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NUTRIENT COMPOSITION, FUNCTIONAL, PHYSICAL AND PASTING PROPERTIES OF YELLOW YAM (*Dioscorea cayenensis*) AND JACK BEAN (*Canavalia ensiformis*) FLOUR BLENDS

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Abstract

The study therefore focused on the nutrient composition, functional, physical and pasting properties of yellow yam and jack bean flour blends. Yellow yam tubers and jack bean seed were processed into flour, blended together and D-optimal mixture design was used to generate the percentage of yellow yam and jack bean flour resulting to a total of nine experimental runs. The flour blends were analyzed for nutrient composition, functional, physical and pasting properties using standard methods. Data obtained were subjected to statistical analysis. Means, analysis of variance were determined using SPSS version 21.0 and the difference between the mean values were evaluated at p<0.05 using Duncan multiple range test. The effect of optimization procedure was investigated using Design expert version (8.0). Crude protein, total carotenoids, starch, amylose and amylopectin ranged from 9.97 to 16.72%, 5.24 to 6.65µg/g, 79.38 to 80.07%, 25.36 to 29.88% and 70.13 to 74.65% respectively. Addition of yellow yam and jack bean flour had no significant (p>0.05) effect on the antinutritional composition (saponin, trypsin inhibitor and total polyphenol). Range of values for bulk density, dispersibility, water absorption capacity, swelling power and solubility index ranged from 0.62 to 0.73g/ml, 75.5 to 80.4%, 4.19 to 6.54g/g, 4.52 to 5.70g/g and 6.53 to 6.77% respectively. The yellowness (b*) of yellow yam and jack bean flour blend were not significantly (p>0.05) affected while the peak viscosity, breakdown viscosity, final viscosity and setback value ranged from 206.0 to 572.0RVU, 5.0 to 17.0RVU, 263.0 to 9.11.0RVU and 279.0 to 372.0RVU respectively. The flour blends were optimized with respect to crude protein, total carotenoid, starch content, amylose, amylopectin, dispersibility, water absorption capacity, swelling power, solubility index, peak viscosity, break down viscosity and yellowness were maximized while bulk density, final viscosity and setback values were minimize. The optimum flour blend ratio was 94.11% yellow yam and 5.89% jack bean flour.

1. Introduction

Yams are the edible tubers of various species of the genus Dioscorea and are important staple foods of many tropical countries particularly West African countries such as Côte d'Ivoire, Ghana, Togo, Burkina Faso and Nigeria (Kouakou *et al.,* 2010; Amanze *et al.,* 2011). The yam tuber, which is the most important part of the plant, can be stored longer than other root and tuber crops, ensuring food security even at times of general scarcity. It is the third most important tropical root and tuber crop after cassava and sweetpotato (Fu *et al.,* 2005). Yam contains mainly starch, with some proteins, lipids, vitamins and minerals (Lasztity *et al.,*1998). Yam tubers have been used as traditional food in the home with little industrial use; however the traditional uses are diverse and the crop still has many more utilization potentials yet untapped. Yam is consumed in different forms, mainly boiled, fried, or baked (Baah, 2009). Tubers are often dried and milled into flour for various products. The genus Dioscorea contains a wide range of yam species used as food. The most economically important species grown are white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*), water yam (*Dioscorea alata*), Chinese yam (*Dioscorea esculenta*) aerial yam (*Dioscorea bulbifera*) and trifolate yam (*Dioscorea dumentorum*) (Ike and Inoni, 2006). *Dioscorea cayenensis* has various varieties but the most popular ones are white and yellow varieties. The yellow variety derives its common name from its yellow flesh, due to the presence of carotenoids (Aseidu, 2010). It is cultivated across yam producing areas in smaller amounts compared to white yam.

Among the locally available under-utilized legumes with high protein content is Jackbean (*Canavalia ensiformis*) (Idowu *et al.,* 2017). Jackbean has its origin in the Western part of India and Central America (Akande, 2016). Jackbean contains significant amounts of niacin, thiamine, phosphorus, calcium and iron (Leon *et al.,* 1990). Jackbean seed, like other legumes showed nutritionally adequate levels of most essential amino acids (EAA) except sulphur amino acids (methionine and cysteine) (Nnamdi-Okani, 2005). Jackbean has been used in foods because of its good thickening and gelling properties (Akande, 2016). They are also a good texture stabilizer and regulator in food systems (Akande, 2016).

Yam is a starchy root crop and widely known and exploited for food such as snacks (Aseidu, 2010) and noodles (Akinoso *et al.,* 2016) with so many varieties. However, *Dioscorea cayenensis* is an underutilized yam variety that is yet to be fully exploited and is fast being driven to extinction. Hence, there is need to explore the use of *Dioscorea cayenensis* into food product such as flour. *Dioscorea cayenensis* has been reported to be a source of carotenoids including α-carotene, β-carotene and numerous xanthophylls and their esters which could help in combating micronutrient deficiency in the country (Champagne *et al.,* 2010; Ukom *et al.,* 2014). Hence, tubers of *Dioscorea cayenensis* when properly processed could be used in the production of instant yam flour, yam flakes and other food products. Jackbean is an underutilized legume and is rich in protein and have unique functional properties owed to its appreciable values of swelling power, solubility and high amylose content of its starch (Marimuthu and Gurumoorthi, 2013). Several information are available on the use of flour from root and tuber with legume such as water yam and distillers spent grain (Awoyale *et al.*, 2015); Greater yam and jackbean flour (Affandi *et al.,* 2016) and water yam and lima bean (Rohmah *et al.,* 2018).This study is therefore aimed to produce flour blends from yellow yam (*Dioscorea cayenensis*) and jackbean and to determine its nutrient composition, functional, physical and pasting properties. Then, the best flour blends based on nutritional composition, functional, physical and pasting properties would be determined.

2. Materials and Methods

2.1. Materials

Matured yellow yam tuber (*Dioscorea cayenensis*) was purchased from Kila in Oke-Ogun, Oyo state while jackbean was obtained from the Research Farm of Federal Polytechnic Offa, Kwara State, Nigeria.

