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Comparative evaluation of the physicochemical and pasting properties of flour from three varieties of *Brachystegia* spp.

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The chemical compositions, functional and pasting properties of flour from three varieties of *Brachystegia* spp. (*Brachystegia eurycoma, Brachystegia nigerica* and *Brachystegia kennedy*) were studied. Results show that the chemical compositions of flour samples ranged from12.31 to 12.67% (protein), 1.66 to 1.72% (crude fiber), 2.06 to 2.39% (ash), 7.18 to 8.45% (fat), 3.85 to 4.75% (sugar) and 58.45 to 59.62% (starch). Functional properties such as water absorption capacity, oil absorption capacity, swelling power, solubility index, pH and amylose content were in the ranges of 80.14 to 80.77, 84.21 to 84.52, 15.64 to 15.78, 15.44 to 15.98, 5.48 to 6.74 and 20.42 to 20.69%, respectively. In addition, pasting properties values were 85.58 to 89.05°C (peak temperature), 128.54 to 133.45 (peak viscosity), 23.75 to 26.53 (trough viscosity), 419.6 to 449.5 (final viscosity) 53.5 to 59.0 (break down viscosity) and 402.6 to 413.4 (Relative value units, RVU) (setback viscosity). No significant difference ($p > 0.05$) was observed in the functional properties of the flours. The pasting profile showed that peak and hot paste viscosities are the key pasting parameters in characterizing flours from the three *Brachystegia* varieties. The variation in peak viscosity of the *Brachystegia* flours might be due to varietals and geographical influence. The study shows that *B. eurycoma* flour had the best functional and pasting properties results that could be exploited in food formulations such as soup, and sauces.

Key word: *Brachystegia* flour, variety, chemical composition, functional, pasting properties.

INTRODUCTION

There is a need to exploit the food and industrial potentials of *Brachystegia* spp. seeds. However, this requires prior information and understanding of desirable functional properties and the behavior of the material in systems during processing, manufacturing, storage, preparation as well as consumption (Sai-Ut et al., 2009). Over the past 30 years, the use of flour from legume seeds has been on the increase because of greater knowledge of their functional properties, processing and nutritive value (Kisambira et al., 2015). While historically, soy bean and cowpea have had a competitive advantage over other legume seeds, there is a need to identify, develop and explore other legume sources. The *Brachystegia* spp. offers such an unexploited opportunity. *Brachystegia* spp. an underutilized legume crop consumed in Nigeria is a seasonal woody plant mainly found along river banks or swamps in Western and Eastern Nigeria, as well as well drained soils. The crop is

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mainly used for soup making and timber. The gum also impacts certain desirable functional properties when added in other foods. *Brachystegia* spp. is a large tree with irregular and twisted spreading branches.

In Nigeria, there are three major species of *Brachystegia* which include *Brachystegia nigerica*, *Brachystegia eurycoma* and *Brachystegia kennedyi*. *B. nigerica* seed or leaf, (specify) is broad in size, round in shape, dark red in colour; has gummy husk which makes dehulling hard and is commonly found in Katsina, Adamawa in Northern Nigeria. *B. eurycoma* is medium in size, round in shape, dark brown in colour with less sticky husk which makes dehulling very easy. It is commonly found along river banks of the Southern Nigeria. *B. kennedyi* is commonly found in Eastern part of Nigeria. The seed is dark brown in colour, round in shape, broad in size with a gummy seed coat and this makes dehulling very hard. Okwu and Okoro (2006), reported that the fruit of *Brachystegia* spp. ripens from September to January and is released by explosive mechanism. In some states of Nigeria, *Brachystegia* spp. is called ‘achi’ in Igbo, “akalado” or “eku” in Yoruba; “akpakpa” or “apaupan” by the Ijaws and ‘dewen’ in Bini (Enwere, 1998).

The lack of information on many basic aspects of three major species of *Brachystegia* in Nigeria hinders their development, diversification and sustainable utilization. There is a need to get more information and understand the characteristics of these crops for their optimal use and application in areas food and allied industries. Therefore, the objective of this study was to determine the nutrient composition, and functional and pasting properties of flour from seeds of *Brachystegia* spp. The data would be of considerable values for food scientists, manufacturers and consumers regarding the selection of suitable *Brachystegia* spp. for preparation of good quality food product and also in the preparation of a much needed food composition table for Nigeria.

