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PHYSICOCHEMICAL AND RHEOLOGICAL PROPERTIES OF OPTIMISED COCOYAM-BASED COMPOSITE FLOUR COMPRISING CASSAVA STARCH

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Abstract: Composite flour comprising cocoyam (*Colocassia esculenta*), bambara groundnut and cassava starch was produced. The proximate and minerals compositions and functional properties were optimized using optimal mixture design of response surface methodology. The antinutritional, pasting and farinograph analyses of the optimum blends were evaluated. Bambara groundnut improved protein, fibre, ash and minerals contents; cassava starch improved swelling capacity, least gelation and pasting characteristics. The optimum blends CBC1 (70% cocoyam flour, 18.33% bambara groundnut flour, 11.67% cassava starch) and CBC2 (69.17% cocoyam flour, 16.67% bambara groundnut flour, 14.17% cassava starch). were comparable to wheat–based flour samples (60% wheat, 30% cocoyam, 10% bambara groundnut flours) and (72% wheat, 19% cocoyam, 9% bambara groundnut flours) in terms of pasting and farinograph analyses.

Keywords: cassava starch, cocoyam flour, composite flour,optimised, viscoelastic, pasting characteristics

INTRODUCTION

Efforts of researchers are being centered on gluten-free composite flours made from cereal, tubers and legumes as possible replacement to 100% wheat flour (Awolu et al., 2016a; Awolu et al., 2016b; Bamigbola et al., 2016). The reduction or total removal of gluten in composite flours and attendant increase in the protein, fibre and mineral compositions will enhance the health of the consumers (Bamigbola et al., 2016; Noorfarahzila et al., 2014). Several researches utilizing rice, maize, sorghum, millet, bambara groundnut, plantain and potato for production of gluten-free products (cakes,

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cookies, biscuits and bread) have been carried out (Awolu et al., 2016a; Awolu et al., 2016b; Awolu et al., 2015).
Cocoyam (*Colocasia esculenta*) is a well-known food plant and an important source of carbohydrate. The nutritional and chemical compositions as reported by FAO (2006) show that cocoyam, if fully exploited would enhance the food security of people living in the tropics.
Bambara groundnut (*Vigna subterranea*) is a pulse cultivated over much of semi-arid Africa (Linnenann and Azam–Ali, 1993). The protein of bambara groundnut is of good quality and has surplus lysine which complements cereals in the diet (Ocran et al., 1998). It is high in protein but unlike ordinary groundnuts contains very little oil (Tweneboah, 2000).
Hydrocolloids are being added to composite flours in order to create a polymer network with similar functionality to that of the wheat gluten protein (Awolu et al., 2016a; Noorfarahzila et al., 2014; Saha and Bhattacharya, 2010). Cassava starch, being a hydrocolloid, is expected to influence dough characteristics of composite flours.
Gluten-free composite flour is produced from cocoyam and bambara groundnut flour in this work. Cassava starch is added in order to improve its viscoelastic properties. The rheological characteristics of the cocoyam-based composite flour will be compared with wheat-based composite flour samples (60% wheat, 30% cocoyam and 10% bambara groundnut flours and 70% wheat, 19% cocoyam and 9% bambara groundnut flours).

MATERIALS AND METHODS

Materials

Cocoyam tubers, bambara groundnuts and wheat flour were sourced from Oja- Oba in Akure. Cocoyam starch was obtained from Matna foods, Akure. Xanthan gum was obtained from Lagos.

Experimental design

The experimental design was carried out using optimal mixture design of response surface methodology (Design Expert 8.0.3.1 trial version). The variables were cocoyam flour (A) (65 – 70%), bambara groundnut flour (B) (15 – 20%) and cassava starch (C) (10 – 15%). The reponses were proximate (protein, carbohydrate, ash, crude fiber, fat and moisture) and minerals (calcium, potassium, magnesium, zinc and iron) compositions. Sixteen experimental runs were generated.

Preparation of cocoyam flour

The method of Ukonze and Olaitan (2010) was adopted for cocoyam flour production. Cocoyam tubers (700 g) were washed in water five times until all debris was removed. The tubers were manually peeled and sliced (3-4 cm), in order to increase the surface area for quick and complete drying in sulphated water. The sliced cocoyam were blanched for 10 min, drained and oven dried at 65°C for 10 h, milled using hammer mill, cooled, sieved and stored at room temperature for further processing.