2.2.Flour preparation

The modified method of Oluwole *et al.* (2013) was used for the preparation of yellow yam flour. Yam tubers were washed with clean water to remove adhering soil and other undesirable materials. The yams were hand-peeled using kitchen knife and sliced into sizes of 2 to 3 cm thickness. The sliced yellow yam was blanched in a water bath at 70 °C for 2mins to reduce browning after which the yam was removed. The sliced yellow yams were dried in a cabinet dryer at 60ºC for 72 h. The dried yam slice was milled using laboratory hammer mill (Fritsch, D-55743, Idar-oberstein-Germany) and the milled sample was sieved (using 250µm screen) to obtain the flour. The yellow yam flour was packed and sealed in polyethylene bags until further analysis.

The method described by Doss *et al.* (2011) was used for the preparation of jackbean flour. The jackbean was weighed and boiled in water (100 ºC) for 10 minutes. The boiled seed was rinsed with distilled water, dehulled and dried in a cabinet dryer at 60ºC for 72 h. The dried boiled seed was milled using laboratory hammer mill (Fritsch, D-55743, Idar-oberstein-Germany) and the milled sample was sieved (using 250µm screen) to obtain the flour. The jackbean flour was packed and sealed in polyethylene bags until further analysis

2.3 Formulation of blends

D-optimal mixture design was used to generate the percentage of yam and jackbean flour blends to investigate the effect of interaction of two independent variables as shown in Table 1

Table 1. Formulation of Yellow Yam and Jackbean Flour Blends using D-Optimal Mixture Design

Runs	Yellow Yam Flour (YF)	Jackbean Flour (JF)
1	90.00	10.00
2	92.50	7.50
3	90.00	10.00
4	93.75	6.25
5	92.50	7.50
6	90.00	10.00
7	95.00	5.00
8	95.00	5.00
9	91.25	8.75

2.4. Nutrient composition of yellow yam and jack bean flour blends

2.4.1. Determination of crude protein content

This was determined using AOAC (2010) method. One gram of the samples was weighed into the digestion flask and Kjeldahl catalyst tablets was added, 20 ml of concentrated H_2SO_4 was also added and the flask fixed into the digester at 410ºC for 6 h until a clear solution was obtained.. The cooled digest was transferred into 100 ml volumetric flask, and made up to mark with distilled water. The distillation apparatus was set up and rinsed for 10 min after boiling. 20 ml of 4% boric acid was pipetted into a conical flask. 5 drops of methyl red was added to the flask as indicator and the sample was diluted with 75 ml of distilled water and 10 ml of the digested sample was pipetted into the Kjedahl distillation flask. 20 ml of 40% NaOH was added through the glass funnel into the digested sample and it wasdistilled, the distillate was collected in the boric acid for 15 min until pink colour changes to green. The content of the flask was then titrated against 0.05 N HCl.

Calculation:

%Nitrogen (W/W)

$$= \frac{14.01 \times (\text{Sample titre-blank titre}) \times \text{Normality of acid}}{10 \times \text{Weight of Sample}} \quad (1)$$

$$\%\text{Crude protein (W/W)} = \%\text{Nitrogen x } 6.25 \quad (2)$$

2.4.2. Determination of total carotenoid content

Total carotenoid content of the flour blends and extrudates were determined spectrophotometrically as described in the Harvest Plus Handbook for Carotenoid Analysis and using slight modifications of the methods described by Lee (2001). During the extraction process, some precautions were taken, like working in a reduced luminosity room. This was determined using spectrophotometric measurements using T60 UV Visible spectrophotometer at 450 nm. Six millilitre of n- hexane, 3 ml of acetone and 3 ml of ethanol ((hexane: acetone: ethanol, 2:1:1) containing 0.05% butylated hydroxytoluene (BHT) was added to 2 g of flour samples. The sample was centrifuge. The top layer of hexane containing the color was recovered and transferred to a cuvette. For total carotenoid, the absorbance of the hexane extract was read at 450 nm.

$$\text{Formula } \mu g/g \text{ Carotenoid} = \frac{A \times VOL \times 10^4}{2505 \times W} \quad (3)$$

A= absorbance, W= weight of sample, VOL= volume of hexane used.

2.4.3. Determination of starch content

The method of Dubois *et al.* (1956) as modified by AOAC (2006) was used for the determination of the starch content of the flour blends. Hot ethanol was used to extract starch from the yam and jackbean flour sample. The extract (supernatant) and digest (from the residue) was quantified calorimetrically for starch, using phenol-sulphuric acid as the colour developing reagent; and absorbance read at 490 nm wave length. 20mg of the flour sample was weighed into a centrifuge tube and wetted with 1 ml of 95% ethanol. 2mL of distilled water was added followed by 10 mL of hot 95% ethanol. The content was vortexed and centrifuged (GALLENKOMP Centrifuge Model 90 - 1, USA) at 2000 rpm for 10 min. The supernatant was decanted while the sediment was hydrolyzed with perchloric acid and used to estimate starch content. The absorbance was read with a spectrophotometer (Milton Spectronic 601, USA) at 490 nm.

$$\%\text{Starch} = \frac{(\text{Absorbance} - 0.0044)4}{\text{sample wt} \times 0.55} \quad (4)$$

2.4.4.Determination of Amylose and Amylopectin content

The amylose content of the yam starch was determined based on the iodine colorimetric method of Williams *et al.* (1958) and Juliano (1971) as described by Addy *et al.* (2014). About 0.1 g of the starch sample was solubilized with 1 ml of 95% ethanol and 9 ml of 1 N NaOH, and heated in a boiling water bath for 10 min; 1 ml of the extract was made up to 10 ml with distilled water. To 0.5 ml of the diluted extract was added 0.1 ml I N acetic acid and 0.2 ml iodine solution (0.2 g I2+2.0 g KI in 100 ml of distilled water)to develop a dark blue colour. The coloured solution was made up to 10 ml with distilled water and allowed to stand for 20 min for complete colour development. The solution was vortexed and its absorbance was read on a spectrophotometer at 620 nm. Absorbance of standard corn amylose with known amylose concentration was used to estimate the amylose content.

