected and considered underutilized [3]. Pigeon pea (*Cajanuscajan* L.), lima bean (*Phaseoluslunatus* L.) and African yam bean (*Sphenostylisstenocarpa* Harms) are examples of underutilized legumes which are cultivated in African countries. These legumes can contribute significantly to food security because they are sources of nutrients and are also rich in bioactive compounds.

The pigeon pea (*Cajanuscajan*) is an erect, short-lived perennial leguminous shrub that usually grows to a height of about 1-2 m, but can reach up to 2-5 m high. It is grown widely in India and parts of Africa and Central America [4]. The fruit is a flat, straight and pubescent pod, 5-9 cm long x 12-13 mm wide. It contains 2-9 seeds that are brown, red, or black in colour, small and sometimes hard-coated [5][6].

The lima bean *Phaseoluslunatus* (Fabaceae) is a herbaceous bush, 30–90 cm in height, or a twining vine 2–4 m long with trifoliate leaves, white or violet flowers, and pods of 5–12 cm containing two to four seeds [7]. The lima bean is a tropical and subtropical legume cultivated for its edible seeds. It can be easily planted in tropical areas, and has been used for food [8][9].

African yam bean (*Sphenostylisstenocarpa* Hochst. ex. A. Rich Harms) is a climbing, annual herbaceous vine that attains a height of 1.5–3 m or more depending on the length of the staking materials and cultivar [10]. The crop is grown for its edible seeds and tuberous roots. AYB seeds are enclosed in pods measuring about 3–15 cm long, such that asingle pod can accommodate up to 30 seeds [11]. The seeds and tubers of AYB are highly rich in protein, minerals, and vitamins [12]. African yam bean is a crop of African origin, and is found in northeast, east, central, and west Africa [13].

Various researchers have reported the nutritional potential of these leguminous crops. Baiyeri et al.[14]; Ajibola and Olapade [15] Soetan and Adeola [16]have reported on the nutritional composition of African yam bean seeds; Yellavila et al. [17]; Palupi et al. [18] have given reports on lima bean seeds while Eltayeb et al. [19]; Olalekan and Bosede [20]have given scientific reports on the nutritional evaluation of pigeon pea seeds. Aside from traditional processing,

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legumes are also utilized to create flour with specific granulation that may be used in a variety of foods, such as mashed potatoes, soups, bread, pastries, and snacks [21]. They can also be used to enrich instant noodles[22][23] and pasta [24]. Moreover, apart from the nutritional compositions of these legumes which are usually considered before they can be used in food fortification, there is the need to have information about their functional and pasting characteristics. Functional properties are the intrinsic physicochemical characteristics of foods that affect product behaviour during and after processing [25] while pasting property is an index for predicting the ability of a food to form a paste when subjected to heat applications [26]. A flour sample's pasting properties are an important indicator of its processing quality. The present study was conducted to evaluate the proximate composition, amylose content, functional and pasting properties of pigeon pea, lima bean and African yam bean whole seed flours.

II. Materials and Methods

A. Sample Collection and Preparation

Pigeon pea, lima bean and African yam bean seeds were purchased from Ado Ekiti King's market in Ekiti State, Nigeria. Bad seeds and debris were removed from the purchased seeds. The cleaned seeds were rinsed with distilled water, dried in the oven at 40^{o}C, and pulverized. The powdered flour samples kept in airtight containers were labelled PPF (pigeon pea flour), LBF (lima bean flour), and AYF (African yam bean flour) before analysis.

B. Proximate Analysis

The proximate analysis of the legume flour sample for moisture, ash, crude fibre, fat and protein were carried out following the standard methods of AOAC [27]. Carbohydrate was determined by difference.