Bambara groundnut flour preparation

Exactly 250 g bambara groundnut seeds were well cleaned by sorting, washing; soaked in boiled water for 30 min, manually dehulled, oven-dried at 65 °C and dry-milled to fine powder. The flour was later stored in a cool, dry air at room temperature (Olapade and Adetuyi, 2007).

Determination of proximate composition of samples

The proximate compositions (moisture, ash, fat, crude fibre, protein) were determined the method of AOAC (2005) while carbohydrate content was determined by difference (Egounlety and Awoh, 1990).

Determination of functional properties

The methods of Onwuka (2005) were used for the determination of water and oil absorption capacities, bulk density, swelling index, least gelation capacity, foaming capacity and foaming stability.

Minerals analyses

Calcium, Magnesium, Zinc, and Iron were analysed using Atomic Absorption Spectrophotometer (AAS) while Potassium was analysed using flame photometry method (AOAC, 2005).

Statistical analyses

The statistical analysis was carried out using response surface methodology,; multiple regressions and ANOVA were employed for correlations between variables and responses and model fittings respectively. The pasting characteristics, farinograph testing and antinutritional properties of the optimal blends were compared with those of wheat-based flour samples CBW1 (60% wheat, 30% cocoyam and 10% bambara groundnut flours) and CBW2 (70% wheat, 19% cocoyam and 9% Bambara groundnut flours) obtained from previous study.

Pasting properties

The pasting characteristics of the composite flours were evaluated using rapid visco-analyser (RVA, model 3D; Newport Scientific, Sydney, Australia) monitored with RVA control software.

Farinograph analysis

Farinograph testing was carried out using Brabender-Farinograph. Exacly 300 g (14% moisture content) was placed into the mixing bowl, water added until dough was formed and readings taken. The curve was centered on the 500-Brabender unit (BU) line ± 20 BU by adding the appropriate amount of water until the curve leaves the 500- BU line.

Antinutritional analyses

Tannin determination was by method of Makkar and Goodchild (1996); phytate by method of Wheeler and Ferrel (1971), while trypsin inhibition was by method of Kakade et al. (1969), as modified by Smith et al. (1980).

RESULTS AND DISCUSSIONS

Proximate composition

The crude protein ranged from 18.69 to 19.55 g/100g. The protein content was higher than what has been obtained for 100% wheat flour. Supplementation of the cocoyam flour with bambara groundnut flour is responsible for the high protein contents. Development of gluten-free bakery product with high protein content have been desirable. Cocoyam has been shown to have about 7.9% protein content (Apata and Babalola, 2012) while bambara groundnut (a legume) has about 22.46% protein content (Oyeleke et al., 2012). The result showed that composite flours consisting tubers and legumes in the proportion obtained in this study will produced bakery products rich in protein.

Cereal-legumes composite flours have been shown to have high protein content (Awolu et al., 2016a; Awolu et al., 2015; Omoba et al., 2013). The ANOVA indicated a significant ($p \leq 0.05$) model (quadratic) and model terms (AB and BC), while the R-squared and adjusted R-squared values were 0.7283 and 0.5925 respectively. These low values indicated low contribution of cocoyam flour and cassava starch to protein. The 3D plot showing the interactions between the variables and protein content is shown in Figure 1a.

The carbohydrate contents ranged from 68.04 to 72.89 g/100g. This carbohydrate content is high and comparable to that of 100% wheat flour. The result is a clear departure from many gluten-free products which normally have high fat content but with low carbohydrate dietary reference intake (Thompson, 2000; Matos and Rosell, 2014). The model (cubic) and model terms (Linear mixture, AB, AB(A-B), and AC(A-C)) were significant ($p \leq 0.05$). Cocoyam flour (A) significantly ($p \leq 0.05$) contributes to the carbohydrate contents than other raw materials used. Cocoyam had been reported to be a good source of carbohydrate (72-87.7%) (Amandikwa, 2012; Oladunmoye et al., 2014). The R-squared and adjusted R-squared values were 0.9755 and 0.9388 respectively. This high values showed that bambara groundnut and cassava starch flours in addition to coocyam flour contributed to the carbohydrate content. The final equation is shown in Eq. (1) while the

3D plot showing the interactions between the variables and carbohydrate is shown in Figure 1b.

$$Carbohydrate = 117.67A + 95.25B + 15.43C - 140.41AB + 25.37AC + 62.81BC + 15.02ABC - 259.88AB(A-B) + 103.01AC(A-C) - 365.06BC(B-C) \quad (1)$$