$$\%\text{ Amylose} = \frac{\%\text{ amylose of standard} \times \text{Absorbance of sample}}{\text{Absorbance of standard}} \quad (5)$$

%Amylopectin= 100- Amylose content. (6)

2.4.5. Antinutritional factors of yellow yam and jack bean flour blends

2.4.5.1.Determination of saponin

The Spectrophotometric method of Brunner (1984) was used for saponin analysis. 1 g of flour sample was weighed into a 250 ml beaker and 100 ml Isobetyl alcohol was added. The mixture was shaken on a UDY shaker for 5 h to ensure uniform mixing. Thereafter, the mixture was filtered through a Whatman No. 1 filter paper into a 100 ml beaker and 20 ml of 40% saturated solution of Magnesium carbonate added. The mixture obtained with saturated $MgC0_3$ was again filtered through a Whatman No 1 filter paper to obtain a clear colourless solution. Then 1 ml of the colourless solution was pipetted into 50 ml volumetric flask and 2 ml of 5% $FeCl_3$ solution was added and made up to mark with distilled water. It was allowed to stand for 30 min for blood red colour to develop.Then 0-10 ppm standard saponin solutions were prepared from saponin stock solution. The standard solutions were treated similarly with 2 ml of 5% FeCl solution. The absorbances of the sample as well as standard saponin solutions were read after colour development on a T60 UV- visible spectrophotometer, U. K. at a wavelength of 380 nm.

Percentage saponin was calculated using the formula:

$$\text{Saponin (\%)} = \frac{\text{Absorbance of sample} \times \text{Average gradient} \times \text{Dilution factor}}{\text{weight of sample} \times 10{,}000} \quad (7)$$

2.4.5.2. Determination of trypsin inhibitor activity

The method of Kakade *et al.* (1974) was adopted for the determination of trypsin inhibitor activity as modified by Oluwole *et al.* (2013). 1g of flour sample was extracted with50ml of 0.01N NaOH, for 1 hr. The pH of the suspension was determined. This suspension was diluted to the point where 1 ml produces trypsin inhibition of 40 to 60%. 2 ml of trypsin solution was added to the test tubes, the tubes were placed in a water bath at 37°C. 5ml of BAPA solution previously warmed to 37°C was added, exactly 10 min, later the reaction was terminated by adding 1ml of 30% acetic acid. After thorough mixing, the contents of each tube was filtered (Whatman No.3) and the absorbance of the filtrate was measured at 410 nm against a reagent blank. Trypsin inhibitor activity is expressed in terms of trypsin units inhibited (TIU).

2.4.5.3Determination of total polyphenol content

Total polyphenols content was determined using the method described by Jayaprakasha *et al.* (2001) using Folin-Ciocalteu reagent with a minor modification. In a 2ml of Eppendorf tube, 780µl deionized water, 20µl sample extract, and 50µl Folin-Ciocalteu reagent (1:1 v/v) with water were added and mixed. After 1 minute, 150µl Sodium carbonate (0.2g/ml) was added, and the mixture was allowed to stand at room temperature in the dark for 1h. Then, 300µlofthe mixture was carefully introduced into a 96 well plate using Eppendorf micropipette. The absorbance was read at 750nm. The total polyphenol concentration was calculated from a calibration curve, using Gallic acid (1mg/ml) as standard (200 – 1000mg/L).

2.5.Functional properties of yellow yam and jack bean flour blends

2.5.1. Bulk density

Bulk density was determined using the method described by Wang and Kinsella, (1976) and Onwuka (2005). Ten grams of sample was weighed into 50ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top. The volume of the sample was recorded.

$$\text{Bulk density (g/ml)} = \frac{\textit{Weight of sample}}{\textit{Volume of sample after tapping}} \quad (8)$$

2.5.2. Dispersibility

This was determined by the method described by Kulkarni (1991) and Adebowale *et al.* (2012) Ten grams of flour was poured into 100 ml measuring cylinder and distilled water 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 dispersibility.

2.5.3. Water absorption capacity

Water absorption capacity of the flour samples were determined using the method described by Beuchat (1977) and Onwuka (2005).1 g of the flour was mixed with 10 ml of water in a centrifuge tube and allowed to stand at room temperature (30 ± 2 ºC) for 1 h. It was then centrifuged at 2000 rpm for 30 min. The volume of water on the sediment water measured. Water absorption capacities were calculated as ml of water absorbed per gram of flour.

2.5.4. Determination of swelling power and solubility index

The swelling power and solubility index was determined using the method described by Takashi and Siebel (1988) and Adebowale *et al.* (2012). One grams of flour was weighed into a 50 ml centrifuge tube. 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 90^{0}C for 15 minutes. During heating the slurry was stirred gently to prevent clumping of the flour. On completion, the tube containing the paste was centrifuged at 3,000rpm for 10 minutes using a centrifuge machine. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content of sediment gel was thereafter determined to get dry matter content of the gel.

$$\text{Swelling Power} = \frac{\text{weight of wet mass of sediment}}{\text{weight of dry matter in the gel}} \quad (9)$$

$$\text{Starch solubility index } \% = \frac{\text{weight of dry solids after drying}}{\text{weight of sample}} \text{ X } 100 \quad (10)$$

2.6. Physical properties of yellow yam and jack bean flour blends

2.6.1. Colour

The method described by Feili *et al.* (2013) was used. To measure the flour blends, Minolta chroma meter (CR- 410, Japan) was used based on (CIE) L* a* b* scale. After calibrating the instrument by covering a zero calibration mask followed by white calibration plate. Flour blends were analyzed by placing them on the petri dish, and then the image was captured on the samples. The colour attributes such as lightness (L*), redness (a*) and yellowness (b*) were recorded.