MATERIALS AND METHODS

Sample procurement and preparation

Brachystegia seeds samples of *B. nigerica*, *B. eurycoma* and *B. kennedyi* were purchased from Eke-Aba market in Abakaliki, Ebonyi State, Nigeria. The seeds were sorted to eliminate the bad ones. Cleaned seeds were conditioned to 25% moisture content by the addition of distilled water and held for 2 h with occasional stirring. The conditioned sample was sun dried to final moisture of approximately 10%. The dry seeds were dehulled for 2 min using a traditionally manufactured disc attrition mill (No1A Premier). The dehulled seeds were ground in an attrition mill and sieved with American standard sieve number 40 with aperture of 435 µm. The flour was packaged, labeled and stored in a refrigerator at 4°C until use.

Chemical analysis

Protein, fat, ash, crude fibre, starch, amylose and moisture contents were determined for the *Brachystegia* spp. flours. These analyses were carried out according to the AOAC official procedures (AOAC, 2000). The nitrogen was determined with a Kjeldahl method. The protein was calculated by Nitrogen x 6.25. Fat was obtained from 4h extraction with hexane. Ash was calculated from the weight remaining after heating the sample at 550°C for 2 h. Moisture was from the weight loss after oven drying at 110°C for 2 h. The total carbohydrates excluding crude fiber were calculated from the difference. The method of AOAC (2000) was also used to determine the sugar content.

Determination of functional properties

The method of Appiah et al. (2011) was used to determine the water and oil absorption capacities of the *Brachystegia* spp. samples. The swelling power and solubility of *Brachystegia* spp. flour samples were determined according to the methods described by Falade and Olugbuyi, (2010). The method of Xianqiao et al. (2015) was used to determine the amylose content.

Pasting properties determination

The pasting properties of defatted yam bean seed flours were analyzed with a Series 4 Rapid Visco Analyzer (RVA) (Newport Scientific from Australia) with Thermocline for Windows software. The analysis was done using standard one profile. The flour suspensions (6.72 g in 25.28 ml H_2O) corrected to 14% moisture content were exposed to the following time/temperature sequence: 50°C for 1 min, heating from 50 to 95˚C at 12.16˚C /min, maintained at 95°C for 2.5 min, and cooled from 95 to 50˚C at 11.84˚C/min rate. The apparent viscosity was expressed in relative value units (RVU).

Statistical analysis

All experimental analyses in this study were done in triplicates. All the data analysis was done using SPSS version 16.0 Software. Analysis of variance (ANOVA) was performed to generate treatment means and Least Significant Difference (LSD) ($P < 0.05$) values were used to separate the means.

RESULTS AND DISCUSSION

Chemical composition

The results of the chemical compositions of *Brachystegia* spp. are shown in the Table 1. The result showed that there were significant differences in all analyzed components of the seeds of *B. nigerica*, *B. eurycoma* and *B. kennedyi* except for crude fibre and moisture content. The results for crude protein and fat contents in this study are higher than those reported by Ajayi et al. (2014) for all the three species. The results in this study reveal that the levels of protein and fat of *Brachystegia* spp. seed flour are lower compared to that of other legumes like *Afzelia african*a which was reported to have 16.52 and 16.35% for crude protein and fat, respectively Ogunlade et al. (2011), and 21.88 and 23.38% (Igbabul et al. 2014). Kisambira et al. (2015) reported that yam bean flour had 32.16 and 24.14 g/100g crude protein and fat, content, respectively. The *B. kennedyi* flour had the lowest ash

Table 1. Chemical composition of three varieties of *Brachystegia* spp grown in Nigeria.

Variety	Fat percentage (%)	Protein percentage (%)	Ash percentage (%)	Moisture content percentage (%)	Fibre percentage (%)	Sugar percentage (%)	Starch percentage (%)	Carbohydrate content percentage (%)
B. nigerica	8.45[a]	12.45[a]	2.39[b]	10.86[a]	1.72[a]	3.85[c]	60.28[a]	64.13[a]
B.eurycoma	8.16[b]	12.31[a]	2.88[a]	11.35[a]	1.66[a]	4.12[b]	59.52[a]	63.64[b]
B.kennedyi	7.18[c]	12.67[a]	2.08[c]	12.22[a]	1.70[a]	4.75[a]	59.40a	64.15[c]

Values are mean values of triplicate determination. Values with the same superscript in the same column are not significantly different (p>0.05).