C. Amylose Determination

Amylose content was determined by using the procedure reported by[28]. 0.1g of sample was weighed into a 100 ml volumetric flask and then 1 ml of 99.7 % - 100 % (v/v) ethanol and 9 ml of 1 M sodium hydroxide (NaOH) were carefully added. The mouth of the flask was covered with parafilm and the content was mixed thoroughly. The sample was heated for 10 min. in a boiling water bath to gelatinize the starch and timing started when boiling began. The sample was removed from the water bath and allowed to cool very well, then made up to mark with distilled water and shaken thoroughly. Thereafter, 5 ml was pipetted into another 100 ml volumetric flask and 1 ml of 1 M acetic acid and 2 ml of iodine solution were added. The flask was topped up to the mark with distilled water. Absorbance (A) was read using a spectrophotometer at 620 nm wavelength. The blank contained 1ml of ethanol, 9 ml of sodium hydroxide, boiled and topped up to the mark with distilled water. Finally, 5 ml was pipetted into a 100 ml volumetric flask, 1ml of 1 M acetic acid and 2 ml of iodine solution were added and made up to the mark. This was used to standardize the spectrophotometer. The amylose content was calculated using Equation below:

$$Amylose\ (\%) \quad = \quad 3.06\ x\ A\ x\ 20$$

where A is the Absorbance value.

D. Determination of Minerals

Dry ashing of flour sample was carried out by using a muffle furnace at 550^{o}C. The ash obtained was dissolved in 100ml standard flask using distilled deionized water with 3 ml of 3M HCl. Sodium and potassium were determined by using a flame photometer (Corning, UK Model 405). Magnesium, calcium, iron, zinc, manganese, copper, cadmium and lead were determined by Atomic Absorption Spectrophotometer (Bulk Scientific, East Norwalk, CT, USA)[29]. The vandomolybdate colorimetric method was used to quantify the level of phosphorus in the flour sample.

E. Functional Properties

Water and Oil Absorption Capacities

1 g of the sample was mixed with 10 ml distilled water/oil (using a vortex mixer) for 30 s. The samples were then allowed to stand for 30 min. at room temperature. These were then centrifuged at 5000 rpm for 30 min. and the volume of the supernatant from each sample was noted in 10 ml graduated cylinder. Density of distilled water was assumed to be 1 g/ml and that of the oil was determined. Results were expressed on a dry weight basis [30].

Emulsifying properties

Emulsifying properties were determined by the method adopted by [31]with slight modification. 1% flour suspension was homogenized with 5 ml of refined oil. The emulsions were then centrifuged at 1,100 rpm for 5 min. Subsequently, the height of the emulsified layer and the total contents in the tube were determined. The emulsion capacity was obtained through the following calculation.

$$Emulsion\ Capacity(\%) = \frac{Height\ of\ the\ emulsified\ layer}{Total\ height\ of\ tube\ contents} x100$$

Emulsion stability was evaluated by heating the emulsion for 30 min at 80°C and centrifuging for 5 min at 1,100 rpm.

$$Emulsion\ Stability(\%) = \frac{\text{Height of the emulsified layer after heating}}{\text{Height of emulsified layer before heating}} x\ 100$$

Bulk Density

Flour sample was gently transferred into 10 ml graduated cylinder that was previously weighed. The bottom of the cylinder was gently tapped on a laboratory bench several times until no further diminution of the sample level was observed after it was filled up to the 10 ml mark. Bulk density is defined as the weight of the sample per unit volume of the sample (g/ml) [32].

pH Determination

The pH was determined at room temperature (30 ± 2 ^{o}C) by suspending 10g of the flour sample in 100 ml distilled water and measuring with Omega HPPX digital pH meter.

F. Swelling Power and Solubility

Swelling power and solubility of the flour sample was measured based on the method of [33] with slight modification. 1 g of sample was placed in a centrifuge tube and 10 ml of distilled water was added. The sample was equilibrated at 25°C for 5 min and then placed in a water bath at 60, 70, 80 and 90 °C for 30 min. The centrifuge tube with sample was then cooled at 20°C for 1 min and centrifuged at 3,500 rpm for 15 min to separate the gel and supernatant. The gel was weighed to determine swelling power.

$$\text{Swelling power} = \frac{(\text{Gel weight} + \text{container}) - (\text{Sample weight} + \text{container})}{\text{Sample weight}}$$