2.7. Pasting characteristics of yellow yam and jack bean flour blends

Pasting characteristics were determined with a Rapid Visco Analyzer (RVA TECMASTER, perten instrument-2122833, Australia). Three grams of sample were weighed into a dried empty canister, and then 25ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed properly so that no lumps were obtained and the canister was fitted into the rapid visco analyzer. A paddle was then placed into the canister and the test proceeded immediately automatically plotting the characteristic curve. Parameters estimated were peak viscosity, breakdown viscosity, final viscosity and setback value.

2.8 Statistical Analysis

All experimental data obtained from nutrient composition, functional, physical and pasting properties were carried out in triplicate. Data obtained were subjected to statistical analysis. Means, analysis of variance were determined using SPSS version 21.0 and the difference between the mean values were evaluated at $p<0.05$ using Duncan multiple range test. The optimization procedure was investigated using Design expert version (8.0) software. Regression analysis and significant effects of the independent variables were determined at 5% confidence level.

3. Results and Discussion

3.1. Nutrient composition of yellow yam-jackbean flour blends

The effect of yellow yam-jackbean flour inclusion on nutrient composition of the blend is shown in Table 2. The protein of the flour blends ranged from 9.97 to 16.72%.The interaction effect of yellow yam and jackbean flour did not significantly ($p>0.05$) affect the protein content of the flour blend as shown in the regression coefficient for the protein content of yellow yam and jackbean flour blends in Table 3. The result of protein content obtained in this study was slightly higher (9.97 to 16.72%) than that reported in previous studied by Awoyale *et al.* (2015) on water yam and distillers spent grain flour blends (7.2 to 15.10%) but lower than the value of Oluwamukomi and Adeyemi (2015) on yam and soybean flour blends (4.21 to 19.50%) and Okorie *et al.* (2016) on yam flour and cowpea flour blends (1.85 to18.21%). This might be due to the differences in the species of the yam and the nutritional composition of the soil from which the yam was harvested, the moisture content and the maturity of the crop (Osagie, 1992). The high protein content of yellow yam and jackbean flour blends reported in this study could also be attributed to the high protein content of jackbean. The high protein content in jackbean substituted with yellow yam flour will be of great nutritional importance in most developing countries such as Nigeria where there is an occurrence of protein malnutrition (Anuonye *et al.,* 2012; Okpala and Okoli, 2011).

The total carotenoid ranged between 5.24 and 6.65μg/g. Inclusion of yellow yam flour with jackbean at 7.50% had the highest value for total carotenoid while inclusion of yellow yam with jackbean flour at 10% had the lowest value. The regression table presented in Table 3 shows that the regression coefficient for total carotenoid content of yellow yam and jackbean flour blends were significantly ($p<0.05$) affected. Carotenoids are rich plants that contain antioxidant components which offer various health benefits such as reducing the risk of cardiovascular diseases, cancer and other degenerating diseases (Eleazu and Eleazu, 2012). In this study, the total carotenoid content of the yellow yam and jackbean flour were low this could be as a result of heat, temperature and drying methods employed during flour processing which could be responsible for the total carotenoid degradation (Olivera *et al.,* 2010). However, Hiane *et al.* (2003) and Thakkar *et al.* (2007) also reported that total carotenoid degradation also occurs in temperature close or superior to 40 °C, which was higher than the temperature (60 °C) used in this study. Other factor such as grinding /milling could influence the total carotenoid degradation of yellow yam and jackbean flour thereby exposing their cellular content to the environment (oxygen) in the passage through the milling machine thus facilitating the oxidative process could also contribute to the low total carotenoid content obtained in this work (Olivera *et al.,* 2010).

The starch content ranged from 79.38 to 80.07% with yellow yam-jackbean blends at 5% had the highest value for starch content while yellow yam-jackbean at 10% had the lowest value for starch. The high starch content of the flour blends obtained in this study might be attributed to the high starch content in yellow yam and jackbean flour. Wireko-Manu *et al.* (2011) reported that tuber crops such as yam are relatively rich in starch and within the range of 60.42 to 77.56%. The result obtained in this study were higher (79.38 to 80.07%) when compared with other species of yam such as greater yam and jackbean flour (67.34 to 69.22%) as reported by Affandi *et al.* (2016); Okorie *et al.* (2016) on water yam and cowpea flour (59.57 to 78.31%) and Rohmah *et al.* (2018) on water yam and lima bean (70.538 to 71.772%). According to Degras (1986); Muthukumarasamy and Pannerselvan, (2000) and Baah (2009), starch is well known to account for 80% on a dry weight basis of yam carbohydrate, hence, it is a key factor in determining the physicochemical, rheological and textural characteristics of yam food products. The interaction effect of yellow yam and jackbean flour had a significant ($p<0.05$) effect on the starch content of the flour blend as shown in Table 3.

The amylose and amylopectin content of the flour blends ranged from 25.36 to 29.88% and 70.13 to 74.65% respectively. Significant ($p>0.05$) effect were not observed in the amylose content of yellow yam and jackbean flour interaction as shown in Table 3. Amylose is a major component of starch which influences pasting and retrogradation behaviour (Zhenghong *et al.,* 2003) and impart definite characteristics to starch (Moorthy, 1994; Rosida *et al.,* 2017) while amylopectin ratio gives specific characteristics and functionality to starches by determining the texture and nature of their product (Moorthy, 1994; Scott, 1996; Ezeocha *et al.,* 2014).The result obtained for amylose (25.36 to 29.88) in this study were in agreement with the values of Rohmah *et al.* (2018) on water yam and lima bean (28.53 to 29.82%) but higher than the findings of Affandi *et al.* (2016) on greater yam and jackbean flour (17.23 to 20.38%) and other root and tuber crops such as sweetpotato and soybean flour blend (12.62 to 12.94%) as reported by

Omoniyi *et al.* (2016). This could be due to the activities of enzyme in the starch biosynthesis (Krossmann and Lioyd, 2000) and different species of yam in which the starch was isolated and analytical methods used to determine the amylose content (Aprianita *et al.,* 2014). However various researchers such as Moorthy (2002) and Rosida *et al.* (2017) reported the amylose content for *Dioscorea cayenensis* to be 21-25%, *Dioscorea rotundata* to be 27.48 to 31.55% (Addy *et al.,*2014), *Dioscorea alata* to be 20-36% (Harijono *et al.,* 2013) while Marimuthu and Gurumoorthi (2013) reported the amylose content of jackbean to be 33.24%. However, Rohmah *et al.* (2018) reported that food with high amylose content will be hard and firm while food high in amylopectin will stimulate puffing process, thereby making the product to be light, dry and crispy. Thus, the interaction effect of yellow yam and jackbean flour on the amylopectin content were not significantly (p>0.05) affected.

