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Effect of inclusion of velvet bean on the proximate composition and functional properties of the wheat-plantain flour blends

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Abstract

Wheat flour is a flour of choice in confectionary industries due to the component gluten. Wheat flour is a powder made from the grinding of wheat used for human consumption. Plantain is a popular dietary staple crop in Nigeria due to its versatility and good nutritional value. It is starchy, the less sweet variety can be used either ripe or unripe, they are very good sources of carbohydrate for more than 50 million people. Velvet bean (*Mucuna pruriens*), belongs to the *Fabaceae* family, it is part of various legumes which is not commonly used by people as a result of anti-nutrients. Velvet bean is commonly grown in the tropical and subtropical part of the world. This study therefore investigated effect of inclusion of velvet bean on the proximate composition and functional properties of wheat-plantain flour blends. The procured velvet bean and plantain were thoroughly washed, peeled, dried and converted into flours. Wheat, plantain and Velvet flours composite were prepared in the ratio 240:37.5:22.5, 210:60:30 and 150:105:45 respectively and 100% wheat flour was used as the control. The samples were evaluated for their proximate and functional properties. proximate revealed that moisture ranged from 9.06-11.62%, crude protein 11.93-13.33%, crude fat 0.97-1.53%, crude fibre 0.24-0.51%, ash 0.901.31% and carbohydrates 73.60-74.80%. Functional properties revealed that loose bulk density ranged from 0.40-0.43, pack bulk density 0.60-0.63, water absorption capacity 66.18-87.56, swelling power 463.37-530.77, solubility index 6.05-8.24, dispersibility 69.75-74.25 and LGC 12.4015.50. Addition of plantain and velvet beans flours significantly (p < .05) improved the crude protein, crude fibre and carbohydrate in respect to the composites. Water absorption capacity (WAC) and swelling power of the composites were significantly (p < .05) improved thus making them viable in baking applications, as thickeners and binders in food products and non-food uses in adhesives and pastes/glues.

Keywords: Velvet bean; Plantain; Proximate composition; Wheat; Functional properties

1. Introduction

Wheat flour is a flour of choice in confectionary industries due to the component gluten. Wheat flour is a powder made from the grinding of wheat used for human consumption. Wheat varieties are called "soft" or "weak" if gluten content is low, and are called "hard" or "strong" if they have high gluten content. Hard flour, or bread flour, is high in gluten, with 12% to 14% gluten content, and its dough has elastic toughness that holds its shape well once baked. Soft flour is comparatively low in gluten and thus results in a loaf with a finer, crumbly texture. Soft flour is usually divided into cake flour, which is the lowest in gluten, and pastry flour, which has slightly more gluten than cake flour. (Ukpebor, 1991).

Plantain is a popular dietary staple crop in Nigeria due to its versatility and good nutritional value. It is starchy, the less sweet variety can be used either ripe or unripe, they are very good sources of carbohydrate for more than 50 million people, it is comparable in nutritive value to yam or potato and are useful as variant on usual staple foods. It is consumed mainly in Nigeria as snacks in form of chips, dodo Ikire, unripe plantain can be roasted used to produce "Boli" which is highly acceptable in Nigeria. Unripe plantain can traditionally be processed into flour in Nigeria and in other West and

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Central African countries (Ukhum and Ukpebor, 1991). Plantain (Musa paradisiaca) is an important starchy staple and commercial crop in the West and Central Africa where fifty percent of the world's plantain crop is produced (Adeniji *et al*., 2007). It constitutes a significant source of carbohydrate, low in protein and fat but rich in starch and mineral elements, especially potassium. It is widely cultivated in most of the eastern and southern parts of Nigeria.

Velvet bean (*Mucuna pruriens*), belongs to the Fabaceae family, it is part of various legumes which is not commonly used by people as a result of ant nutrients. Velvet bean is commonly grown in the tropical and subtropical part of the world. It has been reported to be a great source of dietary protein because it has a higher percentage of protein (about 26%), and it is easily digestible compared to other annual leguminous crop (Janardhanan *et al*., 2003). Velvet bean can also help in stress management and improvement of semen quality (Shukla, 2007). It has been used in India for many centuries as a remedy in the ancient Ayurvedic system (traditional medicinal system in India) to relieve symptoms of Parkinson disease. The use of this crop in Nigeria is limited because of the presence of L-dopa with consequence of causing risk of poisoning and poor palatability or other reason (Shukla, 2007). The pharmacological activities of the beans have been demonstrated in the literature (Medicinal plants of the world, Vol. 1) (Bharadwaj and Chandrashekharaiah (2017) and also a review of the nutritional potential of Mucunapuriens was done by Pugalenthi *et al*., 2005. Although most of the L-dopa (a non-protein amino acid neurotransmitter precursor) used for medicinal purposes is made from synthetic compound, however there seems to be an increase demand for natural L-dopa which are more abundant in *Mucuna pruriens*. Ifemeje, (2016) investigated the chemical and phytochemical composition of *Mucuna pruriens* leaves he reported the crude protein to be 34.16% and the crude fibre 32.50 with high level of ash 5.80% and crude fat of 2.3%.