The ash content ranged from 0.53-2.48 g/100g. The ash content increases with increasing cocoyam and bambara groundnut contents. The ash contents obtained (especially at values of 1.80 g/100 g) were above values obtained for commercial rice flour (1.0 g/100 g) and some wheat flour varieties (1.24 – 1.71 g/100 g) as reporeted by Matos and Rosell (2014) and Vizitiu and Danciu (2011) respectively. It has been shown that cocoyam had ash content between 1.2-2.5% (Amandikwa, 2012) while bambara groundnut flour had about 4.0% ash content (Oyeleke et al., 2012). The cubic model and model terms (Linear mixture, AB, AC, BC, ABC, AB(A-B), AC(A-C), BC(B-C)) were significant ($p \leq 0.05$). This indicates the raw materials to be good minerals sources. The R-squared and adjusted R-squared values were 0.9977 and 0.9943 respectively. The final equation is shown in Eq. (2) while the 3D plot showing the interactions between the variables and ash is shown in Figure 1c.

$$Ash\ - 46.88A + 23.60\,B - 5.54C + 53.72AB + 111.98AC - 28.33BC - 104.61ABC + 177.13AB(A-B) - 9.41AC(A-C) + 54.75BC(B-C) \quad (2)$$

The crude fiber of the sample ranged from 1.18-3.71 g/100 g. The upper limit (3.71 g/100g) of fibre in this work falls within the range (1.3 – 7.20 g /100 g) that has been obtained for GF products. Cocoyam and bambara groundnut had been found to have an appreciable amount of crude fiber (Amandikwa, 2012; Yetunde et al., 2009; Oyeleke et al., 2012). The model (quadratic) and model terms (AC(A-C) and BC(B-C)) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.8875 and 0.7189 respectively while the final equation is shown in Eq. (3). The 3D plot showing the interactions between the variables and crude fiber is shown in Figure 1d.

$$Crude\,fibre\ = -6.00A - 35.44B + 18.05C + 88.43AB - 17.35AC + 41.95BC - 66.09ABC + 100.55AB(A-B) - 121.27AC(A-C) + 219.80BC(-C) \quad (3)$$

Fat content was between 1.32-1.71 g/100g. Since one of the major concern in the development of gluten-free foods is the excessive fat content (Thompson, 2000), the values obtained in this study falls within acceptable limits for flours. The model (quadratic) and model term (Linear mixture) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.8670 and 0.7168 respectively. These attest to the fact that the raw materials are not good sources of fat, hence, the composite flour will serve as a good source of gluten-free flour with moderate fat contents. The 3D plot showing the interactions between the variables and fat is shown in Figure 1e while the final equation is given in Eq. (4).

$$Fat = 0.57A + 3.10B + 3.71C - 2.04AB - 2.19AC - 7.28BC + 40.49A2B + 4.93AB2C - 17.68ABC2 \quad (4)$$

The moisture content ranged from 2.69 to 5.94%. The values are low, hence, the composite flour would be shelf-stable (Bugusu et al., 2001, Eke-Ejiofor et al., 2013).

Minerals content of the composite flour

The calcium content ranged from 2.00 to 4.20 mg/100g. The model (cubic) and model terms (linear mixture, AC, BC, ABC, BC (B-C)) were significant ($p \leq 0.05$) while the R-squared and adjusted R-squared values of 0.9323 and 0.8307 respectively showed that the raw materials are good sources of calcium. The 3D plot showing the interaction between the variables and calcium is shown Figure 2a, while the final equation is shown in Eq. (5).

$$\mathrm{Ca} = 3.48\mathrm{A} + 2.90\mathrm{B} + 4.18\mathrm{C} + 1.23\mathrm{AB} - 4.52\mathrm{AC} - 5.77\mathrm{BC} + 40.06\mathrm{ABC} - 13.42\mathrm{AB}\,(\mathrm{A}-\mathrm{B}) - 5.85\mathrm{AC}\,(\mathrm{A}-\mathrm{C}) - 13.85\mathrm{BC}\,(\mathrm{B}-\mathrm{C}) \quad (5)$$

The potassium content of the sample ranged from 117.0-149.0 mg/100g. The sample has high concentration of potassium. Potassium is required to maintain osmotic balance of the body fluids in addition to regulating muscle and nerve irritability, glucose absorption, and protein retention during growth (National Research Council, 1980). The model (cubic) and model terms (linear mixture, AC, AB, BC, BC (B-C)) were significant ($p \leq 0.05$) while the R-squared and adjusted R-squared values were 0.9878 and 0.9696 respectively. The final equation is shown in Eq. (6). All the samples (A, B, C) have high and positive coefficients, meaning they are good sources of potassium. The 3D plot showing the interactions between the variables and potassium is shown in Figure 2b.