To determine solubility, the supernatant was placed in a petri dish and dried at 100°C for 4 h. The dried supernatant was weighed and the percentage solubility was calculated as given in the equation below

$$\%\ \text{solubility} = \frac{\text{Dry weight of supernatant}}{\text{Sample weight}} x\ 100\%$$

G. Determination of Pasting Properties

Flour pasting properties was evaluated by using the Rapid Visco Analyser model 3D+ (RVA) Newport Scientific, Australia). 3 g of sample was weighed into a weighing vessel. 25 ml of distilled water was dispensed into a new test canister. Sample was then transferred onto the water surface in the canister after which the paddle was placed into the canister. The blade was then vigorously jogged up and down through the samples ten times or more until no flour lumps remained on the water surface or on the paddle. The paddle was placed into the canister and both were inserted firmly into the paddle coupling so that the p addle is properly centred. The measurement cycle was initiated by depressing the motor tower of the instrument. The test was then allowed to proceed and terminate automatically [34]. Pasting properties which includes pasting temperature (PT), peak viscosity (PV), viscosity at trough (also known as minimum viscosity, TV), final viscosity (FV), breakdown (BV) (which is PV minus TV) and setback (SV) (which is FV minus TV) were recorded on the computer system attached to the Visco Analyser.

H. Statistical Analysis

All analyses were carried out in duplicates. Data collected were analyzed using Statistical Package For Social Sciences (SPSS) Version 25.0 software. Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) statistics were employed to test for significant difference among the subgroups at 0.05 level.

III. RESULTS AND DISCUSSION

Table 1: Proximate Composition (%), Amylose Content and Energy Value (kcal/100g) of Pigeon Pea, Lima bean and African yam bean Flours

Parameters	PPF	LBF	AYF
Moisture	6.43 ± 0.01^{b}	6.46 ± 0.06^{b}	7.24 ± 0.03^{a}
Crude Protein	23.6 ± 0.1^{b}	25.8 ± 1.4^{b}	28.5 ± 0.14^{a}
Crude Fat	1.42 ± 0.03^{c}	2.48 ± 0.06^{a}	1.84 ± 0.06^{b}
Ash	3.74 ± 0.06^{a}	3.44 ± 0.33^{a}	3.35 ± 0.07^{a}
Crude Fibre	4.93 ± 0.01^{a}	4.17 ± 0.05^{b}	3.48 ± 0.09^{c}
Carbohydrate	59.9 ± 0.1^{a}	57.7 ± 1.3^{ab}	55.6 ± 0.01^{b}
Energy	347 ± 1^{a}	356 ± 8^{a}	353 ± 5^{a}
Amylose	14.8 ± 0.0^{c}	15.7 ± 0.1^{b}	16.9 ± 0.3^{a}

Values are means of duplicate determination ± standard deviation. Values with different superscripts in the same row are significantly different in means at $p < 0.05$ level
PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

A. ProximateComposition and Amylose Content

Results of the proximate composition and amylose content of PPF, LBF and AYF are presented in Table 1. The level of moisture found in the legume flours ranged between 6.43% -7.24%. AYF had a significantly different value when compared with PPF and LBF. The low moisture contents of the legume flours would not promote microbial attack when properly stored. It has been suggested that the moisture content of flour should be lower than 13% to inhibit microbial growth [35].

The highest crude fibre value was found in PPF (4.93%) while the lowest was found in AYF (3.48%). Dietary fibre present in these samples is advantageous because it can lower serum cholesterol levels, and the risk of coronary heart disease, hypertension, constipation, diabetes, colon and breast cancer [36].

