Effects of blending on the phytochemical, functional and proximate properties of *Mucuna solannie*-based composite flour

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Abstract: *Brachystegia eurycoma* (*BE*), *Afzelia Africana* (*AA*) and *Mucuna solannie* (*MS*) flour**s** were blended (%, w/w) at varying proportions: 50:50, 60:40, 70:30, 80:20 and 100:0, with 100% of flours as the control; then analyzed based on the phyto-chemical, functional and proximate compositions. Tanin, saponin, alkaloid and flavonoid values were 4.19, 1.47, 1.49 and 1.15 mg 100 g^{-1} dm; 3.44, 0.45, 1.34 and 1.13 mg 100 g^{-1} dm; and 4.1, 0.61, 1.36 and 1.18 mg 100 g^{-1} dm in *MS*, *AA* and *BE* flours respectively. Increased *AA* and *BE* proportions in *MS* flour increased the swelling index (1.49% -1.76%) whereas *AA* and *BE* inclusions (%) resulted in significant ($P \leq 0.05$) increase in the moisture content of the composite flours (8.3% - 14%). Increase in % *AA* flour inclusion resulted in significant improvement in carbohydrate content while % *BE* flour inclusion recorded a decrease. As % *BE* flour inclusion increased from 20% to 40%, % protein content in the blends significantly improved (15.65% - 16.25%) while % *AA* inclusion, increased protein content by 30%. The study could help to optimize the products made from *MS, AA* and *BE* flour blends, in terms of their properties than products made solely from single flour.

Keywords: phytochemical composition; postharvest processing; functional properties; proximate composition; *Mucuna solannie*; blending proportion; flour blends

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1 Introduction

Over the past 30 years, the use of composite flour from leguminous seeds for soup thickening or other culinary enhancement purposes has skyrocketed because of greater knowledge of their phytochemical potential, functional properties and high-quality nutritious values (Sathe and Salunkhe, 1981; Mbanali et al., 2018; Okorie and Ikegwu, 2018). Culinary enhancers are compounds added to foods in other to supplement or enhance its own natural properties, nutrient and appeal. Thickening agents, or thickeners, are substances which, when added to an aqueous mixture, increase its viscosity without substantially

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modifying its other properties.

The use of composite flour has been identified by researchers as means of reducing the huge cost of main choice soup thickeners (Nwosu, 2011). *Mucuna solannie* (*MS*), "Ukpo" is a tropical leguminous crop belonging to the sub-family, *Papilionaceace*. It is a flowering plant which has a high nutritional content. They are mostly climbing wooden vines that twine through the rain forest trees like botanical boa constrictors. *Brachystegia eurycoma* (*BE*), "Achi" is a tree crop with a large, flat crown of huge, twisted, widely spreading branches. It can grow up to 37 metres tall. The bole is irregular and usually branches from low down; it can be 70 – 200 cm in diameter. The tree is harvested from the wild for local use as a food and medicine, and also for its wood, which is used locally and also exported. It is suitable for use as a shade providing ornamental tree, especially in the dry season when it produces masses of coloured young foliage. *Afzelia Africana* (*AA*), "Akpalata" is also a leguminous crop belonging to the family of leguminosae. The crop is abundant in savannah region, fruiting between December and March (harmattan period) every year. Very small quantities of this seeds are traditionally used as condiment by few Nigerian communities while large quantities are allowed to waste in the fields. Traditionally, *MS* are choice ingredient and well-sought-after for culinary enhancement. However, due to cost constraints and several culinary considerations, *MS* flours are normally blended with *BE* and (or) *AA* as composite flours. These flours constitute some of the most profound economic culinary enhancing agents or food thickeners widely consumed in many tropical countries, due mainly to their thickening, emulsification, stabilization, drawability and spicing function/ flavoring capabilities (Igbe and Okhuarobo, 2018).

By including *BE*, *MS* and *AA flours* in human diet, at different proportions, have been well reported to have profound positive effects on their phytochemical and nutritional compositions of the food as well as the composite flours used in soup thickening. Scientific literature is well-stocked with data on acceptance of *MS, BE* and *AA* flours as culinary enhancing agents or food thickeners across Nigeria and the entire West Africa; their phytochemical properties, functional capabilities and proximate potentials (Chukwuma et al., 2019; Okorie and Ikegwu, 2018; Igbabul et al., 2012; Uhegbu et al., 2009). Despite the fore mentioned efforts, information gap still exist on the effects of blending on the composite flours/products.

Bridging this gap has become necessary with a view to providing in-depth information on its food value and explore their beneficial properties for culinary or food applications. It is, therefore, the objective of this study to first determine the phytochemical, functional and proximate properties of *MS*, *BE* and *AA* flours and then to study the effects of the degree of blending of *MS* flour with *BE* and *AA* on the different properties of the resultant composite flour/ product.

2 Materials and methods

2.1 Preparation of flour samples

The matured dried seeds of *Brachystegia eurycoma* (*BE*) or *Achi* (*AC*), *Afzelia africana* (*AA*) or *Akpalata* (*A*) and *Mucuna solannie* (*MS*) or *Ukpo* (*U*) were purchased from Ogbete Main Market, Nsukka, Enugu State, Nigeria. The seeds were sorted to remove extraneous materials, immature and malformed seeds and stored in air-tight plastic container at ambient temperature (37^{o}C) in other to avoid contamination, for subsequent use. Seeds (5 kg) of *BE* were roasted for 10-15 minutes, and then soaked immediately for at least 1 hour in cold distilled water and the coat removed. Thereafter, the white seed cotyledons were soaked overnight in distilled water, drained and sun dried (45^{o}C). The seed was ground into a fine powder (20 μm size) using a 5 horse power disc attrition mill (Krupp attrition grinder, Model 16409, Chowchilla, CA, USA) and the resultant flour was kept in air tight container for laboratory analysis (Uhegbu et al., 2009).