2. Material and methods

Velvet bean, plantain and wheat flour were purchased from Owode market, Offa, Kwara State, Nigeria. The equipment used was made available from the Department of Food Technology, Federal Polytechnic Offa, Nigeria. All chemicals that were used are of food standard and analytical grade.

2.1. Methods

2.1.1. Sample preparation

Preparation of plantain flour

Plantain flour was prepared following the processing steps described by Kure *et al.,* (2012). Plantain fingers were separated from the bunches, washed, peeled manually and sliced to (2 mm thickness) using a stainless-steel kitchen slicer. The sliced chips were blanched at 70 °C for 5 min, and dried in a cabinet drier at 50 ^{0}C for 48 h. The dried slices were milled, sieved and packaged in a low density polyethylene bag; and stored at ambient conditions for subsequent use. See figure 1
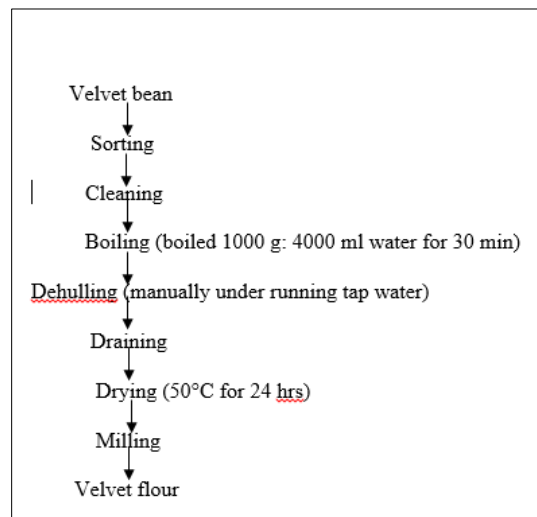
Preparation of boiled-velvet beans into flour

Velvet beans were processed into flour as described by Balogun and Olatidoye (2010). About 1000 g of matured velvet beans seed were sorted cleaned to remove extraneous materials like stones and defective seeds. The seeds were introduced into already boiling distilled water (1000:4000 g/ml) and boiled for 30 min. The seeds were dehulled manually and washed thoroughly under running water and drained. The seed was oven-dried at 50 ^{0}C for 24 hrs and milled into flour (300 µm). see figure 2
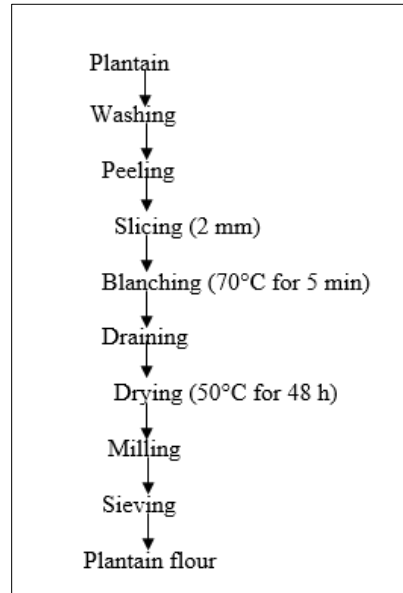
Source: (Kule *et al.*, 2021)

Figure 1 Flow chart for the production of plantain flour

Source: (Balogun and Olatidoye, 2010)

Figure 2 Flow chart for the production of Soaked-velvet bean flour

2.1.2. Composite Flour Preparation

Boiled-velvet bean flour and plantain flour composite flours were prepared by blending them with wheat flour. The composite flour of wheat-plantain-velvet beans (240:37.5:22.5, 210:60:30 and 150:105:45 respectively and 100% wheat flour was used as the control.