The level of the crude protein in AYF (28.5%) was the highest among the three legumes studied and this was followed by LBF (25.8%) and PPF (23.6%). The difference between the protein content of AYB and the other two samples was significant at $p < 0.05$. The results obtained in this study fell within the range of protein content (17-40%) in legume grains [37]. The protein value of AYB was slightly above the range of 22.72- 26.68 % obtained in the previous study by [15]; while the result for LBF was fairly above the range reported by[17]for five lima bean accessions (20.69-23.08%). The protein value of PPF agrees with the report of [38]. The protein content of these legume flours was much higher than in cereals (7–13%) [37], therefore they can be added to cereal-based foods as a composite to improve their nutritional composition and they can be used as an alternative source of protein to overcome protein malnutrition among children and adults in developing countries.

In the current study, low fat content was observed in all the legume flours, with AYF having the highest value (2.48%) and PPF the least value (1.42%). The fat content of these legumes were significantly different. Except for peanut and soybean which can be considered oilseeds [39], legumes generally have low fat contents. Most legumes have a range of 1-3% of crude fat [40]. The flours will be less prone to lipid deterioration because of their low fat contents.

Ash values of the analyzed legume samples varied from 3.44% in LBF to 3.74% in PPF and were not significantly different. The percentage ash value of PPF in the present study was in agreement with the literature report of [38] on the seeds of pigeon pea from varying distances (0.47-4.08%) while for AYF the value was slightly above 1.01-2.09 % range reported for five accessions of processed AYF by [15]. The percentage of ash in the sample gives an idea of the inorganic content of the samples [41].

The carbohydrate contents of these legumes which ranged from 55.6% in AYF to 59.9 % in PPF implied that they have the potential for providing energy for human beings and animals. The carbohydrate in AYF in the current study was fairly lower than the range found in five accessions of processed AYF (56.28-59.79%) [15]. For LBF, the value obtained was in the range of 54.31-59.64% as reported by [17]for five lima bean accessions. The result obtained for PPF was close to the reported value of 56.63g/100g [20].

The energy value of the legumes was between 347 and 356 kcal/100g and no significant difference was found among the three samples. Energy values obtained for PPF, LBF and AYF were within the range of energy values of Ethiopian chickpea varieties 322.58 to 388.10 (kcal/100 g) [42].

The apparent amylose contents of PPF, LBF and AYF were 14.8%, 15.7% and 16.9% respectively. These values differ significantly among the three legume flours. Amylose plays a very important role in the gelatinization and pasting properties of flour [43]. Amylose is also an important factor with regard to the end-use properties of various products such as noodles and dough [44],[26].

B. Mineral Profiles

The mineral profiles of PPF, LBF and AYF are shown in Table 2. Phosphorus (421-572mg/100 g) was the most abundant element in the three legumes studied and this was followed by potassium (394-463 mg/100 g) and calcium (141-244 mg/100 g). Yellavila et al. [17] reported that phosphorus was the prominent mineral in five lima bean accessions, although the range of value recorded (154.98-172.77mg/100g) was lower than the phosphorus content of LBF in the current study. Amarteifo et al. [45] recorded a higher concentration range for potassium 1845-1941mg/100g, but a lower concentration range for phosphorus 163-293mg/100g and calcium 120mg/100g in pigeon pea flour when compared with the result in the present study. Calcium and phosphorus are very important in the formation of strong bones and teeth, for growth, blood clotting, heart function and cell metabolism [46]. Potassium the principal cation in intracellular fluid, functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction, and cell membrane function [47].

Table 2: Mineral Profiles of Pigeon Pea, Lima Bean and African Yam bean Flours

Minerals (mg/100g)	PPF	LBF	AYF
Sodium	90.3±0.6^{a}	63.1±0.9^{c}	72.7±0.3^{b}
Potassium	463±4^{a}	423±4^{b}	394±6^{c}
Magnesium	66.6±0.3^{a}	60.8±0.6^{b}	58.5±0.6^{c}
Calcium	244±3^{a}	152±0^{b}	141±2^{c}
Phosphorus	572±1^{a}	542±2^{b}	421±1^{c}
Iron	6.87±0.1^{a}	1.95±0.06^{b}	1.94±0.05^{b}
Zinc	8.85±0.07^{a}	1.60±0.03^{b}	1.74±0.16^{b}
Manganese	4.41±0.01^{a}	1.16±0.03^{b}	0.64±0.01^{c}
Copper	2.78±0.03^{a}	1.15±0.07^{c}	1.76±0.06^{b}
Cadmium	ND	ND	ND
Lead	ND	ND	ND