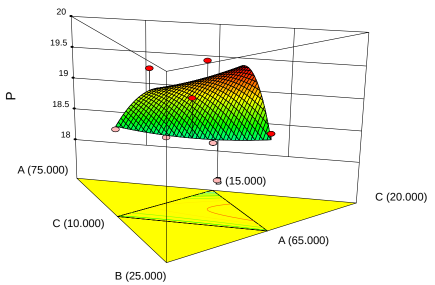

Figure 1a: Response surface plot for protein content

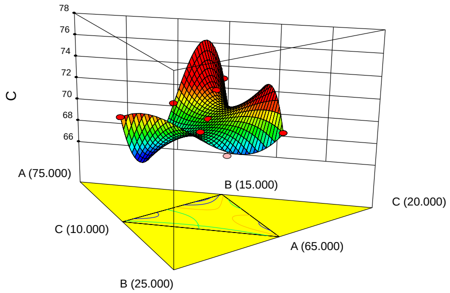

Figure 1b: Response surface plot for carbohydrate content

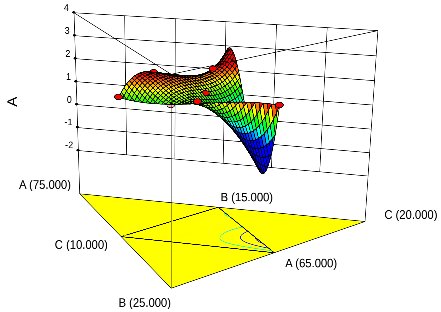

Figure 1c: 3D plot for ash content

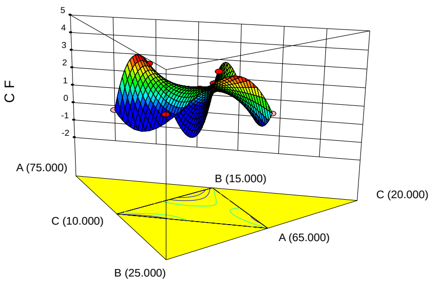

Figure 1d: 3D plot for crude fiber content

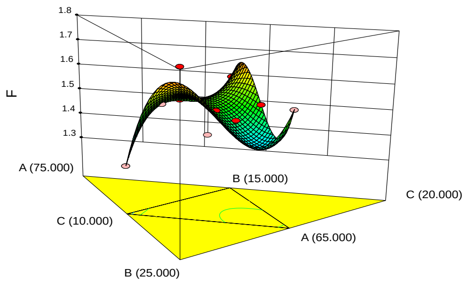

Figure 1e: 3D plot for fat content

$$K = 128.10A + 123.00B + 149.10C - 34.21AB - 29.13AC + 23.79BC + 80.76ABC + 40.46AB(A - B) - 20.25AC(A - C) + 117.31BC(B - C) \quad (6)$$

Magnesium content ranged from 6.67 to 7.62 mg/100g. Magnesium is needed in the body for regulation biochemical reactions such as protein synthesis, muscle and nerve function, blood glucose control and blood pressure regulation. The cubic model and model terms (linear mixture, BC, ABC, AB (A-B)) were significant ($p \leq 0.05$); the R-squared and adjusted R-squared values were 0.9388 and 0.8469 respectively. The 3D plot showing the interactions between the variables and magnesium is shown in Figure 2c while the final equation is shown in Eq. (7).

$$Mg = 7.11A + 7.43B + 7.61C - 0.37AB - 0.61AC - 1.17BC + 7.34ABC + 14.42AB(A - B) + 1.53AC(A - C) + 2.07BC(B - C) \quad (7)$$

Zinc content ranged from 0.2 to 0.35 mg/100g. Zinc plays a key role in maintaining good vision and can also be used to boost the immune system. The model (cubic) and model terms (linear mixture, AC, BC, ABC) were significant ($p \leq 0.05$); the R-squared and adjusted R-squared values were 0.9472 and 0.8681 respectively. The 3D plot showing the interactions between the variables zinc and is shown in Figure 2d while the final equation is shown in Eq. (8).