Table 2. Functional properties of three varieties of *Brachystegia* spp. grown in Nigeria.

Properties	Variety		
	B. nigerica	***B. eurycoma***	***B. kennedyi***
Water absorption capacity (%)	80.45[a]	80.77[a]	80.14[a]
Oil absorption capacity (%)	84.21[a]	84.52[a]	84.26[a]
Swelling power (%)	15.78[a]	15.66[a]	15.64[a]
Solubility index (%)	15.44[a]	15.89[a]	15.68[a]
Amylose content (%)	20.45[a]	20.74[a]	20.42[a]
pH	5.48[a]	6.74[a]	6.14[a]

Values are mean values of triplicate determination. Values with the same superscript in the same column are not significantly different (p>0.05).

content (2.08%) while *B. eurycoma* had the highest ash content of 2.88%. The ash content obtained in this study is lower than the reported value of 5.0% by Ajayi et al. (2014), and 3.5% for *B.eurycoma* by Uhegbu et al. (2009). The high ash content reflects the high mineral contents of *B. eurycoma*. Ogunlade et al. (2011), reported that *Pachira glabra* and *Afzelia africana* had ash content of 4.34 and 4.03% respectively, while melon seed had 3.3% (Peter-Ikechukwu et al., 2016).

Moisture in foods is actively involved in various metabolic reactions which determine the shelf life and microbial susceptibility of food items. The moisture content of *Brachystegia* samples showed that *B. kennedyi* had the highest moisture content (12.22%) while *B. nigerica* had the lowest (10.86%). The result of the moisture content in this study is in agreement with the one reported by Ajayi et al., (2014). However, the results of the three *Brachystegia* spp. are higher than the (3.21%) value of *Moringa oleifera* leaves reported by Ogbe and John (2012) but extremely lower than the 70.30 to 75.54 range value of some Nigerian pumpkins (*Cucurbita spp*) reported by Blessing et al. (2011). High amount of moisture in crops makes them vulnerable to microbial attack, hence, spoilage. Moisture value obtained in this study were within the range (9 to15%), implying that *Brachystegia* spp. would keep for a long period without spoilage especially in the tropics where wastage of crops is estimated to be around 50% due to high moisture content. The crude fiber content of *B. eurycoma* harms (17.20 ± 0.87) as reported by Ajayi et al. (2014) which was evidently higher than that of *Brachystegia* spp. as reported in this study (1.66 to 1.72%). The total carbohydrate, sugar and starch contents of the *Brachystegia* spp. ranged from 68.05 to 69.16%, 3.85 to 4.75%, and 59.45 to 59.62%, respectively. The difference in the proximate composition of *Brachystegia* spp. might be attributed to the difference in the geographical location, climate and agronomical practices.

Functional properties

Functional properties of food materials play a significant role in manufacturing, transportation, storage, stability, texture, taste and flavor of food products. These properties directly or indirectly depend on type, variety, particle size and chemical composition of flour and type of processing method (Nawaz et al., 2015). The functional properties of flours from three *Brachystegia* varieties are presented in Table 2. The ability to absorb water is a very important property of all flours used in food preparations. Water and oil absorption capacities (WAC, OAC) are useful indices of the ability of the protein in the material to prevent fluid loss from a product during food storage or processing (Kiosseoglou and Paraskevopoulou, 2011). The range of water absorption capacity (80.14 to 80.77%) observed for the different

Table 3. Pasting characteristics of three varieties of *Brachystegia* spp. grown in Nigeria.

Variety	P Temp (°C)	P Time (min)	PV (RVU)	TU (RVU)	FV (RVU)	BD (RVU)	SB (RVU)
B.nigerica	88.25^{b}	7.00^{a}	130.22^{b}	26.53^{a}	449.5a	59.0^{a}	413.4^{a}
B.eurycoma	85.58^{c}	5.13^{c}	133.45a	23.75^{c}	428.8^{b}	53.5^{c}	402.6^{b}
B.kennedyi	89.05^{a}	5.40b	128.54^{c}	25.61^{b}	419.6^{c}	56.8^{b}	405.4^{b}

Values are mean values of triplicate determination. Values with the same superscript in the same column are not significantly different (p>0.05). PV= peak viscosity; TU= Trough viscosity; FV= Final viscosity; BD= Break down viscosity; SB= Set back viscosity; RVU= Rapid viscosity unit.