2.2. Proximate Analysis

2.2.1. Moisture Content

Exactly 3.0 g of the sample was weighed using analytical balance (Denver Instrument Company, TR-2102) into previously weighed Petri dishes. The weighed samples were put into the pre-set oven (Fisher Scientific Isotemp Oven, Model 655 F, Chicago, USA) regulated at 105 °C for 3 h. The samples were removed and cooled in desiccators to room temperature and the weight was noted. They were then returned to the oven at 105 °C for 30 min until a constant weight

was obtained for each sample. The differences in weight between each Petridish and dried residue were recorded as the percentage of the initial sample (AOAC, 2000).

% Moisture Content =(Weight of sample before drying – Weight of sample after drying)/(Weight of sample) x 100

2.2.2. Crude fat

This was determined by using the method described by (AOAC, 2000). One gram of dried sample was weighed into a fat free thimble plugged tightly with cotton wool and was extracted with petroleum ether in Soxhlet assembly set up for 5 h. The residue extract was evaporated in an air oven at 100 °C for 30 min, cooled and weighed. The fat content was calculated using equation (AOAC, 2000).

%Fat = ((Weight of flask + fat) – Weight of empty flask)/ (Sample weight) x 100

2.2.3. Crude fibre

Two gram (2 g) of the sample was accurately weighed into a flask (W1) and 100 ml of 0.255 N H2SO4 was added, the mixture was heated under reflux for 30 min. The hot mixture was filtered through a fibre muslin cloth. The residue was returned to the fibre flask and 100 ml of 0.313 N and NaOH was added then heated for another 30 min. The residue was removed and finally transferred into the crucible. The crucible and the residue was oven-dried at 105 °C overnight to dry off the moisture. The oven-dried crucible containing the residue was allowed to cool in a desiccators and later weighed to obtain the W2 (AOAC, 2000).

The difference (W2–W1) gives the weight to fiber.

% Crude Fibre = (W_2 - W_1)/(weight of sample)

2.2.4. Crude protein

The Kjeldhal method of (AOAC, 2000) was used. The flour sample (0.2 g) was weighed into digestion tubes and one (AOAC, 2000) tablet of Kjeldhal catalyst (copper sulphate) was added. This was followed by the addition of 20 ml each of concentrated H_2SO4 and hydrogen peroxide. The samples were digested by heating with a heating mantle in a fume cupboard for 5 h until a clear solution was obtained. The digest was cooled and transferred into 100 ml volumetric flask and make up to mark with distil water. The distillation apparatus was then set-up and rinsed for 10 min after boiling. About 20 ml of boric acid was pipetted into 100 ml conical flask, 5 drops of screened methyl red indicator were pipetted into the Kjeldhal distillation flask, after which the conical flask containing the boric acid was fixed with it and 20 ml of 20% NaOH was added through the glass funnel into the digest. The steam exit was then distilled for 15 min. The distillate was titrated with 0.05 N HCl. The percentage protein was then calculated using equation:

% Protein (crude)=%Total Nitrogen x Conversion factor

%Total Nitrogen = (TV x Conc. of acid used x 0.014 x DF)/(Weigth of sample) x 100

Where,
TV= Titre Value
DF= Dilution Factor

2.2.5. Ash

Ash content was determined using the (AOAC, 2000) method. Finely grinded sample (5 g) was weighed into an empty porcelain crucible. This was transferred into the muffle furnace set at 550 °C and left for about 4 h. About this time, it was turned to white ash. The crucible and its content were cooled to room temperature in a desiccator. The crucible with the sample was weighed and the percentage ash calculated using equation:

% ash content = (Weight of Ash Original)/(Weight of sample) x 100

2.3. Estimation of carbohydrate

Carbohydrate was calculated by difference (subtracting the sum of percentage moisture contents, crude fiber, lipid, crude protein and ash content from 100%).

2.3.1. Determination of Functional Properties of the Composite Flour

Functional properties such as bulk density, water absorption capacity, swelling power, dispersability, solubility index, least gelatinization concentration, and pasting properties of the composite flour blend were determined.

2.3.2. Determination of bulk density

Bulk density of the composite flour sample was determined by measuring the packed volume of a known weight of sample according to Wondimu and Malleshi (1996) method. Twenty gramme of the sample blends was weighted into 50 ml graduated measuring cylinder. The cylinder was allowed to drop through a height of 150 ml on to a soft pad. This procedure was repeated 15 times before the flour was leveled off and the bulk density measured in g / ml.