Matured and dried *MS* seeds (5 kg) were partially cracked manually using hammer, boiled for 45-60 minutes with distilled water, cooled, oven-dried and the cotyledons were milled to powder (20 μm size) using a disc attrition mill (Krupp attrition grinder, Model 16409, Chowchilla, CA, USA), sieved and kept in air-tight containers prior to laboratory analysis (Onuegbu et al., 2013). The seeds of *AA* (5 kg) was prepared according to the method by Chukwuma et al. (2019) with slight modifications. The waxy orange cup like structure at the base of the *AA* seeds were traditionally processed by being toasted at a temperature of 100°C for about 25 minutes until they started to crack open and the white endosperm turned crispy brown. The toasted seeds were cracked/ decorticated manually with the use of wooden pestle. The toasted endosperm was milled using a disc attrition mill (Krupp attrition grinder, Model 16409, Chowchilla, CA, USA); sieved with a sieve size of 20μm and sun-dried (24 hr) in other to obtain the *AA* seed flour. The flow chart for *AA*, *BE* and *MS* seed flour production is presented in Figure 1.

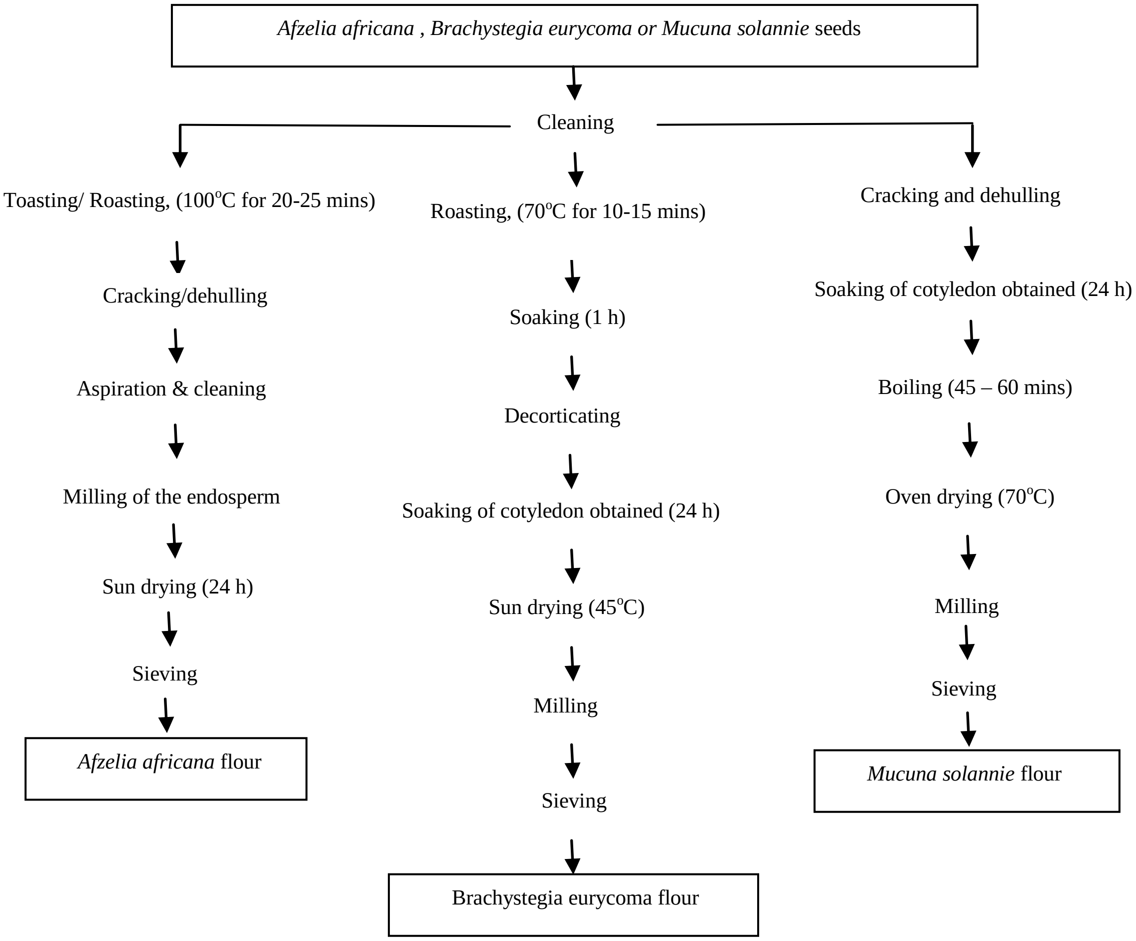


Figure 1 Flow chart for *Afzelia africana*, *Brachystegia eurycoma* and *Mucuna solannie* seed flour production

Experimental designs in completely randomizes design (CRD) with total observations of 231 (11 blending proportions × 7 levels of properties × 3 replications), 264 (11 levels of blending proportions × 8 levels of properties × 3 replications) and 198 (11 blending proportions × 6 levels of properties × 3 replications) for phytochemical analyses, functional properties and proximate composition respectively were conducted.The ground *MS* flour samples used for the study was blended with *AA* and *BE* flours at the percentage ratios of 50:50, 60:40, 70:30 and 80:20 and 100: 0 respectively. The phyto-chemical properties (alkaloids, flavonoids, tanins, phenols, saponins, glycosides and steroids), proximate composition and the functional properties (viscosity, water absorption capacity, oil absorption capacity, foaming capacity and emulsifying capacity, swelling index, wettability and water solubility index) were analysed.

2.2 Phytochemical composition

Alkaline precipitation-gravimetric method described by Harborne (1973) with slight modification was employed in determining the alkaloid content (AC). Flavonoid content (FC) was determined by the methods earlier described by Teixeira-Guedes et al. (2019) using aluminum chloride colorimetric method. Saponin and phenolic contents were determined according to the methods described by Obadoni and Ochuko (2001), Sharanagat et al. (2019) and Padhan et al. (2020). Steroids content was carried out using the method earlier described by Subhadhirasakul and Pechpongs (2005). Quantitative estimation of the tannins was carried out using the method described by Mohapatra et al. (2018) using a centrifuge at 5000 rpm for just 20 minutes. Glycoside content was determined according to the method reported by Ezeonu and Ejikeme (2016)