$$Zn = +0.23A + 0.35B + 0.35C - 0.038AB - 0.19AC - 0.52BC + 2.80ABC + 1.31AB(A - B) - 0.068AC(A - C) - 0.21BC(B - C) \quad (8)$$

The iron (Fe) content ranged from 0.51-1.86 mg/100g. Bambara is a good source of iron. The model terms (linear mixture, AB, AC, BC and AB (A-B)) as well as cubic model were significant ($p \leq 0.05$) while the R-squared and adjusted R-squared values were 0.9992 and 0.9979 respectively. The 3D plot showing the interactions between the variables and iron is shown in Figure 2e while the final equation is shown in Eq. (9).

$$Fe = 0.64A + 1.86B + 0.84C - 2.80AB - 0.45AC - 2.20BC + 0.060ABC + 6.62AB(A - B) + 0.11AC(A - C) + 0.69BC(B - C) \quad (9)$$

Functional properties of composite flour

The foaming capacity ranged from 5.1 to 13.75%. Foaming capacity (FC) increased with increasing protein content. High foaming capacity enhances flour functionality for cakes production (Lee et al., 1993) and whipping topings where whipping is an important property (Kinsella, 1976). The model (quadratic) and model terms (linear mixture and AB) were significant ($p \leq 0.05$); the R-squared and adjusted R-squared values were 0.7716 and

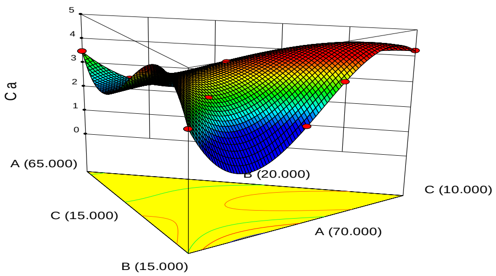

Figure 2a: 3D plot for calcium content

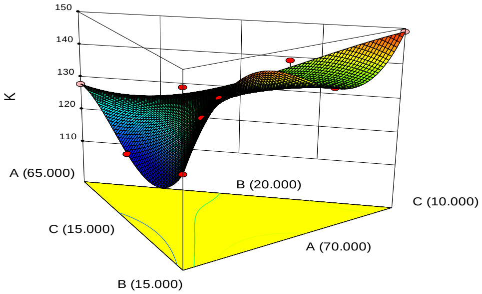

Figure 2b: 3D plot for potassium content

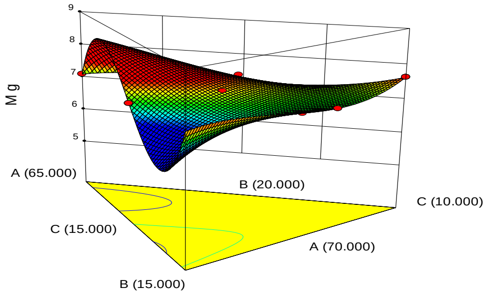

Figure 2c: 3D plot for magnesium content

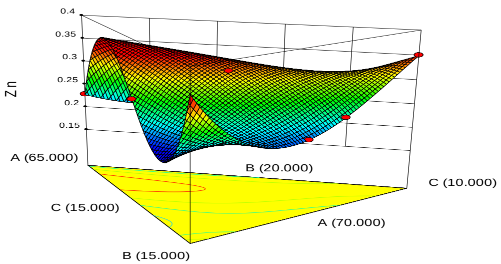

Figure 2d: 3D plot for zinc content

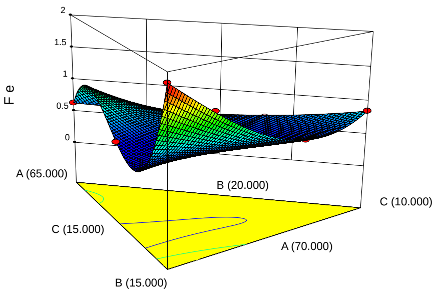

Figure 2e: 3D plot for iron content

0.6575 respectively. The 3D plot showing the effect of the variables on the foaming capacity is shown in Figure 3a while the final equation is presented in Eq. (10).