Values are means of duplicate determination± standard deviation. Values with different superscripts in the same row are significantly different in means at $p < 0.05$ level

PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

The present report showed that sodium had the highest concentration in PPF (90.3 mg/100 g) and the least concentration in LBF (63.1 mg/100 g). This implies that PPF had a higher sodium value than the other two legume flours. Sodium is an important mineral element that aids the transmission of nerve impulses as well as the maintenance of the osmotic balance of the cells [48]. The concentration of magnesium in the legume flours ranged between 58.5 in AYF and 66.0 mg/100g in PPF. The concentrations of phosphorus, potassium, calcium, magnesium and sodium were significantly different in all three legume samples studied.

Results of the trace minerals present in the legume flours showed that the level of zinc, iron, manganese and copper present in PPF was higher than the level found in AYF and LBF. These microminerals are required in small quantities and they participate in various biochemical processes. For example, zinc is an essential trace element for protein and nucleic acid synthesis and normal body development [49] while iron helps in blood formation and the transfer of oxygen and carbon dioxide from one tissue to another [50]. The concentration of manganese and copper were significantly different in the flour samples, while the concentration of iron and zinc in PPF was significantly different from the concentration found in LBF and AYF.

Cadmium and lead were not detected in the flour samples. Even at low concentrations, cadmium and lead are known to be toxic and have no function in biochemical processes [51].

Table 3: Functional Properties of Pigeon pea, Lima bean and African yam bean Flours

Parameters	PPF	LBF	AYF
WAC (%)	120±0^{c}	240±6^{a}	200±14^{b}
OAC (%)	97.0±13^{b}	160±14^{a}	120±3^{b}
Emulsion Capacity	42.8±3^{a}	40.7±3^{a}	38.5±3^{a}

(%)			
Emulsion Stability (%)	82.4±2[a]	78.1±1[a]	72.4±2[b]
LGC (%w/v)	10.0±0.0[a]	6.0±0.0[a]	10.0±0[a]
Bulk Density (g/ml)	0.866±0.014[a]	0.867±0.002[a]	0.827±0.005[b]
pH	6.34±0.03[b]	6.28±0.01[b]	6.51±0.02[a]

Values are means of duplicate determination ± standard deviation. Values with different superscripts in the same row are significantly different in means at $p < 0.05$ level

PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

C. Functional Properties

Table 3 shows the functional properties of PPF, LBF and AYF. The water absorption capacity (WAC) significantly varied and ranged from 120-240%. The highest level of WAC was observed for LBF and the lowest for PPF. The difference in WAC of the legume samples may be due to the different hydrophilic carbohydrates in their components [52]. The high WAC reported in the present study for LBF and AYF suggests that these flours may be used in the formulation of some foods such as sausage, dough, processed cheese, baked products and soups [53]. The results of the oil absorption capacity (OAC) were in the range of 97.0-160% with PPF having the minimum value and LBF the maximum value. The OAC of legume flours is important for improving the mouth texture and maintaining the flavour of food products [32]. The result implies that LBF would be a better flavor retainer than AYF and PPF.

Emulsifying properties are useful functional characteristics that play an important role in the development of new sources of plant protein products for use as foods [54]. Emulsion capacity is the maximum oil required for water-oil phase separation [55]. Emulsion capacity was within 38.5 and 42.8 % range while the emulsion stability range was between 72.4 and 82.4% for the legume flours in this study. There was no significant difference among the emulsion capacity of the flours, however, there was a significant difference between the emulsion stability of AYF and the other two legume flours at $p<0.05$. The emulsion capacity of foods is associated with the amount of oil, and non-polar amino acid residues on the surface of the protein, water, and other components in the food [56].