2.3 Functional properties

The viscosity of culinary flour was carried out using a RheoStress 6000 (Thermo Scientific, Karlsruhe, Germany).under frequency sweep test. Culinary sample pastes were prepared according to the method earlier described by Qian et al. (2020) using parallel stainless plate with a diameter of 35 mm and measuring gap between the plates fixed at 1 mm. The heating was maintained between 25°C to 90°C at 3.25°C min^{-1}, and holding at 90°C for 10 min, then cooled down to 25°C at 3.25°C min^{-1}; the angular frequency and strain amplitude was set at 1.0 Hz and 0.1%. Equations 1 and 2 were used to calculate the water absorption capacity (*WAC*) (%) and water solubility index (*WSI*) (%) respectively.

$$WAC = \left[{(M_1 - M_2)}\big/{M_2} \right] \times 100 \tag{1}$$

$$WSI = \left[{(M_0 - M_1)}\big/{M_0} \right] \times 100 \tag{2}$$

The mass of the sample, M_o (g) was added to the tube with weight, M_1 (g), and then a 2 cm^3 of rapeseed oil was added to it. At room temperature, the tube was centrifuged for 4000 rpm for 30 min. After removing the upper oil, the tube was reversed and drained. The mass of the tube (M_2) (g) was recorded. Oil absorption capacity (*OAC*) was calculated according to the expression in Equation 3

$$OAC = \left[{(M_2 - M_1 - M_0)}\big/{M_0} \right] \tag{3}$$

The volume of the foam produced was recorded and foaming capacity (FOC) (%) was calculated using Equation 4.

$$FOC = {V_a - V_b}\big/{V_b} \times 100 \tag{4}$$

Where, V_a is volume after whipping (cm^3) and V_b is volume before whipping (cm^3)

Emulsifying capacity (*EC*) was determined according to the method by Zhang et al. (2015) using a centrifuge, 2000 rpm for 15 minutes at 25°C. The EC (%) was calculated using Equation 5

$$EC = {V_e}\big/{V_c} \times 100 \tag{5}$$

Where, V_e is volume of emulsion layer (cm^3) and V_c is volume of liquid in the centrifuge tube (cm^3).

Swelling index (*SI*) of the culinary flour samples was evaluated by the method earlier reported by Mbanali et al. (2018) and calculated using Equation 6.

$$SI = {V_a}\big/{V_b} \times 100 \tag{6}$$

Where, V_a is volume occupied by sample after swelling (cm^3) and V_b is volume occupied by sample before swelling (cm^3).

In determining the wettability, 1 g of the sample was placed in a 25 cm^3 graduated cylinder with a diameter of 1 cm. A finger was placed over the open and the cylinder was inverted and clamped at a height of 10 cm from the surface of a 600 cm^3 beaker containing 500 cm^3 distilled water. The finger was removed to allow the materials to be dumped and the time required of the sample to become completely wet was recorded.

2.4 Proximate composition

The proximate compositions were determined according to the method of AOAC (2010). Carbohydrate content was determined by difference.

2.5 Statistical analysis

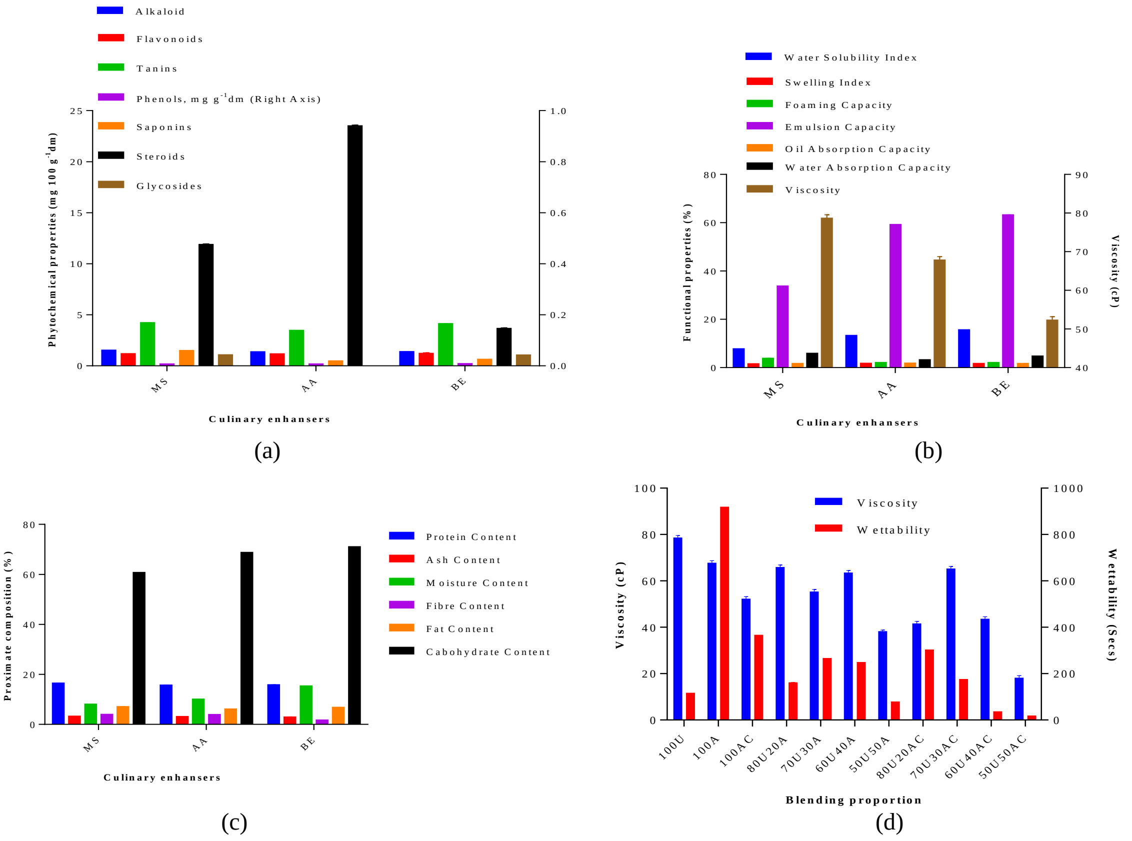
Data was analyzed and expressed as mean values with standard deviations by using descriptive and inferential statistics with IBM SPSS version 23, Prism Graph 6 and Excel, windows 10 packages. Two-way analysis of variance (ANOVA) in statistical analysis was performed to determine significant differences amongst means. When significant differences ($p < 0.05$) were found, results were compared using a post-hoc F-test and presented in a Duncan Multiple Range Test (DMRT) format.