$$FC = +5.61A + 8.08B + 13.84C + 15.13AB - 7.24AC - 5.69BC \quad (10)$$

The foaming stability (FS) ranged from 1.0 to 5.65. It shows that the composite flour will serve as a good whipping agent, being able to its ability to maintain the whip as long as possible (Aremu et al., 2008). The cubic model and model terms (linear mixture, AB, AC, AC (A-C)) were significant ($p \leq 0.05$). The R-squared and adjusted R-square values were 0.9491 and 0.8727 respectively while the 3D plot showing the effect of the variables on the foaming stability is shown in Figure 3b. The final equation is presented in Eq. (11)

$$. \ FS = 3.97A + 3.90B + 4.02C - 4.15AB - 4.96AC + 0.15BC - 30.28ABC - 1.30AB(A-B) - 31.28AC(A-C) + 1.57BC(B-C) \quad (11)$$

The water absorption capacity (WAC) ranged from 7.15 to 8.05 g/g. WAC increased with increasing protein content (Kinsella, 1976). Increase in water absorption capacity is useful in baking products which requires hydration to improve dough handling characteristics (Kiin-Kabari et al., 2015). The model (cubic) and model terms (Linear mixture, AB, AC, BC, ABC, AB (A-B), AC (A-C), BC (B-C)) were all significant ($p \leq 0.05$); the R-squared and adjusted R-square values were 0.9491 and 0.8727 respectively. While the 3D plot showing the effect of the variables on the WAC is shown in Figure 3c, the final equation is given in Eq. (12).

$$WAC = +7.95A + 7.35B + 7.65C + 1.21AB - 1.41AC - 0.79BC + 8.44ABC - 8.04AB(A-B) - 4.39AC(A-C) - 1.06BC(B-C) \quad (12)$$

Oil absorption capacity (OAC) (7.25 and 7.84 g/g) is useful in flavor retention and to improve palatability of bakery products (Adebowale and Lawal, 2004). The model (cubic) is significant ($p \leq 0.05$) while Linear mixture, AB (A-B), BC (B-C) were significant ($p \leq 0.05$) model terms; the R-squared and adjusted R-square values were 0.9112 and 0.7779 respectively. The 3D plot showing the effect of the variables on the OAC is shown in Figure 3d while the final is given in Eq. (13).

$$OAC = +8.24A + 8.25B + 7.84C + 0.42AB - 0.69AC - 0.78BC + 12.32ABC + 23.65AB(A-B) + 2.48AC(A-C) + 7.47BC(B-C) \quad (13)$$

The bulk density (0.708 and 0.762 g/cm^3) was higher than 100% wheat flour (0.34g/ml) obtained by Kiin-Kabari et al., (2015). This considerable high value (Awolu et al., 2015) enhances ease of dispersibility as well as reduces paste thickness (Amadinkwa, 2012). The model (special cubic) and model terms (Linear mixture, AB, AC and ABC) were all significant ($p \leq 0.05$); the R-squared and adjusted R-square were 0.8892 and 0.8153 respectively. The 3D plot showing the effect of the variables on the bulk density is shown in Figure 3e while the final equation is given in Eq. (14).

$$BD = 0.71A + 0.74B + 0.73C + 0.13AB + 0.11AC - 0.021BC - 1.29ABC \quad (14)$$

The swelling index ranges from 4.5 to 8.5%. Composite flour with highest cassava starch (binder) content had the highest swelling index which enhances flour quality. It has been shown that swelling power reflects the water absorption index of granules during heating. The model (quadratic) and model terms (Linear mixture, AB, AC and BC) were significant ($p \leq 0.05$), while the R-squared and adjusted R-square values were 0.8484 and 0.772 respectively. The 3D plot showing the effect of the variables on the swelling index is shown in Figure 3f; the final equation is given in Eq. (15).

$$SI = 6.91A + 5.54B + 5.50C + 9.19AB - 4.36AC + 4.27BC \quad (15)$$

The least gelation ranged from 0.37 to 1.50. Gelation is associated with the disruption of the granular structure of starches, including appearance of polarization cross linkages and irreversible swelling of the starch granule when heated in excess water to progressively higher temperatures (Ogungbenle, 2009). Gels are characterized by relatively high viscosity, plasticity and elasticity (Circle et al., 1964). Better gelling properties indicated provision of structural matrix for holding water, flavour, and sugar of food products (Ogungbenle, 2009). The model (cubic) and model terms (linear mixture, AB, BC, ABC, AB(A-B), AC(A-C) and BC(B-C) were significant ($p \leq 0.05$); the R-squared and adjusted R-square values were 0.9756 and 0.9391 respectively. The high the R-squared and adjusted R-square values indicates that the raw materials enhances gelling characteristics. The final equation is given in Eq. (16).