Brachystegia spp. flours, analyzes was significantly the same (p ≥ 0.05). The *B. kennedyi* had the lowest (80.14%) water absorption capacity than flours from *B. nigerica* and *B. eurycoma*. These results are lower to those reported by Fekria et al. (2012) for defatted ground nut which ranged from 3.03 to 3.07 ml/g for two groundnut varieties. The consistency and stability of viscous foods such as soups entirely depend on WAC of starch and protein present in the flour. The observed water absorption capacity of *Brachystegia* spp. flours in this study might be attributed to their protein and starch contents (Table 1).

The oil absorption capacity (OAC) of the flours from *Brachystegia* varieties ranged from 84.21 to 84.52%. *B. eurycoma* had the highest level (84.52%) of oil absorption capacity while *B. nigerica* had the lowest value of OAC. The result of the oil absorption capacity of the flour samples exhibited no significant (p>0.05) difference from one other. The observed OAC values were lower than 2.87 and 2.93ml/g for defatted ground nut flour (Fekria et al., 2012) and 1.48 and 1.52 g/g for yam bean flour (Kisambira et al., 2015). The low OAC means that, the flour could be used as a coating in deep fat frying to reduce oil absorption by the fried food. The mechanism of oil retention is due to the physical entrapment of oil. Hence, the ability of food to absorb oil may help to enhance sensory properties such as flavour retention and mouth fell, therefore the flour from *Brachystegia eurycoma* may have a high degree of flavour retention and mouth feel.

The amylose content of *Brachystegia* varieties ranged from 20.42 to 20.69% with *B. eurycoma* having the highest apparent amylose content while *B. kennedyi* had the lowest level of amylose content. The amylose content obtained in this study are within the range of values (1.5 to 24%) as reported for rice by Xianqiao et al. (2015). The extractable starch and the amylose contents of the varieties were comparatively different. This observation suggests that the composition of Brachystegia spp is affected by variety and possibly by the location of where it is cultivated. The apparent amylose content of the *Brachystegia* samples were not significantly (p >0.05) different from each other.

The pH levels varied from 5.48 to 6.74. Such pH value of *Brachystegia* spp. shows that they are less acidic. Correlationship was observed between pH and solubility index and items inferring that an increase in the pH tends to increase the water solubility of the components in *Brachystegia* spp. This is true in general as far as the protein solubility is concerned. The pH level of the *Brachystegia* spp. flour samples did not vary significantly (p>0.05) with variety.

The swelling power is a measure of the ability of flour to imbibe water. Food eating quality is often connected with retention of water in the swollen starch granules (Sreerama et al., 2012). The swelling power ranged from 15.64 to 15.78%. *B. nigerica* flour had the highest value (15.78%) while *B. kennedyi* had the lowest (15.78%) value. The values in this study are higher than 0.98 to 1.64% reported by Yellavila et al. (2015) but lower than 2.87 ml/g for *Afzelia africana* (Igbabul et al., 2014). The samples were not significantly different (p>0.05) from each other in terms of swelling power. The *Brachystegia* spp. exhibited restricted swelling/solubility. Sanni et al. (2005) reported that, the swelling index of granules reflect the extent of associative forces within the granule, therefore the higher the swelling index, the lower the associative forces. The extent of swelling of the flour depends on the temperature, availability of water, species of starch, extent of starch damage due to thermal and mechanical processes and other carbohydrates (such as pectins, hemicelluloses and cellulose) and protein.

The solubility index of *Brachystegia* spp. ranged between 15.44 and 15.98%, with *B. eurycoma* variety having the highest value while *B. nigerica* had the lowest value. There was no significant difference (p > 0.05) in the solubility index of the samples. The low solubility index of the *B. nigerica*, might be due to its high amount of protein and fat contents that might have formed inclusion complexes with amylose.

Pasting properties of flours from three varieties of *Brachystegia*

The results of Rapid Visco Analyzer (RVA) of *Brachystegia* spp. flours are presented in Table 3. The processing characteristics of flours can be predicted by testing the rheological characteristics. The pasting properties of *Brachystegia* spp. flour samples namely peak viscosity, break down viscosity, final viscosity, trough viscosity, set back viscosity, peak time and pasting temperature were analyzed. There were significant differences ($p < 0.05$) in the pasting properties of *Brachystegia* spp. flour samples. The pasting property is important in predicting the behaviour of *Brachystegia* spp. paste during and after cooking.