3 Results and discussion

The results for blending proportions of samples were coded and defined as shown: 100_{U} represent 100% *Ukpo* (*MS*); 100_{A} represents 100% *Akpalata* (, *AA*); 100_{AC} represents 100% *Achi* (*BE*); $80_{U}20_{A}$ is 80% *Ukpo* (*MS*) and 20% *Akpalata* (*AA*); $70_{U}30_{A}$ is 70% *Ukpo* (*MS*) and 30% *Akpalata* (*AA*); $60_{U}40_{A}$ is 60% *Ukpo* (*MS*) and 40% *Akpalata* (*AA*); $50_{U}50_{A}$ is 50% *Ukpo* (*MS*) and 50% *Akpalata* (*AA*); $80_{U}20_{AC}$ represents 80% *Ukpo* (*MS*) and 20% *Achi* (*BE*); $70_{U}30_{AC}$ represents 70% *Ukpo* (*MS*) and 30% *Achi* (*BE*); $60_{U}40_{AC}$ represents 60% *Ukpo* (*MS*) and 40% *Achi* (*BE*); $50_{U}50_{AC}$ represents 50% *Ukpo* (*MS*) and 50% *Achi* (*BE*).

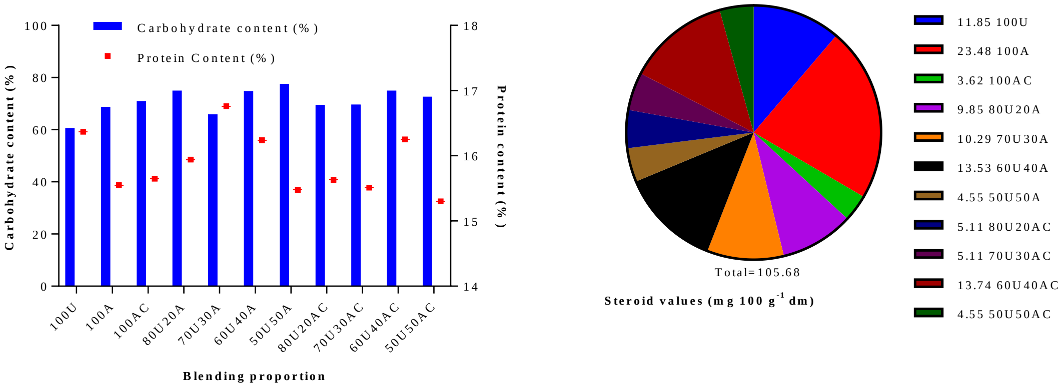
3.1 Effects of blending proportions on the phytochemical properties

Figure 2(a) shows that *BE*, *AA* and *MS* flours are rich in phytochemicals, which varied with the seed flours. Significant differences ($p \leq 0.05$) exist between the phytochemical properties and all the seed flours investigated. The steroids values in all the culinary enhancing agents (control) were generally higher, followed by tannin values. Steroid values in *AA* (23.48 mg 100 g^{-1} dm) and *MS* (11.89 mg 100 g^{-1} dm) were significantly higher than that of *BE* (3.62 mg 100 g^{-1} dm). Tanin, saponin, alkaloid and flavonoid values were 4.19, 1.47, 1.49 and 1.15 mg 100 g^{-1} dm; 3.44, 0.45, 1.34 and 1.13 mg 100 g^{-1} dm; and 4.1, 0.61, 1.36 and 1.18 mg 100 g^{-1} dm in *MS*, *AA* and *BE* respectively. Tannin values were close to the values of 4.19, 4.11 and 3.55 mg 100 g^{-1} dm earlier reported by Okorie and Ikegwu (2018) for *MS*, *BE* and *AA* flours respectively.



(a) (b)

(c) (d)



(e) (f)

Phytochemicals (a), functional (b), proximate (c) compositions of *Brachystegia eurycoma* (*BE*) or *Achi* (*AC*), *Afzelia africana* (*AA*) or *Akpalata* (*A*) and *Mucuna solannie* (*MS*) or *Ukpo* (*U*) flours and effects of blending proportion on viscosity and wettability (d); carbohydrate and protein content (e); and steroid values (f)

Figure 2 Effects of blending proportions on the phyto-chemical properties

Phenolic content value was generally the least property recorded in the flours of *MS* (0.14 mg g^{-1}), *AA* (0.16 mg g^{-1}) and *BE* (0.18 mg g^{-1}) (Figure 2). Similar low values (0.146% – 0.154%) were also earlier reported by Onuegbu et al. (2013) for *MS* flour. The presence of some phytochemicals shows that flours may have medicinal, pharmaceutical and industrial applications for the production of drugs, foods and supplements.

Blending had significant effects (*P≤0.05*) on the phytochemical properties of the composite flour. Tannin values were significantly higher in all the blends. 70% *MS* and 30% *AA* (70_U30_A) recorded the highest values of tannins (5.1 mg 100 g^{-1} dm) whereas 60% *MS* and 40% *BE* (60_U30_{AC}) had the lowest value (3.2 mg 100 g^{-1} dm). Blending 70% *MS* with 30% *AA* (70_U30_A) significantly increased the values of tannins in the resultant composite flour by 410% (4.19 - 5.1 mg 100 g^{-1} dm). Saponins (3.31 mg 100 g^{-1} dm), alkaloids (1.67 mg 100 g^{-1} dm) (Figure 3), flavonoids (2.91 mg 100 g^{-1} dm) and glycosides (1.057 mg 100 g^{-1} dm) achieved their highest values in 80_U20_{AC}, 60_U40_{AC}, 60_U40_A and 70_U30_A blends respectively and their lowest values of 2.33 mg 100 g^{-1} dm, 1.26 mg 100 g^{-1} dm, 1.4 mg 100 g^{-1} dm and 1.013 mg 100 g^{-1} dm in blends of 80_U20_A, 70_U30_{AC}, 70_U30_{AC} and 50_U50_{AC} respectively.