$$LG = 0.38A + 0.80B + 0.78C + 2.57AB + 0.064AC + 2.85BC - 14.29ABC + 26.22AB(A-B) + 2.93AC(A-C) + 13.73BC(B-C) \quad (16)$$

Optimum blends

The optimum blend selected based on the proximate composition, minerals properties and functional properties of the samples are samples CBC1 (70% cocoyam, 18.333% bambara groundnut and 11.667% cassava starch flours)

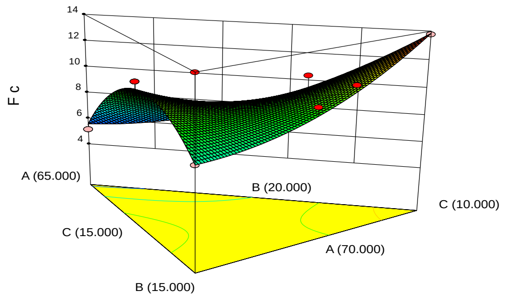

Figure 3a: 3D plot of foaming capacity

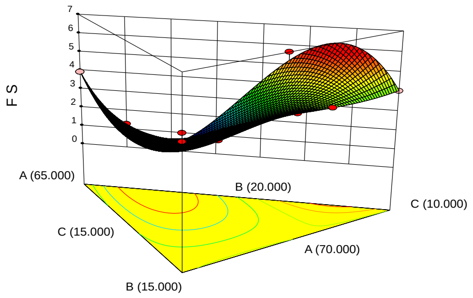

Figure 3b: 3D plot of foaming stability

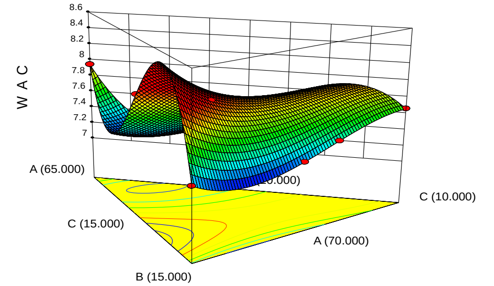

Figure 3c: 3D plot of water absorption capacity

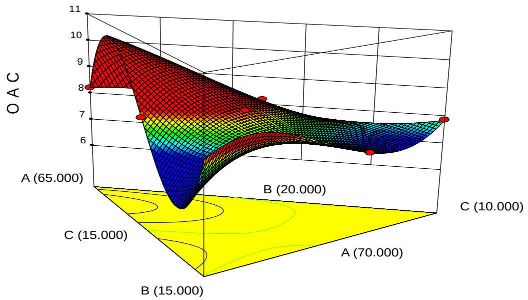

Figure 3d: 3D plot of oil absorption capacity

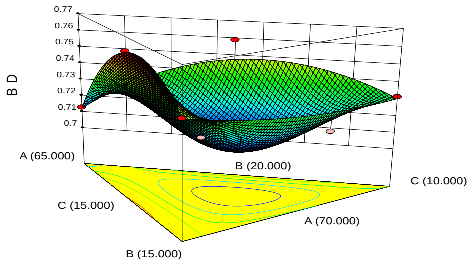

Figure 3e: 3D plot of bulk density

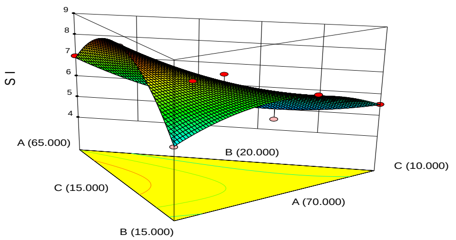

Figure 3f: 3D plot of swelling index

and CBC2 (69.167% cocoyam, 16.667% bambara groundnut and 14.167% cassava starch).

Antinutritional contents of the optimised flour blends

The results of the antinutritional contents of the optimised composite flour and wheat-based samples are presented in Table 1.