The least gelation concentration of the samples ranged from 6.0 to 10.0 %. The lower the level of the least gelation concentration, the higher the gelating ability of the protein ingredient (Akintayo *et al.*, 2002) [57]. The result implied that the gelating ability of the protein in PPF was higher than in LBF and AYF.

The bulk density of the flours which ranged between 0.827-0.867 was higher than the reported bulk density for whole legume flour (0.543- 0.816 g/ml) by [32]. The results suggest that PPF, AYF and LBF can be used as thickeners in different food products because flours with high bulk densities (>0.7 g/mL) are used as thickeners in food products [58].

The pH values of the legume flours were in the acid range of 6.28 and 6.51 and comparable to the reported pH values of pea, chickpea and lentil whole flours (6.38, 6.41 and 6.52 respectively) [59] .

D. Swelling Power and Solubility

Figures 1 and 2 show the swelling power and solubility of PPF, AYF and LBF at different temperatures. LBF had the highest swelling power at 60, 70 and 95°C as seen in the figure, while PPF had the lowest swelling power at each temperature studied. The lower swelling power in PPF may be due to stronger bonding forces in the starch granules present in the flour. The high swelling power of LBF and AYF suggests that they would be valuable as a thickening and bulking agents in food industries.

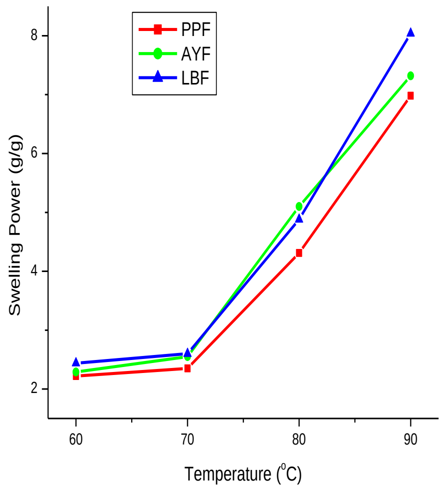

Figure 1: Swelling power of Pigeon pea, African yam bean and Lima bean flour
PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

Solubility is the ability of solids to dissolve or disperse in an aqueous solution [60]. LBF also had the highest solubility at 80 and 90°C but the values were lower than AYF at 60 and 70°C. High solubility has been associated with high content of amylose which is believed to leach out easily during the swelling process [61].

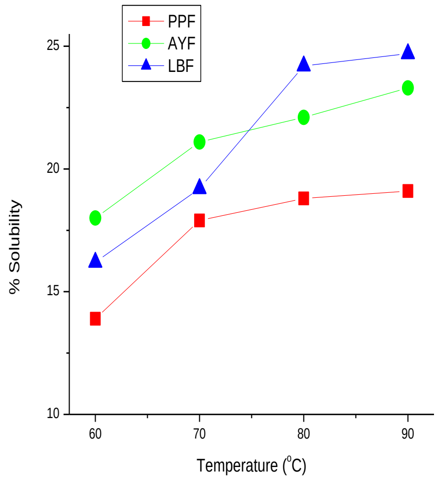

Figure 2: % Solubility of Pigeon pea, African yam bean and Lima bean flours
PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

E. Pasting Properties

The pasting characteristics play an important role in the selection of a flour variety for use in the industry as a thickener, binder, or for any other use [62]. The pasting properties of the three legume flours measured using the RVA are summarized in Table 4. The highest viscosity reached during heating or pasting is recorded as the peak viscosity (PV). The PV of the samples was in the range of 99.8 to 139 RVU with PPF having the lowest value while the highest value was found in LBF. The PV of LBF was not significantly different from AYF, but it was significantly different from PPF. The reason for the low PV observed in PPF when compared with the other legume flours may be a result of stronger bonding forces in PPF when compared with AYF and LBF. PV is an indication of the water-holding capacity of the starch or mixture thereof [63] and is often correlated with other quality properties of the sample. The high PV observed in LBF and AYF implies that these flours will form a thicker viscous gel on cooking and this would probably make them more suitable for products that require high gel strength.
The trough viscosity (TV) is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of the paste to withstand breakdown during cooling [64].TV values were significantly different among the three samples. However, the breakdown viscosity (BV) which measures the ability of the flour to withstand heating and shear stress during cooking [65] ranged from 6.70 -13.0 RVU and the values were not significantly different at $p < 0.05$. The low BV exhibited by the legume flours was an indication of their ability to withstand heating and shear stress that is usually encountered during processing and is an important factor for many processes, especially those requiring stable paste and low retrogradation/syneresis [66]. Final viscosity (FV) is generally used to determine the quality of starch-based flour as it implies the capability of the flour to form a viscous paste after cooking and cooling [67].