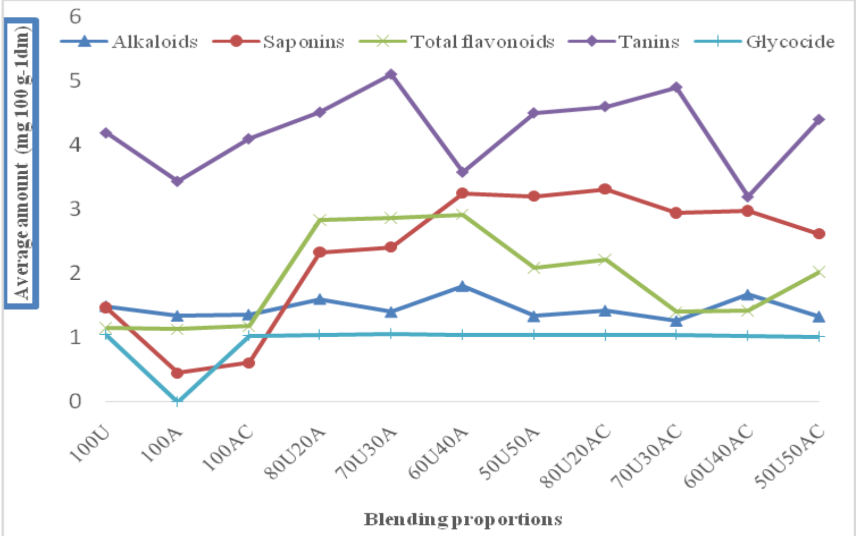


Figure 3 Change in phytochemical properties of *Brachystegia eurycoma* (*BE*) or *Achi* (*AC*), *Afzelia africana* (*AA*) or *Akpalata* (*A*) and *Mucuna solannie* (*MS*) or *Ukpo* (*U*) flours with blending proportions.

When 60% *MS* was blended with 40% *AA*, the values of steroids in the composite flour were enhanced from 11.85 (control) to 13.53 mg 100 g^{-1} dm (Figure 2(f)). Similarly, the value of steroids in *BE* in the composite flour was beefed-up from 3.62 to 13.74 in 60_U40_{AC} blend (Figures 2(a), 2(f)). However, this was not the case with AA which had a significant reduction ($P\leq0.05$) in steroids values (23.48 – 13.53 mg 100^{-1} dm) in 60_U40_A blend (Figure 3). Most of the plant parts used in the cure of diseases have been reported to contain traces of alkaloids. Alkaloids and their synthetic derivatives are used as a basic medicinal agent for its analgesic, antispasmodic and bacterial affects (Okwu, 2005). Flavonoids have been reported to act as an antioxidant to many biological systems, act as protection against allergies, inflammation, free radicals, platelet aggregation, microbes, ulcers, hepetoxins, viruses and tumours (Okwu and Ndu, 2006). Phenolic compounds from plant extracts act as an antimicrobial agent (Ofokansi et al., 2005). The darkening of soup is due to the oxidation of phenolic constituents, especially o-hydroxy or trihydroxy phenolics, by a phenol oxidase present in the tissue of plant based culinary enhancing agents (Toivonen and Brummell, 2008).

3.2 Effects of blending proportions on the functional properties

Functional properties of foods or flours are parameters used to access its application and end use (Adeleke and Odedeji, 2010). They usually indicate how such food or flour will interact with other components, thereby affecting their processing applications, food quality, and ultimate general consumers' acceptance. Figure 2(b) shows the functional properties of 100% flours (control) for *MS*, *AA* and *BE*. Significant ($P\leq0.05$) differences were seen in some of the functional properties of *MS*, *AA* and *BE* flours. Functional properties varied with the three culinary seed flours investigated (Figure 2(b)). The viscosity values of 100% *MS* flour (78.5 cP) (control) was significantly ($P\leq0.05$) higher than those of 100% *AA* (67.74 cP) and *BE* (52.2 cP) flours (control) (Figure 2(d)). The EC and the WSI values for the *MS*, *AA* and *BE* flours were 33.64% and 7.64%; 59.0% and 13.2%; and 63.11% and 15.49% respectively. The SI, FOC, OAC, WAC and wettability for 100% *MS*, *AA* and *BE* flours were 1.42%, 3.7%, 1.54%, 5.8% and 116 sec; 1.65%, 1.97%, 1.7%, 3.11% and 919 sec; and 1.58%, 1.94%, 1.57%, 4.63% and 366 sec respectively (Figure 2(b) and Table 1). Relatively similar values of WAC (5.2%), OAC (1.37%), EC (42.65%), FOC (0.9%) and SI (1.31%) for *MS* flour had also been documented Okorie et al. (2013) while Nwosu (2011) also reported ranges of *MS* values of 45-72 secs, 50.1-75.5 cP and 7.19%-9.9% for wettability, viscosity and *SI* respectively, under different storage conditions.

Table 1 presents the functional properties of various blends of *BE*, *AA* and *MS* flours. WSI, SI, FC, EC, OAC and WAC vary with blending proportions. WSI was highest in 80_U20_{AC} (80% *MS* and 20% *BE*) blend (14.53%) and minimum when 80% of *MS* was blended with 20% *AA* (80_U20_A) (8.11%). The minimum value of (8.11%) obtained was not significant ($P\geq0.05$) to values obtained in 70_U30_A (8.17%) and 50_U50_A (8.13%) blends. The maximum value of WSI obtained in 80_U20_{AC} blend was significant different from values gotten in 80_U20_A (8.11%), 60_U40_A (8.81%), 60_U40_{AC} (13.44%) and 50_U50_{AC} (13.42%) blends respectively, but however not significant to the value of 14.01 obtained in 70_U30_{AC} blend. It is obvious that blending *MS* with *AA* increased the WSI of the composite flours whereas doing same with *BE* decreased the WSI.

Blending *MS* with *AA* and *BE* at different proportions significantly ($P\leq0.05$) affected the *SI* of the resultant flours. Increased % proportions of *AA* and *BE* in *MS* flour increased the *SI* values. *SI* values of 1.49% in (80_U20_A) blend was significant (($P\leq0.05$)) to those of 1.69%, 1.76%, 1.52%, 1.57%, 1.75% and 1.76% in 60_U40_A, 50_U50_A, 80_U20_{AC}, 70_U30_{AC}, 60_U40_{AC} and 50_U50_{AC} blends respectively. The *SI* value in 100% *BE* flour (control) was not significant ($P\geq0.05$) to the value in 70_U30_{AC} blend (1.57%). Similarly, *SI* values in 60_U40_{AC} (1.75%) and 50_U50_{AC} (1.76%) were statistically ($P\geq0.05$) the same.