Table 2. Nutrient Composition of Yellow Yam and Jackbean Flour Blends

YF (%)	**JF (%)**	**Protein (%)**	**Total carotenoid (μg/g)**	**Starch (%)**	**Amylose (%)**	**Amylopectin (%)**
90.00	10.00	16.68^{d}	5.24^{a}	79.35^{a}	29.86^{d}	70.15^{a}
92.50	7.50	13.71^{c}	6.59^{bc}	79.91^{b}	28.75^{c}	71.25^{b}
90.00	10.00	16.72^{d}	5.24^{a}	79.38^{a}	29.88^{d}	70.13^{a}
93.75	6.25	9.97^{a}	6.16^{b}	79.94^{b}	26.68^{b}	73.32^{c}
92.50	7.50	13.75^{c}	6.65^{c}	79.93^{b}	28.73^{c}	71.27^{b}
90.00	10.00	16.68^{d}	5.24^{a}	79.43^{a}	29.83^{d}	70.18^{a}
95.00	5.00	10.42^{a}	6.27^{bc}	80.07^{b}	25.89^{ab}	74.11^{cd}
95.00	5.00	10.42^{a}	6.26^{bc}	79.97^{b}	25.91^{ab}	74.09^{cd}
91.25	8.75	11.81^{b}	5.42^{a}	79.67^{ab}	25.36^{a}	74.65^{d}

Mean values with different superscripts within the same column are significantly different (p <0.05); YF- Yellow Yam flour, JF- Jackbean flour

Table 3. Regression Coefficient of Nutrient Composition of Yellow Yam and Jackbean Flour Blends

Parameter	**Protein**	**Total carotenoid**	**Starch content**	**Amylose**	**Amylopectin**
A	10.35	6.24	80.01	26.08	73.92
B	16.45	5.19	79.40	29.47	70.54
AB	-3.97	2.45*	0.75*	-0.90	0.89
F-value	15.24	14.45	147.77	3.69	3.66
R^2	0.84	0.83	0.98	0.55	0.55

*Significant at (p<0.05): A- Yellow Yam flour, B- Jackbean flour, AB- Interaction effects of Yellow Yam and Jackbean Flour, R^2- Coefficient of determination

3.2. Antinutritional Factor of Yellow Yam and Jackbean Flour Blends

The effect of yellow yam-jackbean flour addition on the antinutritional factors of the blend is shown in Table 4. The saponin, trypsin inhibitor and total polyphenol ranged from 4.97 to 6.86%, 112.44 to 283.1% and 7.81 to 16.84% respectively. Saponins are considered important due to their toxicity in yams (Okwu and Ndu, 2006). The saponin content of yellow yam and jackbean flour blends were higher than 2.51 to 4.31% reported by Adelekan *et al.* (2013) on trifoliate yam and pumpkin seed flour. The high level of saponin (4.97-6.86) observed in the yellow yam and jackbean flour blends might be responsible for its characteristic bitter after taste. Saponins have natural affinity to ward off microbes which are helpful for treating fungal infection (Okwu and Ndu, 2006). They inhibit growth of cancer cells and help to lower blood cholesterol hence useful in the treatment of cardiovascular disease and other health related problems (Del-Rio *et al.,* 1997). The interaction effect of yellow yam and jackbean flour had no significant (p>0.05) effect on the trypsin inhibitor and total polyphenol as shown in Table 5. Trypsin inhibitor in legumes has been reported to be a limiting factor for their effective and efficient utilization (Leiner, 1996; Bamigboye and Adepoju, 2015). The high level of trypsin inhibitor (112.44-283.10%) of yellow yam and jackbean flour can be attributed to the high level of trypsin inhibitor in jackbean flour. However, Doss *et al.* (2011) reported the value of trypsin inhibitor in jackbean seed to be 378.3%. Trypsin inhibitor may hamper protein digestibility, trypsin inhibitor is thermo liable and may be destroyed with application of heat (Ohizua *et al.,* 2016; Olatunde *et al.,* 2019).

Polyphenol oxidase activity plays a significant role in enzymatic browning (Asiyanbi-Hammed, 2016). Poly phenol oxidase detected in yam and jackbean flour confirmed to the report that major yam species contain polyphenol oxidase activity with variation among species (Sanni and Fatoki, 2017). Ukom *et al.* (2014) reported the value of total polyphenol content for fresh *Dioscorea cayenensis* to be 27mgCE/100g. The high level of total polyphenol (8.42- 16.84%) of yellow yam and jackbean flour observed in this study can be due to the high level of polyphenol present in yam (*Dioscorea cayenensis*) flour. The result observed in this study for yellow yam and jackbean flour blends are higher than the values of 0.79 to 1.58% reported by Affandi *et al*. (2016) on greater yam and jackbean. This could also be due to different species of yam used in this study. However, the high quantities of total polyphenol compounds indicate that the flour samples could act as immune enhancers, hormone modulators, antioxidants, anti-clotting and anti-inflammatory (Okwu and Omodamoro, 2005). However, the interaction effect of yellow yam and jackbean flour on the total polyphenol content was not significantly (p>0.05) affected.