Table 4: Pasting properties of pigeon pea, lima bean and African yam bean flours

Pasting Parameters	PPF	LBF	AYF
Peak (RVU)	99.8 ± 3^{b}	139 ± 7^{a}	128 ± 2^{a}
Trough (RVU)	93.1 ± 3.5^{c}	128 ± 5^{a}	115 ± 5^{b}
Breakdown (RVU)	6.70 ± 0.65^{a}	11.0 ± 6.6^{a}	13.0 ± 6.6^{a}
Final Viscosity (RVU)	114 ± 4^{c}	198 ± 4^{a}	176 ± 4^{b}
Setback (RVU)	14.2 ± 1.1^{b}	59.0 ± 3.2^{a}	48.0 ± 5.8^{a}
Peak time (Min)	6.13 ± 0.28^{a}	5.87 ± 0.19^{a}	5.04 ± 0.0^{b}
Pasting Temp (°C)	52.2 ± 1.8^{a}	54.6 ± 6.2^{a}	53.2 ± 3.2^{a}

Values are means of duplicate determination ± standard deviation. Values with different superscripts in the same row are significantly different ($p < 0.05$)

PPF-Pigeon Pea Flour LBF- Lima bean Flour AYF- African yam bean Flour

There was a significant difference in the FV values obtained for the three samples. LBF had the highest FV value (198 RVU), followed by AYF and PPF with 176 and 114 RVU respectively.
The setback viscosity (SV) is the increase in viscosity resulting from the rearrangement of amylose molecules that have leached out from the swollen starch granules during cooling. The setback value of the samples analyzed in this study ranged from 14.2 to 59.0 RVU, with PPF having the lowest value. The setback value of LBF was not significantly different from AYF. Since a low setback value indicates a low rate of starch retrogradation and syneresis [68], the result implies that PPF had a low tendency of retrogradation when compared with AYB and LBF. Peak time is the time at which peak viscosity occurred in minutes [65]. The peak time was within the range of 5.04-6.13 min and there was no significant difference at $p < 0.05$ for the three samples. The pasting temperature (PT) indicates the minimum temperature required to cook flour [69]. The PT of the flour samples which ranged between 52.0 and 54.6 °C were not significantly different at $p < 0.05$. The results revealed that the samples will form a paste in water at a temperature below its melting point. Pasting properties are greatly influenced by plant source, starch content, interaction among the components, and testing conditions [70].

IV. CONCLUSION

The three legume flours had different proximate and mineral compositions, functional and pasting properties, which could influence their suitability for various food applications. The legume flours were found to be good sources of protein, with African yam bean having the maximum value. The presence of reasonable amounts of calcium, potassium, magnesium, phosphorus, and sodium in these legumes will help in the maintenance of human health when consumed. Lima bean flour had a high water absorption capacity, emulsion stability when compared with the other two samples.

The high peak viscosity observed in lima bean and African yam bean flours implied that these flours will form a thicker viscous gel on cooking, which would probably make them more suitable for products that require high gel strength. The low setback value of pigeon pea flour implied a low tendency for retrogradation.

The use of these legumes as complementary foods with cereals and their incorporation into processed foods such as pasta and noodles will boost the nutritional quality of the food products. This in turn would increase their demand and lead to an increase in production by local farmers. Cultivating these legumes in large quantities would therefore contribute to food security and financial stability.

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