$$\text{Bulk Density (g/ml)} = \text{Mass (g)} / \text{Volume (ml)}$$

2.3.3. Determination of water absorption capacity (WAC)

The water absorption capacity of each sample blends was determined in triplicate using the method described by Sosulski (1962). To 1g of the sample was added 15 ml of distilled water in a pre-weighed centrifuge tube. The tube with its content was agitated on a Flask Gallenkamp shaker for 2 min and centrifuged at 4000 rpm for 20 min on a centrifuge (SORVALLGLC.1, Model 06470, USA). The clear supernatant was discarded and the centrifuge tube was weighed with the sediment. The amount of water bound by the flour was determined by difference and expressed as the weight of water bound by 100 g dry flour.

$$\text{WAC (\%)} = W1 - W2 / W3$$

Where W1 = weight of centrifuge tube + sample, W2 = weight of centrifuge tube +   sediment after draining for 10 min, W3 = weight of sample

2.3.4. Swelling power

The swelling power of the composite flour sample blends was determined in triplicate using the method of Idowu *et al*. (2017). It involved weighing 1 g of composite cake flour blends into 100 ml conical flask, 15 ml of distilled water was added and mixed gently at low speed for 5 min. The slurry was heated in a thermostat water bath (THELCO model 83, USA) at 80 ^{0}C, respectively for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a pre weighed centrifuge tube and 7.5 ml distilled water was added. The tubes containing the paste were centrifuged at 2,200 rpm for 20 min using SORVALLGLC-1 centrifuge (Model 06470, USA). The supernatant was decanted immediately after centrifuging into a pre-weighed can and dried at 100 ^{0}C to constant weight. The weight of the sediment was taken and recorded.

$$\text{Swelling power (g/g)} = \text{Weight (g) of sediment} - \text{Weight (g) of soluble} / \text{Sample weight, g}$$

2.3.5. Determination of Dispersibility

The method described by Idowu *et al*. (2017) was adopted. Ten gram (10 g) of each sample blends were weighed into 100 ml measuring cylinder and distilled water was added to reach a volume of 100 ml. The set up was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersability.

$$\text{Dispersability (\%)} = \text{Initial level} - \text{Final level.}$$

2.3.6. Determination of solubility index

The solubility index of each sample blend was determined in triplicate using the method of Akinsola *et al*. (2017). It involved weighing one gram of starch into 100 ml conical flask, 15 ml of distilled water was added and mixed gently at low speed for 5 min. The slurry was heated in a thermostat water bath (THELCO model 83, USA) at 80 ^{0}C respectively for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a pre weighed centrifuge tube and 7.5 ml distilled water was added. The tubes containing the paste were

centrifuged at 2,200 rpm for 20 min using SORVALLGLC-1 centrifuge (Model 06470, USA). The supernatant was decanted immediately after centrifuging into a pre-weighed can and dried at 100 ^{0}C to constant weight. The weight of the dried sediment was taken and recorded as weight of dried soluble.

$$\text{Solubility index (g / g)} = \text{Weight (g) of dried soluble} / \text{Weight (g) of sample}$$

2.3.7. Determination of least gelation concentration

The method as described by Akinsola (2017) was used to determine least gelation concentration of the sample blends. Sample suspensions of 2 to 20% (w/v) were prepared in 5 mL distilled water in test tubes. The tubes containing the suspensions were then heated for 1 hr in a boiling water bath. The tubes, after heating, were cooled rapidly in water at 4 °C for 2 hr. Each tube was then inverted. The concentration at which the sample from the inverted test tube did not slip was taken as the LGC.

2.4. Statistical Analysis

Data generated from this study were analyzed using Analysis of Variance (ANOVA). Values were expressed as mean ± standard error of mean (SEM) from three determinations. Differences in mean were compared using Duncan multiple test range. P<0.05 was considered significant (Osuocha, 2018).

3. Results and discussion

The result of proximate composition of composite flour blends from wheat, plantain and velvet bean flour is presented in Table 1. The moisture contents of the composite flours ranged between (9.06 – 11.62%) with CSA (300 g wheat flour) having the highest moisture (11.62%) while the least value (9.06%) was noted in CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour). There were significant differences between the moisture contents of the composite flours at 95% confidence level; hence, an indication that the levels of plantain and velvet bean flour supplementations with the wheat flour significantly (p < .05) reduced their respective moisture contents. The moisture contents of the composite flours are in agreement with the permissible moisture content level for flour based food products (≤13%) (James and Roy, 2009; Eke-Ejifor and Owuno, 2012). Therefore, the composite flours will have less susceptibility to microbial proliferation, suggesting longer shelf stability for the blends especially when properly packaged, which could be very useful in flour based food products requiring lower moisture contents such as biscuits, bread, pasta, etc. The report in this current study corroborate the findings of Igbua *et al.* (2018) whose study reported (11.45 – 11.91%) for maize- cassava-soybean composites, (9.78 – 10.36%) for wheat-breadfruit composite flour by Abegunde *et al.* (2019) as well as the results (9.65 – 9.80%) from the study of Abioye *et al.* (2011) for soy-plantain flour blends. On the flip side, Vivienne *et al.* (2016) reported (18.48 – 20.43%) for ripe, unripe plantain and wheat flours which are higher than the values obtained for the composite flours in this investigation.