Table 4. Antinutritional Factors of Yellow Yam and Jackbean Flour Blends

YF (%)	JF (%)	Saponin (%)	Trypsin inhibitor (%)	Total polyphenol (%)
90.00	10.00	5.04^{a}	283.05^{c}	16.82^{a}
92.50	7.50	5.33^{b}	244.41^{c}	13.02^{a}
90.00	10.00	5.08^{a}	283.10^{c}	16.82^{a}
93.75	6.25	6.16^{c}	214.25^{bc}	9.07^{a}
92.50	7.50	5.34^{b}	244.45^{c}	13.14^{a}
90.00	10.00	4.97^{a}	283.05^{c}	16.84^{a}
95.00	5.00	6.43^{d}	201.85^{ab}	8.42^{a}
95.00	5.00	6.41^{d}	201.87^{ab}	8.47^{a}
91.25	8.75	6.86^{e}	112.44^{a}	7.81^{a}

Mean values with different superscripts within the same column are significantly different (p <0.05); YF- Yellow Yam flour, JF- Jackbean flour,

Table 5. Regression Coefficient of Antinutritional Factors of Yam and Jackbean Flour Blends

Parameter	Saponin	Trypsin inhibitor	Total polyphenol
A	6.35	211.71	8.71
B	5.19	267.97	16.17
AB	0.31	-135.13	-6.05
F-value	2.33	1.20	6.32
R^2	0.44	0.29	0.68

A- Yellow Yam flour, B- Jackbean flour, AB- Interaction effects of Yellow Yam and Jackbean Flour, R^2- Coefficient of determination

3.3. Functional properties of Yellow Yam and Jackbean Flour Blends

The effect of yellow yam-jackbean flour substitution on some functional properties of the blend is presented in Table 6. The bulk density of flour blends ranged from 0.62 to 0.73g/ml. The interaction effect of yellow yam and jackbean flour significantly ($p<0.05$) affect the bulk density of the flour blend as presented in Table 7. Bulk density depicts the behaviour of the material in dry mixes and is a significant parameter that can determine packaging requirement of the product (Mohammed *et al.,* 2009). The bulk density of yellow yam and jackbean flour blend (0.62 to 0.73g/ml) from this study were slightly higher than 0.62 to 0.68g/ml reported by Adelekan *et al.* (2013) on trifoliate yam and pumpkin seed flour but lower than the values of 0.56 to 0.84g/ml reported by Malomo *et al.* (2012) on yam (*Dioscorea rotundata*) and soybean flour. This may be due to different species and composition of flour used in substitution. Bulk density is an index of the heaviness of flour materials and expresses the relative volume of packaging material required. Bulk density is usually affected by the particle size and density of flour blend and it has significant application in packaging, transportation and raw material handling (Adebowale *et al.,* 2008; Ajanaku *et al.,* 2012; Adegunwa *et al.,* 2015). However, the low bulk density of the flour blends observed in this study would be of an advantage in the formulation of complementary food (Akpata and Akubor, 1999).

The dispersibility of flour blends ranged from 75.5 to 80.4%. Inclusion of yellow yam with jackbean at 5% had the highest value for dispersibility while inclusion of yellow yam with jackbean at 6.25% and 10% had the lowest dispersibility value. Dispersibility is a measure of how individual molecules of food sample usually flour is able to reconstitute in water. The higher the dispersibility value of yam and jackbean flour, the better the flour reconstitutes (Kulkarni *et al.,* 1991). The dispersibility values obtained for yellow yam-jackbean flour blends are relatively high and this is an indication that the flour blends will easily reconstitute to give fine consistency dough during mixing (Adebowale *et al.,* 2008; 2012). The dispersibility of the blends were not significantly ($p>0.05$) affected as shown in Table 7.

The water absorption capacity ranged from 4.19 to 6.54g/g. The interaction effect of yellow yam and jackbean had a significant ($p<0.05$) effect on the water absorption capacity as shown in Table 7. Water absorption capacity is the ability of flour to take up water and swell for improved consistency in food. It is also advantageous in food systems to improve yield and uniformity and give shape to the food products (Osundahunsi *et al.,* 2003). High water absorption capacity is attributed to loose structure of the starch polymers while low value indicates the compactness of the molecular structure. The values obtained for water absorption capacity of yellow yam and jackbean flour blends in this present work were low and this could be due to the protein and carbohydrate content of the flour blend (Omoniyi *et al.,* 2016; Khuthadzo *et al.,* 2019). This agrees with the study of Afoakwa (1996) that reported the significance of protein and starch in water uptake of flour at room temperature. The water absorption capacity of the yellow yam and jackbean flour blend could also be influenced by low solubility, thereby leaching out of amylose, and loss of molecular structure of the starch as well as the crystalline structure (Khuthadzo *et al.,* 2019). Therefore, low water absorption capacity of the yellow yam and jackbean flour blends obtained in this study has good ability to bind water and would useful in foods such as baked products which involved hydration to improve handling features (Oppong *et al.,* 2015).

The swelling power and solubility index ranged from 4.52 to 5.70g/g and 6.53 to 6.77% respectively. Interaction effect of yellow yam and jackbean flour had no significant effect on the swelling power and solubility index of the flour blend as shown in Table 7. Swelling power is the ability of the flour to absorb water and hold it in the swollen flour granule. Swelling power is influenced by amylose and amylopectin content. The higher the amylose content the lower the swelling power (Rosida *et al.,* 2017). The result obtained for the swelling power of yellow yam and jackbean flour blends were low and this might be attributed to the protein-amylose complex formation of the flour blend (Pomeranz, 1991; Oke *et al.,* 2013). According to Pomeranz (1991), formation of protein-amylose in flours may be the cause of a decrease in swelling power. The low value of swelling power of yellow yam and jackbean flour blends obtained in this study will be desirable for manufacture of value added product such as extruded product. The result of swelling power of yam and jackbean flour blends was slightly higher than 2.70 to 4.83g/g reported by Malomo *et al.* (2012) on other species of yam such as *Dioscorea rotundata* and soybean flour blends. The extent of swelling depends on the temperature, availability of water, species of starch and other carbohydrates and proteins (Sui *et al.,* 2006)