There were significant differences ($P \le 0.05$) in the *FOC* values in *MS*, *BE* and *AA* blends. Generally, all the flours had low *FOC*. The maximum value of *FOC* was obtained when 30% of *AA* was incorporated into 70% *MS* (70_U30_A) (3.54%). However incorporating *AA* into *MS* reduced the *FOC* of *MS* in the composite flour from 3.7% (control) to 3.52% and increased the *FOC* value of *AA* in the composite flour from 1.97% (control) to 3.54%.

Blending significantly ($P \le 0.05$) affected the *EC* for *MS*, *AA* and *BE* flours. *EC* in *MS* flour varied from 33.64% (control) to 40% (50_U50_A) while that of *BE* decreased from 63.11% (control) to 43% (80_U20_{AC}).

Blends of *MS*, *AA* and *BE* absorbed more water than oil. Significant differences (($P \le 0.05$)) in means of *WAC* and *OAC* exist amongst the blends. The composite blends (except 50_U50_{AC}) had greater water and oil absorption capacities than 100% *MS*, *BE* and *AA* flours. These properties may give an advantage to the blends relative to *MS*, *BE* and *AA* flours in soups, stews and supplement making where hydration to improve handling characteristics is required and in products where oil holding property is an important consideration (Akubor and Chukwu, 1999). *MS* flour (control) had the lowest *OAC* (1.54%) while *AA* flour (control) had the highest (1.7%). Conversely, *MS* flour had twice the capacity to retain water (5.8%) than *AA* flour (3.11%). High protein content of *MS* and *BE* flours showed their ability to absorb more water than *AA* flour. Protein absorb up to 200% of its weight whereas carbohydrate absorbs only 15% of its weight (Akubor and Ukwuru, 2003). The *OAC* in the composite flour ranged between 1.51% (50_U50_{AC}) and 2.96% (50_U50_{AC}). It can be seen that increase in the percentage proportion of *AA* (0-50%) reduced the *WAC* values of the composite flours from 5.8%-5.46%. However, the reverse is the case with *OAC*. The reduction in the *WAC* values and increase in the *OAC* could be as a result of low water holding and high oil holding capacity of *AA* which probably affected the structural matrix for holding water and other components (Jideani, 2011). *WAC* of *MS*, *BE* and *AA* blends ranged from 3.5% (50_U50_{AC}) to 6.8% (70_U30_A). Igbabul et al. (2012) had earlier reported that blending flours at different proportions changed some of the important functional properties of the composite flours and makes it better for use as food/soup thickeners.

Table 1 Functional properties of *Brachystegia eurycoma* (*BE*) or *Achi* (*AC*), *Afzelia africana* (*AA*) *or Akpalata* (*A*) and *Mucuna solannie* (*MS*) or *Ukpo* (*U*) flours at varying blending proportions

Blending proportion (%)	Water solubility index (%)	Swelling index (%)	Foaming capacity (%)	Emulsion capacity (%)	Oil absorption capacity (%)	Water absorption capacity (%)
100_U	$7.64^a \pm 0.01$	$1.42^a \pm 0.01$	$3.7^g \pm 0.1$	$33.64^g \pm 0.1$	$1.54^b \pm 0.0$	$5.8^{abc} \pm 0.001$
100_A	$13.2^c \pm 0.01$	$1.65^e \pm 0.01$	$1.97^b \pm 0.06$	$59.09^j \pm 0.1$	$1.7^c \pm 0.0$	$3.11^a \pm 0.001$
100_{AC}	$15.49^e \pm 0.1$	$1.58^d \pm 0.01$	$1.94^b \pm 0.01$	$63.11^k \pm 0.1$	$1.57^b \pm 0.0$	$4.63^{abcde} \pm 0.001$
80_U20_A	$8.11^a \pm 1.0$	$1.49^b \pm 0.0$	$2.64^c \pm 0.01$	$31.82^e \pm 0.1$	$1.85^d \pm 0.06$	$6.03^{def} \pm 0.001$
70_U30_A	$8.17^a \pm 0.01$	$1.52^{bc} \pm 0.02$	$3.54^f \pm 0.02$	$33.33^f \pm 0.1$	$2.02^{fg} \pm 0.01$	$6.86^f \pm 0.001$
60_U40_A	$8.81^b \pm 0.1$	$1.69^f \pm 0.02$	$3^d \pm 0.1$	$27.27^b \pm 0.1$	$2^f \pm 0.01$	$6.33^{ef} \pm 0.001$
50_U50_A	$8.13^a \pm 0.01$	$1.76^g \pm 0.0$	$2.6^c \pm 0.1$	$40^h \pm 0.1$	$2.96^h \pm 0.01$	$5.46^{cdef} \pm 0.001$
80_U20_{AC}	$14.53^d \pm 0.1$	$1.52^c \pm 0.01$	$2.6^c \pm 0.1$	$43^i \pm 0.1$	$2.01^{fg} \pm 0.01$	$5.34^{bcdef} \pm 0.001$
70_U30_{AC}	$14.01^d \pm 0.01$	$1.57^d \pm 0.04$	$3.21^e \pm 0.01$	$30^c \pm 0.1$	$2.04^g \pm 0.01$	$5.32^{bcdef} \pm 0.001$
60_U40_{AC}	$13.44^c \pm 0.01$	$1.75^g \pm 0.0$	$1.8^a \pm 0.1$	$31^d \pm 0.1$	$1.92^e \pm 0.01$	$4.33^{abcd} \pm 0.001$
50_U50_{AC}	$13.42^c \pm 0.01$	$1.76^g \pm 0.1$	$2.97^d \pm 0.06$	$24.27^a \pm 0.1$	$1.51^a \pm 0.01$	$3.5^{ab} \pm 0.001$