The protein contents of the composite flours ranged between (11.93 – 13.33%) with CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour) having the highest protein (13.33%) while the least value (11.93%) was observed in whole wheat flour (CSA). There were significant differences (p < .05) between the protein contents of the composite flours, thus, an indication that addition of velvet bean flour to wheat flour at different levels of supplementation improved the protein contents of the respective composites. Similar report had been established by Igbua *et al.* (2018) whose study reported significant (p < .05) improvement in protein contents of maize-cassava-soybeans composite with increase in soy flour supplementation. Our values are in consonance with the findings of Moses and Adebola (2017) who researched composite blends of yam, soybean and plantain flours (4.82 – 15.32%) but higher than the report (4.54 – 8.40%) of Abioye *et al.* (2011) for soy-plantain flour and (3.95 – 6.68%) reported for moringa fortified plantain flours by Ilelaboye (2019). Variation in protein contents of the composite flours in this study and those in the cited literatures could be attributed to the inherently high protein concentration (23 – 35%) of velvet bean used in this study (Rajiv and Chandrashekharaiah, 2017; Ezeagu *et al.*, 2003). Therefore, the high protein contents of the composite flours present them as a nutritional advantage for utilization in staples that are flour-based such as bread, biscuit, cakes, etc especially in developing countries where majority of the populace cannot afford protein-dense foods due to rising costs.

The crude fat contents of the composite flours ranged from 0.97 – 1.73% with CSA (300 g wheat flour) having the highest value (1.73%) while the least value (0.97%) was observed in CSB (240 g wheat flour, 37.5 g plantain flour and 22.5 g velvet bean flour). There were significant differences at (p < 0.01) between -the crude fat contents of the flours. Although not significant (p > .05), addition of plantain and velvet bean flour slightly reduced the fat contents of the composite flours. The fat contents of the composite flours in this study corroborate the findings of Abegunde *et al.* (2019) for

wheat-bread fruit flour (0.56 – 1.82%). Contrarily, the reports of Moses and Adebola (2017) for yam-soy-plantain flour (0.48 – 6.70%), (1.55 – 2.85%) for moringa-plantain flour by Ilelaboye (2019) and (1.29 – 8.57%) for plantain-groundnut-cinamon flour blends by Adegunwa *et al.* (2019) are higher than the values obtained for the composites in this study. Furtherance, the low fat contents of the composite flours in this study suggest that they may not contribute much to energy content since fat increases the energy density as well as being a transport vehicle for fat soluble vitamins (Okwunodulu *et al.*, 2019). Considerably, the low fat contents of the composite flours in this study may be advantageous as they are less prone to rancidity; hence, an indication of long shelf stability as well as being suitable for weight watchers (Igbua *et al.*, 2018).

Crude fibre such as lignin, cellulose and hemicellulose represents the content of the non-digestible components of foods (Ilelaboye, 2019). As indicated in table 4.1, the crude fibre contents of the composite flours differed significantly at 95% confidence level (p < .05) with values ranging between (0.24 – 0.51%). The highest crude fibre content (0.51%) was observed in CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour) while CSA (300 g wheat flour) had the least fibre content. Our values are not in agreement with the report of Moses and Adebola (2017) for yam-soy-plantain flours (0.56 – 1.28%) and (1.83 – 1.90%) for soy-plantain flour mixes by Abioye *et al.* (2011). Crude fiber functions to decrease absorption of bile acids and cholesterol from the bowel, by getting attached to them (Adegunwa *et al.*, 2019). Similarly, the findings of Ilelaboye (2019) for moringa fortified plantain flours (2.45 – 9.44%) are higher than the report of this study. Thus, an indication that the composites from the literatures will digest without hassle and contribute to the avoidance of colon cancer much more than the composite flours in this study. High crude fibre facilitates bowel movement (Ilelaboye, 2019).