Solubility is an indication of the existence of strong bonding forces probably due to high amount of protein and fat that might form inclusion complexes with amylose (Pomeranz, 1991). The value of solubility (6.53-6.77%) observed in this study were moderately high, this could be as a result of starch degradation in the flour blends (Khuthadzo *et al.,* 2019). Sanni *et al.* (2001) reported that high solubility index could be due to high amount of amylose which leaches out easily during the swelling process. However, various factors such as characteristic of the flour granules (granule size and the size distribution), amylose and amylopectin ratio, mineral content and presence of other components may influence the solubility of starch index in a flour blends (Singh *et al.,* 2003). A higher value of solubility of flour signifies an improved digestibility. The high value of solubility index obtained in this study might be useful for food preparations especially for infants and the aged who needs more readily digestible food (Diah *et al.,* 2018).

Table 6. Functional Properties of Yellow Yam and Jackbean Flour Blends

YF (%)	JF (%)	Bulk density (g/ml)	Dispersibility (%)	WAC (g/g)	Swelling power (g/g)	Solubility index (%)
90.00	10.00	0.73^{b}	76.5^{a}	4.22^{a}	4.52^{a}	6.55^{a}
92.50	7.50	0.64^{a}	78.0^{a}	4.34^{a}	4.73^{a}	6.63^{ab}
90.00	10.00	0.73^{b}	75.5^{a}	4.22^{a}	4.59^{a}	6.56^{a}
93.75	6.25	0.64^{a}	75.5^{a}	6.02^{b}	5.60^{b}	6.62^{ab}
92.50	7.50	0.63^{a}	77.5^{a}	4.37^{a}	4.79^{b}	6.62^{ab}
90.00	10.00	0.71^{b}	76.0^{a}	4.19^{a}	4.60^{b}	6.59^{ab}
95.00	5.00	0.62^{a}	80.4^{a}	6.50^{c}	5.65^{b}	6.65^{ab}
95.00	5.00	0.62^{a}	80.1^{a}	6.54^{c}	5.70^{b}	6.77^{b}
91.25	8.75	0.63^{a}	78.0^{a}	4.49^{a}	5.70^{b}	6.53^{a}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); YF- Yellow Yam flour, JF- Jackbean flour, WAC- Water absorption capacity

Table 7. Regression Coefficient of Functional Properties of Yellow Yam and Jackbean Flour Blends

Parameter	Bulk density	Dispersibility	WAC	Swelling power	Solubility index
A	0.62	79.64	6.61	5.66	6.71
B	0.72	72.29	4.22	4.66	6.56
AB	-0.18*	-2.90	-3.02*	-0.095	-0.14
F-value	24.85	3.84	40.82	3.98	7.27
R^2	0.89	0.56	0.93	0.57	0.71

*Significant at ($p<0.05$): A- Yellow Yam flour, B- Jackbean flour, AB- Interaction effects of Yellow Yam and Jackbean Flour, R^2- Coefficient of determination, WAC- Water absorption capacity

3.4. Physical (Colour) Attribute of Yellow Yam and Jackbean Blends

The effect of yam-jackbean flour inclusion on the yellowness (b*) of the blend is presented in Table 8. There were no significant ($p>0.05$) effect on the yellowness of yellow yam and jackbean flour interaction as shown in Table 9.The yellowness (b*) of yellow yam and jackbean ranged from12.28 to 13.77 with inclusion of yellow yam and jackbean at 6.25% having the lowest value for yellowness while inclusion of yellow yam and jackbean at 8.75% had the highest value for yellowness (b*). Colour is an important characteristic in food product identification and acceptability (Adeola *et al.,* 2018). According to Szabo *et al.* (2016), the resulting b* of the flour blends signifies the yellowness of the flour blends. The result obtained for the yellowness of yam and jackbean flour in this study could have been caused by carotenoids content because *Dioscorea cayenensis* is a rich source of total carotene (Ukom *et al.,* 2014). Colour is the first property that consumers consider in food products (Kumar *et al.,* 2012)

Table 8. Colour Attributes of Yellow Yam and Jackbean Flour Blends

YF (%)	JF (%)	Yellowness (b*)
90.00	10.00	13.12[d]
92.50	7.50	12.73[c]
90.00	10.00	13.22[d]
93.75	6.25	12.28[a]
92.50	7.50	12.76[c]
90.00	10.00	13.19[d]
95.00	5.00	12.50[b]
95.00	5.00	12.53[b]
91.25	8.75	13.77[c]

Mean values with different superscripts within the same column are significantly different ($p <0.05$); YF- Yellow Yam flour, JF- Jackbean flour,

Table 9. Regression Coefficient of Colour Attribute of Yellow Yam and Jackbean Flour Blends

Parameter	Yellowness (b*)
A	12.40
B	13.28
AB	0.11
F-value	4.38
R^2	0.59

A- Yellow Yam flour, B- Jackbean flour, AB- Interaction effects of Yellow Yam and Jackbean Flour, R^2- Coefficient of determination

3.5. Pasting properties of Yellow Yam and Jackbean Blends

The effect of yellow yam-jackbean flour substitution on the pasting properties of the blend is presented in Table 10. The peak and final viscosity of the flour blends ranged from 206.0 to 572.0RVU and 263.0 to 911.0 RVU. The peak and the final viscosity was significantly ($p<0.05$) affected by the interaction effect of yellow yam and jackbean flour blends as illustrated in Table 11. Peak viscosity is the ability of starches to swell freely before their physical breakdown and indicates the strength of the pastes formed during gelatinization (Sanni *et al.,* 2004). The differences in the peak viscosity of yellow yam and jackbean flour blend obtained in this study indicates that there were differences in the rate of water absorption and starch granule swelling during heating (Ragaee and Abdel-Aal, 2006). The high peak viscosity exhibited by yellow yam and jackbean flour indicates that the flour will be suitable for products requiring high gel strength and elasticity such as extruded snacks (Adebowale *et al.,* 2005). High peak viscosity is an indication of high starch content and it also indicates water binding capacity of the flour and is often correlated with final product quality as well as providing an indication of the viscous load likely to be encountered by mixing cooking (Ikegwu *et al.,* 2010).