Note: Where, 100_U represent 100% *Ukpo* (*Mucuna solannie*); 100_A represents 100% *Akpalata* (*Afzelia africana*); 100_{AC} represents 100% *Achi* (*Brachystegia eurycoma*); 80_U20_A is 80% *Ukpo* (*Mucuna solannie*) and 20% *Akpalata* (*Afzelia africana*); 70_U30_A is 70% *Ukpo* (*Mucuna solannie*) and 30% *Akpalata* (*Afzelia africana*); 60_U40_A is 60% *Ukpo* (*Mucuna solannie*) and 40% *Akpalata* (*Afzelia africana*); 50_U50_A is 50% *Ukpo* (*Mucuna solannie*) and 50% *Akpalata* (*Afzelia africana*); 80_U20_{AC} represents 80% *Ukpo* (*Mucuna solannie*) and 20% *Achi* (*Brachystegia eurycoma*); 70_U30_{AC} represents 70% *Ukpo* (*Mucuna solannie*) and 30% *Achi* (*Brachystegia eurycoma*); 60_U40_{AC} represents 60% *Ukpo* (*Mucuna solannie*) and 40% *Achi* (*Brachystegia eurycoma*); 50_U50_{AC} represents 50% *Ukpo* (*Mucuna solannie*) and 50% *Achi* (*Brachystegia eurycoma*).

From Figure 2(d), blending significantly ($P \le 0.05$) affected both the wettability and viscosity values of *MS*, *AA* and *BE* flours. Optimum values of viscosity (65.9 cP) and wettability (303.1 Secs) were attained in 80_U20_A and

80_U20_{AC} blends respectively, whereas minimum values of 18.11cP and 18.1 Secs for viscosity and wettability respectively was attained in 50_U50_{AC} blend. The viscosity and wettability values in 100% (control) of *MS*, *AA* and *BE* flours were 78.57 cP, 67.74 cP and 52.2 cP; and 116.1 secs, 919.1 secs and 366.1 secs respectively. Multiple comparison test showed that there were significant differences ($P \leq 0.05$) in all the means for both viscosity and wettability in the various blends. However, the blends of 70_U30_{AC} and 80_U20_A showed no significant differences ($P \geqslant 0.05$).

3.3 Effects of blending proportions on the proximate composition

The effects of blending on the carbohydrate, protein, moisture, fat, fibre and ash contents in the flours of *MS*, *AA* and *BE* was evaluated. From Figure 2(c), the flours had considerably higher carbohydrate than protein. Carbohydrate content (60.68%, 68.61% and 70.87%) was highest in the three culinary enhancing agents investigated, followed by protein content (16.37%, 15.55% and 15.65%), moisture content (7.89%, 9.9% and 15.2%) and fat content (6.93%, 6% and 6.69%). The moderately high protein content of *MS* flours makes it a useful protein supplement in *AA* and *BE* based foods (Akubor and Ukwuru, 2003). The fibre and ash contents were 3.84%, 3.77% and 1.56%; and 3.1%, 3% and 2.78% in the flours (100%, control) for *MS*, *AA* and *BE* respectively. These were closely related to values for protein content (16.18%, 15.2% and 15.25%), moisture content (10.94%, 11.34% and 11.27%), fat content (6.53%, 6.1% and 6.12%), fibre content (2.05%, 1.81% and 1.84%) and ash contents (1.6%, 1.47% and 1.48%) for *MS*, *AA* and *BE* flours respectively, earlier reported by Ndulaka et al. (2017). However, lightly different ranges of values of moisture content (12.14%-12.93%), ash content (4.0%-4.4%), fat content (3.62%-3.87%) and protein content (26.27%-27.69%) for *MS* flour at varying boiling time (0 – 60 mins) had earlier been reported by Onuegbu et al. (2013). This shows that *MS*, *AA* and *BE* are rich sources of energy-giving and body building nutrients. The observed differences in values may be attributed to methods of preparation of flour, ecological, agronomic and soil factors of the seeds.

Blending had significant ($P \leq 0.05$) effects on the proximate composition of *MS*, *AA* and *BE* flours. Proximate composition of blends is presented in Table 2. Ash content of blends ranged from 2.5% to 3.5%. Percentage inclusion of *AA* flour in *MS* flour resulted in no significant ($P \geq 0.05$) reduction in the ash content whereas % increase in *BE* flour resulted in significant ($P \leq 0.05$) reduction in ash content in the composite flour.

Moisture content of composite flour blend was least in 80_U20_A (8.3%) blend and optimum in 80_U20_{AC} (14%) blend. Increase in percentage inclusions of *AA* and *BE* resulted in significant ($P \leq 0.05$) increase in the moisture content of the composite flours. This makes it more susceptible for the proliferation of spoilage organisms like mold, thereby affecting the shelf life of the resultant flour blends. The storage therefore would require a careful reduction of the moisture content by drying. Least percentage inclusions of *AA* (80_U20_A) and *BE* (50_U50_{AC}) flours are also strongly recommended in other to keep the moisture content of the composite flours at minimum levels.

Significant ($P \leq 0.05$) increase in the fibre content in composite flour was recorded by decreasing the percentage inclusion of *MS* flour. Highest fibre content (3.88%) was recorded in blend of 60% *MS* and 40% *AA* flours while the lowest (20%) fibre content was obtained in blend of 80% *MS* flour and 20% *BE* flour. The increase in fibre content may be due to the combination of effects between *MS* and *AA* flours.

Fat content of the composite flour ranged from 6.32% (70% *MS* and 30% *BE*) to 8.33% (60% *MS* and 40% *AA*). Decrease in percentage inclusion of *AA* flour resulted in no significant ($P \geq 0.05$)effect in fat content value in the composite flour. Decrease in percentage inclusion of *BE* flour in blends resulted in significant ($P \leqslant 0.05$) reduction in fat content value of the resultant composite flour.

Significant($P \leqslant 0.05$) increase in carbohydrate content in *MS* and *AA* in the composite flour was recorded with increase in percentage inclusion of *AA* flour whereas significant reduction in carbohydrate content in *MS* and *AA* in the composite flour was recorded with percentage increase in *BE* flour inclusion. Carbohydrate content was maximum (77.75%) in 50_U50_A (50% *MS* and 50% *AA*) blend and minimum (65.8%) in 70_U30_A (70% *MS* and 50% *AA*) (Figure 2(e)). Significant ($P \leqslant 0.05$) increase in protein content (16.37% – 16.76%) in *MS* and *AA* composite flour was attained as percentage *AA* inclusion increased to 30%. Percentage protein content in the blends significantly ($P \leqslant 0.05$) increased from 15.65% to 16.25% as percentage *BE* flour inclusion increased from 20% to 40%. Protein content in composite flours or food systems could be increased by incorporating *BE* flour. This will help for better nutritional values and functionality than products produced solely from single products.