Ash content of a product is the residue remaining after destroying combustible organic matter (Edima-Nyah *et al.*, 2019). The ash contents of the composite flours varied between (0.90 – 1.31%) with CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour) significantly (p < .05) having the highest value (1.31%) while the least value (0.90%) was observed in CSA (300 g wheat flour). The results showed that addition of plantain and velvet bean flour improved the ash contents of the composite flours, thus, inferring that plantain-velvet bean flours supplementation with wheat flour improved the mineral content of the composites (Ijeh *et al.*, 2010). Literatures abound on the mineral contents of plantain and (Honfo *et al.*, 2007; Adebowale *et al.*, 2005). This observed increase in ash content conform to the report of Ilelaboye (2019) on moringa fortified plantain flours (3.07 – 3.99%) and (1.95 – 2.10%) for soy-plantain flour blends by Abioye *et al.* (2011). The ash contents of this study are slightly lower than (0.82 – 2.81%) reported in by Igbua *et al.* (2018) for maize, cassava and soybean composites but in consonance with the findings of Ikya *et al.* (2013) for maize-soybean composite flours (0.3 – 1.33%).

Table 1 Result for proximate composition of wheat, plantain and velvet beans flour blends

Parameters (%)	CSA	CSB	CSC	CSD	Mean
Moisture	11.62±0.21[d]	10.41±0.08[c]	9.77±0.14[b]	9.06±0.16[a]	10.22
Crude protein	11.93±0.19[a]	12.37±0.01[b]	12.89±0.02[c]	13.33±0.06[d]	12.63
Crude fat	1.73±0.09[b]	0.97±0.03[a]	1.20±0.14[a]	1.53±0.06[b]	1.36
Crude fibre	0.24±0.02[a]	0.31±0.02[b]	0.39±0.02[c]	0.51±0.02[d]	0.36
Total ash	0.90±0.03[a]	1.15±0.02[b]	1.20±0.01[b]	1.31±0.04[c]	1.14
Carbohydrate	73.60±0.31[a]	74.80±0.09[b]	74.54±0.23[b]	74.27±0.09[b]	74.30

Values are mean ± standard deviation. Data with different superscripts in the same row are significantly different at p < .05; Key: CSA = 300 g wheat flour; CSB = 240 g wheat flour, 37.5 g plantain flour and 22.5 g velvet bean flour; CSC = 210 g wheat flour, 60 g plantain flour and 30 g velvet bean flour; CSD = 150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour

The carbohydrate contents of the composite flours ranged between (73.60 – 74.80%) with CSB (240 g wheat flour, 37.5 g plantain flour and 22.5 g velvet bean flour) significantly (p < .05) having the highest value (74.80%) while the least carbohydrate content (73.19%) was observed in CSA (300g wheat flour). There were no significant differences (p > .05) between the carbohydrate contents of the plantain-velvet composite flours which showed slight increase in the carbohydrate contents of the composites. Literatures have shown that legume based flours have carbohydrate reduction capabilities, especially when in composites (Moses and Adebola, 2017; Abioye *et al.*, 2011; Adekunle and Mayowa, 2018). However, the slight increase in carbohydrate composition of the composites in this study might be attributed to the plantain flour which is used in the blends. This justifies the report of United States Department of Agriculture (USDA) (2010) which showed that plantain is a rich source of carbohydrate (32%). The findings of this present report agree to

the reports of Vivienne *et al.* (2015) for wheat, ripe and unripe plantain flours (72.87 – 74.56%), (66.64 – 83.69%) for plantain-watermelon rind composites by Adegunwa *et al.* (2019) and (73.91 – 78.74%) for moringa-plantain flours studied by Ilelaboye (2019). The high carbohydrate contents of the composite flours in this study are of advantage as they will provide the energy needed to do work (Ijeh *et al.*, 2010).

3.1. The Results for the Functional Properties of Composite Flours

The results for the functional properties of composite flours from wheat, plantain and velvet bean flour are presented in Table 2

Table 2 Result for functional properties of composite flours

Samples	Loose bulk density	Pack bulk Density	WAC	Swelling Power	Solubility Index	Disper-sibility	LGC
CSA	0.43[b]	0.63[b]	66.18[a]	463.37[a]	6.05[a]	74.25[c]	12.40[a]
CSB	0.42[b]	0.63[b]	70.09[b]	504.91[b]	8.24[c]	71.75[b]	13.04[a]
CSC	0.43[b]	0.62[b]	83.06[c]	518.77[c]	7.73[c]	71.00[b]	14.25[b]
CSD	0.40[a]	0.60[a]	87.56[d]	530.77[d]	6.78[b]	69.75[a]	15.50[c]
Mean	0.42	0.62	76.72	504.46	7.2	71.69	13.79

Values are mean ± standard deviation. Data with different superscripts in the same row are significantly different at p < .05. WAC = Water absorption capacity; LGC = Least gelation capacity; **Key:** CSA = 300 g wheat flour; CSB = 240 g wheat flour, 37.5 g plantain flour and 22.5 g velvet bean flour; CSC = 210 g wheat flour, 60 g plantain flour and 30 g velvet bean flour; CSD = 150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour

Functional properties are the essential physicochemical properties of foods that reflect the complex interactions between the structures, molecular conformation, compositions, and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated (Suresh and Samsher, 2013).