The final viscosity is the ability of the starch to form a viscous paste and gel during cooking and after cooling respectively (Maziya-Dixon *et al.,* 2007). The high value obtained for the final viscosity (263.0-911.0RVU) of yellow yam and jackbean flour compared to the peak viscosity (206.0-572.0RVU may be due to high degree of association between starch–water and their ability to recrystallize. The high final viscosity obtained in this study indicates their high resistance to shear stress during cooking and cooling. The final viscosity of flour is affected by protein content which could bind water so that water availability is decreased

The breakdown and setback viscosity ranged from 5.00 to 17.0RVU and 279.0 to 372.0 RVU respectively. The interaction effect of yellow yam and jackbean flour had no significant ($p>0.05$) effect on breakdown and setback viscosity as shown in Table 11. The breakdown viscosity of flour is referred to as a measure of the degree of disintegration of starch granules or its paste stability during heat (Asaam *et al.,* 2018). A higher breakdown viscosity value indicates a lower ability of the flour blends to withstand heating and shear stress during cooking (Adebowale *et al.,* 2005). Therefore the result obtained for yam and jackbean flour blend in this study suggest, they might withstand heating and shear processes without major change in consistence. Low stability of starch paste is associated with high value of breakdown (Ikegwu *et al.,* 2010).

Setback involves retrogradation or re-ordering of the starch molecules and setback viscosity has been correlated with the texture of various products (Maziya-Dixon *et al.,* 2005). The high setback (279.0 to 372.0RVU) observed for yam and jackbean flour blends in this study suggests that the flours were relatively unstable when cooked and have higher tendency to undergo retrogradation during freeze/thaw cycles. The higher the setback, the lower the retrogradation during cooling and the lower the rate of staling of the products made from the flour (Adeyemi and Idowu, 1990).

Table 10. Pasting Properties of Yellow Yam and Jackbean Flour Blends

YF (%)	JF (%)	Peak (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback value (RVU)
90.00	10.00	209.0^{b}	5.00^{a}	554.0^{c}	350.0^{e}
92.50	7.50	435.0^{f}	9.00^{b}	755.0^{a}	329.0^{b}
90.00	10.00	206.0^{a}	6.00^{a}	559.0^{e}	345.0^{d}
93.75	6.25	549.0^{g}	14.0^{d}	907.0^{f}	372.0^{g}

92.50	7.50	429.0^{e}	10.0^{b}	263.0^{b}	333.0^{c}
90.00	10.00	212.0^{c}	11.0^{bc}	556.0^{d}	350.0^{e}
95.00	5.00	568.0^{h}	10.0^{b}	908.0^{f}	350.0^{e}
95.00	5.00	572.0^{i}	12.0^{cd}	911.0^{g}	354.0^{f}
91.25	8.75	292.0^{d}	17.0^{e}	555.0^{cd}	279.0^{a}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); YF- Yellow Yam flour, JF- Jackbean flour,

Table 11. Regression Coefficient of Pasting Properties of Yellow Yam and Jackbean Flour Blends

Parameter	Peak	Breakdown viscosity	Final viscosity	Setback viscosity
A	578.56	16.34	956.59	361.49
B	203.16	6.55	561.95	340.88
AB	162.22*	2.17	-1334.96*	-100.99
F-value	221.09	26.44	6.24	1.14
R^2	0.99	0.90	0.68	0.28

*Significant at ($p<0.05$): A- Yellow Yam flour, B- Jackbean flour, AB- Interaction effects of Yellow Yam and Jackbean Flour, R^2- Coefficient of determination

3.6. Optimisation of yam and jackbean flour blends

The flour blends was optimized based on some important properties attributed to extruded snacks product. The flour blends were maintained within the range of the study while the desired goal for each parameter and response was chosen with respect to the following dependent factors and as well as their main quality parameters serving as the constraints to process optimization: Protein, total carotenoid, starch content, amylose, amylopectin, dispersibility, water absorption capacity, swelling power, solubility, peak, breakdown viscosity, yellowness were maximize, bulk density, final viscosity, setback value were minimize and saponin, trypsin inhibitor, total polyphenol were set at none. The optimum flour blend ratio was 94.11% yellow yam flour and 5.89% jackbean flour. The solution to the optimised yellow yam and jackbean flour is presented in Table 12.

Table 12: Solution to Process Optimisation of Yam and Jackbean Flour Blends

YF	JF	PROT	TC	SC	AMY	AMYL	BD	DIS	WAC	SP
94.11	5.89	10.85	6.41	80.10	26.55	73.45	0.61	78.63	5.75	5.47

SOL	PEAK	BRD	FINAL	SB	YEL	DESIRABILITY
6.66	535.6	14.92	691.6	343.0	12.57	0.744

YF-Yam flour, JF-Jackbean flour, PROT- Protein, TC-Total carotenoid, SC-Starch content, AMY-Amylose, AMYL-Amylopectin, BD-Bulk density, DIS-Dispersibility, WAC-Water absorption capacity, SP-Swelling power, SOL-Solubility, BRD- Breakdown viscosity, YEL-Yellowness.

4. Conclusions

The study showed that the use of jackbean has the advantage of improving the protein content. The amylose, amylopectin and the starch content of yellow yam increases while the carotenoid content of the blend decreases. Addition of jackbean flour had a pronounced effect on the functional and pasting properties leading to lower bulk density, water absorption capacity, swelling power, peak viscosity and final viscosity. Hence, flour blends from yellow yam and jackbean can be used in development of food product such as extruded snacks and cooked paste.

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