Table 2 Proximate composition of *Brachystegia eurycoma* (*BE*), *Afzelia africana* (*AA*) and *Mucuna solannie* (*MS*) flour at varying blending proportions

Proximate composition (%)	Blending Proportion (%)										
	100_U	100_A	100_{AC}	80_U20_A	70_U30_A	60_U40_A	50_U50_A	80_U20_{AC}	70_U30_{AC}	60_U40_{AC}	50_U50_{AC}
Ash content	$3.1^c \pm 0.1$	$3^c \pm 0.10$	$2.78^b \pm 0.1$	$2.5^a \pm 0.1$	$2.5^a \pm 0.1$	$2.5^a \pm 0.1$	$3^c \pm 0.1$	$3^c \pm 0.1$	$3.5^d \pm 0.1$	$3.5^d \pm 0.1$	$2.5^a \pm 0.1$
Moisture content	$7.9^a \pm 0.1$	$9.9^e \pm 0.1$	$15.2^k \pm 0.1$	$8.3^b \pm 0.12$	$14.9^j \pm 0.02$	$8.5^c \pm 0.1$	$9.7^d \pm 0.1$	$14^i \pm 0.1$	$12.76^h \pm 0.01$	$11.26^g \pm 0.1$	$10.75^f \pm 0.1$
Fibre content	$3.84^f \pm 0.1$	$3.77^f \pm 0.1$	$1.56^a \pm 0.1$	$3.88^f \pm 0.1$	$3.88^f \pm 0.1$	$3.88^f \pm 0.1$	$3.37^e \pm 0.1$	$2^b \pm 0.1$	$2.43^c \pm 0.1$	$2.79^d \pm 0.1$	$2.07^b \pm 0.15$
Fat content	$6.93^{de} \pm 0.15$	$6^a \pm 0.1$	$6.67^c \pm 0.1$	$7.67^f \pm 0.1$	$7.67^f \pm 0.1$	$8.33^g \pm 0.1$	$6.99^{de} \pm 0.1$	$7^e \pm 0.1$	$6.32^b \pm 0.1$	$6.83^{cde} \pm 0.1$	$6.8^{cd} \pm 0.1$

Note: Where, 100_U represent 100% *Ukpo* (*Mucuna solannie*); 100_A represents 100% *Akpalata* (*Afzelia africana*); 100_{AC} represents 100% *Achi* (*Brachystegia eurycoma*); 80_U20_A is 80% *Ukpo* (*Mucuna solannie*) and 20% *Akpalata* (*Afzelia africana*); 70_U30_A is 70% *Ukpo* (*Mucuna solannie*) and 30% *Akpalata* (*Afzelia africana*); 60_U40_A is 60% *Ukpo* (*Mucuna solannie*) and 40% *Akpalata* (*Afzelia africana*); 50_U50_A is 50% *Ukpo* (*Mucuna solannie*) and 50% *Akpalata* (*Afzelia africana*); 80_U20_{AC} represents 80% *Ukpo* (*Mucuna solannie*) and 20% *Achi* (*Brachystegia eurycoma*); 70_U30_{AC} represents 70% *Ukpo* (*Mucuna solannie*) and 30% *Achi* (*Brachystegia eurycoma*); 60_U40_{AC} represents 60% *Ukpo* (*Mucuna solannie*) and 40% *Achi* (*Brachystegia eurycoma*); 50_U50_{AC} represents 50% *Ukpo* (*Mucuna solannie*) and 50% *Achi* (*Brachystegia eurycoma*)

4 Conclusion

BE, *AA* and *MS* flour**s** are rich potential sources of nutritional food ingredients and phytochemicals with excellent functional properties. Inference from the Figures and Tables revealed that steroid values in *AA* (23.48 mg 100 g^{-1} dm) and *MS* (11.89 mg 100 g^{-1} dm) flours were significantly higher ($p \leq 0.05$) than that of *BE* (3.62 mg 100 g^{-1} dm). Optimum alkaloids, saponin and flavonoids were 1.8, 3.25 and 2.91 mg 100 g^{-1} dm and were obtained in 60% *MS* and 40% *AA* (60_U40_A) blend as against 100% *MS*, *AA* and *BE* flours (control) which gave values of 1.49, 1.34, and 1.36; 1.47, 0.45 and 0.61; and 1.15, 1.13 and 1.18 mg 100 g^{-1} dm) for alkaloids, saponins and flavonoids respectively. Maximum values for tannin (5.1 mg 100 g^{-1} dm) and glycosides (1.067 mg 100 g^{-1} dm) were obtained in 70% *MS* and 30% *AA* (70_U30_A) flour blend. The water absorption capacity obtained showed that these mixtures can be useful as ingredients in paste products and also in the production of some baked products. Percentage *AA* (0 - 50%) and BE (0 - 40%) flour inclusions in *MS* flour significantly ($p \leqslant 0.05$) increased the carbohydrate content of the composite flours from 60.58% – 77.45% and 70.87% – 74.89% respectively. Percentage *AA* (0 – 30%) flour inclusion in *MS* flour significantly ($p \leqslant 0.05$) increased the protein content (16.37% – 16.76%) in the composite flour whereas percentage (0 – 50%) *BE* flour inclusion in *MS* flour decreased the protein content (15.65 -15.225%). In this study, blending proportions not only had significant effects ($p \geq 0.05$) on the phyto-chemical properties, functional properties and proximate composition of the composite flours but also demonstrated its potential to help for better nutritional values and functionality than products produced solely from single products. Further studies should be focused on the use of different varieties of *MS*, *AA* and *BE* seeds; optimization of the processing conditions and flour particle sizes. Further studies are also recommended on how to improve the sensory quality and overall acceptability of *MS*, *AA* and *BE* composite flours as well as the packaging and pelletization of ready-to-use *MS*, *AA* and *BE* composite flours for culinary enhancement.

Declaration of competing interest

The authors confirm that they have no conflicts of interest concerning the work described in this manuscript

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