The loose bulk density of the samples ranged from 0.40 to 0.43 mg/100 g. for sample CSD and sample CSA and CSC (having the sample value). The samples showed that there was no significant difference between sample CSA, CSB and CSC (p<0.05) while sample CSD was significantly difference (p<0.05) from others. Loose bulk density promotes easy digestibility of food products. The small amount of loose bulk density of food samples would be advantage in the preparation of cake. Therefore sample CSD (0.60 mg/100 g) would be advantage in the preparation of composite flour.

Also, the same trend was observed for pack bulk density in which sample CSD had the least value (0.60 mg/100 g) and sample CSA and CSB having the sample value were high in pack bulk density value (0.63 mg/100 g). The samples showed that there was no significant difference between sample CSA, CSB and CSC (p<0.05) while sample CSD was significantly difference (p<0.05). Packed bulk density could aid easy packing and transportation of food products. The bulk density is influenced by particle size and density of the flour. It is an important requirement for determining the packaging and material handling and low bulk density is influenced by the loose structure of the starch polymer (Olu *et al.,* 2012). The result obtained in both loose and pack bulk density were low compare to the value (1.34 mg/100 g) of 100 % velvet bean flour used in production of bread by Olatunde *et al.*, (2020). The bulk density of a food material is important in relation to its packaging requirement (Adebowale *et al.*, 2012). Increase in bulk density offers greater packaging advantage as greater quantity may be packed within the constant volume (Wahab *et al.*, 2016).

The water absorption capacity (WAC) of the composites ranged between (66.18 – 87.56%). The highest water absorption capacity (87.56%) was observed in CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour) while CSA had the least value (66.18%). There were significant differences at 95% confidence level between the water absorption capacities of the composite flours. This could be indicative of the fact that addition of plantain and velvet bean flours at different levels of supplementation improved the water absorption capacities of the composites which in turn conferred high water binding capacity due to loose structure of starch polymers in the composites (Adebowale *et al.*, 2005; Oladipo *et al.*, 2011).Protein has been reported to be responsible for high WAC and to a lesser extent, starch and cellulose levels at room temperature (Ahaotu *et al.*, 2013); hence, high protein contents (23 – 35%) inherent in velvet beans (Duru *et al.*, 2020) might have been the contributory factor for the increase in WAC of the composites. The report of this study are higher than the findings of Abegunde *et al.* (2019) for wheat-bread fruit flour (1.50 – 3.15%),

(0.98 – 1.05%) for acha based biscuits by Ayo *et al.* (2018) and those of Igbua *et al*. (2018) for maize-cassava-soybean composites (1.82 – 2.17%). Water absorption capacity describes flour-water association ability under limited water supply (Ayo *et al.*, 2018). Our results suggest that addition of plantain and velvet bean flours could decrease the baking application of the composite flours due to their high water absorption capacities (Chinma *et al.*, 2012); hence, more water would be required for better re-constitutionality.

The swelling power capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations (Chandra and Samsher, 2013). The mean results for the swelling power of the composite flours ranged from 463.37 to 530.77%. CSD had the highest value (530.77%) while the least value (463.37%) was observed in CSA (300g wheat flour). There were significant differences at 95% confidence level between the swelling power of the composites which showed that as the level of plantain and velvet bean flours increased, so did the swelling powers of the respective blends. The swelling power of the composites in this study are than the results (4.27 – 12.21%) of Tharise *et al,* (2014) for composite flour from cassava, rice, potato, soybean and xanthan gum, (5.25 – 7.85%) for breadfruit-wheat composite flour by Abegunde *et al.* (2019) and those reported by Ezeocha *et al.* (2022) for wheat-bambara groundnut-velvet tamarind composite flours (1.24 – 1.65%). The high swelling capacities of composite flours in this study are good criteria for good quality products; hence, could find practical applicability as thickeners and binding agents in food products, and in the non-food sector as adhesives and pastes/glues (Apotiola and Fashakin, 2013; Sanni *et al.*, 2008). Swelling capacity (index) is considered a quality measure in some food products such as bakery products. It is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the α-amylose and amylopectin ratios (Iwe *et al.*, 2016).