The pasting temperature is a measure of the minimum temperature required for cooking a given food sample (Ikegwu et al., 2010). It is the temperature at the onset of starch granules swelling and increases in viscosity. The pasting temperature of the samples ranged from 85.58 to 89.05°C with *B. kennedyi* having the highest (89.05°C) pasting temperature while *B. eurycoma* had the lowest (85.58°C) pasting temperature. This implies that *B. eurycoma* flour can form paste in hot water below boiling point. This, at commercial level, is a remarkable cost saving. Varietal differences exist in the pasting temperature of the *Brachystegia* spp. flours at $p <0.05$.

Peak viscosity, which is the ability of starch to swell freely before their physical breakdown, ranged from 128.54 to 133.45 RVU. *B. eurycoma* flour had the highest peak viscosity value of 133.45 RVU and *B. kennedyi* flour had the lowest value of 128.54 RVU. The relatively high peak viscosity exhibited by *B. eurycoma* flour is an indication of high starch content (Table 1) which makes the flour more suitable for products requiring high gel strength and elasticity. Peak viscosity is often correlated with the final product quality and also provides an evidence of the viscous load which is likely to be encountered during mixing.

The trough is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand break down during cooling ranged between 23.73 and 26.53 RVU. *B. nigerica* flour had the highest trough value of 26.53 RVU and *B. eurycoma* flour had the lowest value of 23.73 RVU. Large values of trough viscosity indicate little breakdown of sample starches; this implies that *B. nigerica* will exhibit little breakdown compared to *B. eurycoma* and *Kennedyi* paste during cooling.

The final viscosity which indicates the ability of the starch-based food to form a viscous paste or gel after cooking and cooling ranged from 419.6 to 449.5 RVU. The flour sample from *B. nigerica* had the highest (449.5 RVU) final viscosity value and *B. Kennedyi* flour had the lowest (419.6 RVU) final viscosity. This implies that, *B. nigerica* flour might have the ability to form a viscous paste, while the paste formed from *B. kennedyi* flour maybe less viscous. Thus, consumers who prefer high viscous soup made from *Brachystegia* can use *B. nigerica* flour, while those who prefer less viscous soup can use *B. kennedyi* flour.

The breakdown viscosity which is an index of the stability of starch ranged between 53.50 and 59.00 RVU. The *B. nigerica* flour had the highest break down viscosity (59.0 RVU), while *B. eurycoma* flour had the lowest break down viscosity (53.50 RVU). The ability of a mixture to withstand heating and shear stress that is usually encountered during processing is an important factor for many processes especially those requiring stable paste and low retro-gradation (Adebowale et al., 2008). The higher the breakdown viscosity, the lower the ability of starch sample to withstand heating and shear stress during cooking. Hence, the flour sample from *B. eurycoma* might be able to withstand heating and shear stress.

The setback viscosity ranged from 402.6 to 413.4 RVU. Flour from *B. nigerica* had the highest (413.4 RVU) setback value while flour from *B. eurycoma* has the lowest (402.6 RVU). Lower setback viscosity during the cooling of the paste indicates greater resistance to retrogradation. Hence, *B. eurycoma* flour paste might indicate greater resistance to retrogradation. The peak time, which is a measure of the cooking time, ranged between 5.13 and 7.0 min. The *B. eurycoma* flour was highest with a value of 7.0 min while *B. nigerica* flour has d lowest.

Conclusion

Brachystegia spp flours differed significantly in their chemical composition and pasting properties, with fat, ash and sugar being the key component of variation in chemical composition of *Brachystegia* flour. *B. kennedyi* flour showed lowest peak and final viscosities. The highest setback viscosity value for *B. nigerica* flour indicated the higher tendency of this flour to retrograde. The variations in the functional properties of *Brachystegia* spp. flour were observed to be statistically the same ($p \geq 0.05$) among varieties. The swelling power of flour from *Brachystegia* varieties studied fall on the group of restricted swelling. This shows that they are good soup thickeners and might be used for the manufacture of value-added products such as composite blends, as they could meet the functional demands of the processors and nutritional requirements of the body of consumers. The study showed that *Brachystegia eurycoma* flour had the best functional and pasting properties results.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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