Flour solubility is one of the functional properties usually determined during the development and testing of a new flour or flour composite (Awuchi *et al.*, 2019). The solubility index of the composite flours ranged from 6.05 – 8.24% with CSB (240 g wheat flour, 37.5 g plantain flour and 22.5 g velvet bean flour) having the highest value (8.24%) while the least solubility index (6.05%) was observed in CSA (300 g wheat flour). There were no significant differences (p > .05) between the solubility index of CSB and CSC while other composite flours differed significantly (p < .05). The result showed that supplementation of plantain-velvet bean flours at different blends improved their respective solubility. Hence, the higher the solubility with increase in plantain-velvet bean flours, the better the dissolving ability of the blends in water or oil (Awuchi *et al.*, 2019). Our reports are in agreement with the findings of Eke-Ejiofor *et al.* (2021) for solubility index of orange fleshed sweet potato starch-soy bean -groundnut flour composites (5.57 – 9.45%) but lower than (22.85 – 27.49%) reported for solubility index of plantain-watermelon rind flours by Adegunwa *et al.* (2019). The high solubility of the composite flours in this study indicate high digestibility of the flours, thus, showing their excellent usability in food formulations especially as infant formula (Oppong *et al.*, 2015).

The dispersibility of a mixture in water indicates its ability to reconstitute, the higher the dispersibility of a mixture, the better is its reconstitution property (Ghavidel and Davood 2011; Aranwande and Ashogbon, 2019). The mean results for the dispersibility of the composite flours ranged between (69.75 – 74.25%) with CSA (300 g wheat flour) significantly (p < .05) having the best dispersibility while the least value (69.75%) was observed in CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour). Although there were no significant differences (p > .05) between the dispersibility of CSB and CSC, the results showed decrease in dispersibility of the composite flours with increase in plantain and velvet bean flour substitution. The dispersibility of plantain-water melon rind composite flour (0.89 – 1.70%) by Adegunwa *et al.* (2019) are lower than the values obtained for dispersibility of composite flours in this investigation. Contrarily, the findings of Fadimu *et al.* (2018) for dispersibility of plantain flours (70.0 – 80.5%) and those of Obadina *et al.* (2014) on yam flour (61.83 – 68.83%) are in consonance with the report of the current study. Due to the high dispersibility of the composite flours, they may be suitable in applications such as the adsorptive removal of ions from contaminated water systems (Eke-Ejiofor and Onwuno, 2014)

The least gelation concentration (LGC) which is defined as the lowest protein concentration at which gel remained in the inverted tube was used as index of gelation capacity (Chandra *et al.*, 2015). The mean score values for the least gelation capacity (LGC) of the composite flours ranged between (12.40 – 15.50%). Composite flour from CSD (150 g wheat flour, 105 g plantain flour and 45 g velvet bean flour) had the highest LGC (15.50%) while CSA (300 g wheat flour) formed gel quickly at the lowest concentration (12.40%). Pulse/legume flours such as velvet bean, soybean, lima bean, etc flours contain high protein and starch content and the gelation capacity of flours is influenced by physical competition for water between protein gelation and starch gelatinization (Kaushal *et al.*, 2012). The more reduced the gelation capacity, the better gelation ability of flours (Chandra *et al.*, 2015); hence, CSA had commendable gelation ability than other composite flours. The least gelation concentration values in this study are not in consonance with those reported for plantain-wheat flours (30.01 – 35.0%) by Vivienne *et al.* (2015). However, lower values were recorded for plantain flours (6 – 8%) by Fadimu *et al.* (2018). Therefore, since the inclusion of velvet bean flour resulted

in increase in gelation capacity of the composites in this study due to its high protein contents (23 – 35%) (Duru *et al.*, 2020), this infer that it is capable of resulting in poor gelation; hence, the composites in this study may not effectively form thick gels (low dietary bulk) especially at lower concentration. However, the least gelation capacity of the composites in this study indicates their suitability as commendable binders in breakfast foods, and could be incorporated into food systems to provide semisolid consistency in beverages (Osundahunsi, 2006).

4. Conclusion

The results of this study show that velvet bean flour significantly improved both proximate and functional properties of the flour blends. Thus, making them viable in baking applications, as thickeners and binders in food products

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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