Table 1: Results of the Antinutritional Properties of Optimized Flour Blends

Sample	Tannin (mg/g)	Trypsin inhibitor (%)	Phytate (mg/g)
CBC1	1.76±0.11^{c}	52.12±2.12^{a}	35.43±0.82^{a}
CBC2	1.78±0.00^{c}	55.08±4.24^{a}	30.49±0.00^{b}
CBW1	3.19±0.5^{b}	25.25±1.02^{d}	11.12±1.24^{e}
CBW2	4.33±0.16^{a}	30.51±1.69^{c}	12.36±0.00^{d}

Values are mean ± standard deviation of triplicate samples. Values along the colomn with the same superscript are not significantly different at P>0.05.
CBC1- (70% cocoyam flour, 18.33% bambara groundnut flour, 11.67% cassava starch); CBC2- (69.17% cocoyam flour, 16.67% bambara groundnut flour, 14.17% cassava starch); CWC1- (60% wheat, 30% cocoyam, 10% bambara groundnut flours); CWC2 - (72% wheat, 19% cocoyam, 9% bambara groundnut flours).

Antinutrients interfere with absorption and utilization of important minerals (Ca, Fe, Zn and Mc) and protein, hence, the need for their presence at minimum and nutritional acceptable values in foods. The tannin values ranged from 1.76 to 4.33 mg/g which is nutritionally safe. Cocoyam-based composite flour had lower tannin content compared with wheat based composite flour. Higher tannin contents (18.9-22.9%)) had been obtained for malted sorghum-soy composite flour reported by Bolarinwa et al. (2015) and tannin content (23.8-27.4%) for sorghum-soy-plantain flour reported by Onoja et al. (2014). Bolarinwa et al. (2015) also reported tannin content of 18.7% for 100% wheat flour.

The trysin inbition content (25.25-55.08%) obtained in this work is comparable to 58% reported by Iwe and Ngoddy (2000) for whole soybean meal and trypsin inhibition content (40-46.1%) reported by Anuonye et al. (2007) for acha/soybean extruded snack.

The phytate content ranged from 11.12 to 35.43 mg/g. Bolarinwa et al. (2015) had also reported phytic content of 25.7% for 100% wheat flour, 39.4% for 100% malted sorghum flour and phytic content (28.6-36.8%) for malted sorghum-soy composite flour.

Pasting property forselected optimised flour blends

The results of the pasting properties of optimised flour blends are presented in Table 2. Sample CBW1 had the highest peak viscosity followed by CBW2. The high cocoyam flour content in sample CWC1 must have accounted for the high value of the peak viscosity which was higher than in sample CBW2 (72% wheat flour but 19% cocoyam flour). Sample CBC2 had a peak viscosity next to that of sample CBW2. Though sample CBC1 and CBC2 had almost the same cocoyam flour content, the amount of cassava starch in CBC2 was higher (14%) which must have accounted for the better peak viscosity content of sample CBC1. Peak viscosity has been shown to be correlated to final product quality and an indication of viscous loads likely to be encountered during mixing (Kiin-Kobani, 2015). The results showed that although addition of starch, which acts as a binder, could enhance peak viscosity of wheat-free composite flour; wheat flour had better effect on peak viscosity.

Table 2: Result of Pasting Property of Optimized flour Blends

Sample	P (RVU)	T (RVU)	B (RVU)	FV (RVU)	SB (RVU)	PT (min)	PTE (^{o}C)
CBW1	231.90 ± 0.5^{a}	145.30± 0.5^{c}	83.70± 0.0^{a}	339.30 ± 0.5^{a}	190.96± 0.5^{a}	5.93± 0.00^{a}	85.55± 0.00^{b}
CBW2	199.20 ± 0.5^{b}	126.50± 0.5^{d}	72.80± 0.0^{b}	316.70 ± 0.5^{b}	190.20± 0.5^{b}	5.87± 0.00^{b}	86.30± 0.00^{a}
CBC1	188.30 ± 0.5^{d}	175.90± 0.5^{b}	12.40± 0.5^{d}	279.40 ± 0.5^{d}	103.50± 0.5^{c}	5.73± 0.00^{c}	78.30± 0.00^{c}
CBC2	199.30 ± 0.5^{c}	176.80± 0.5^{a}	14.50± 0.0^{c}	279.60 ± 0.0^{c}	102.70± 0.5^{d}	5.67± 0.00^{d}	76.75± 0.01^{d}

Values are mean ± standard deviation of triplicate samples. Values on vertical row with the same superscript are not significantly different at P =0.05.

P= Peak, T= Trough, B= Break down, FV= Final viscosity, SB= Setback, PT= Peak time, PTE= Pasting temperature

CBC1- (70% cocoyam flour, 18.33% bambara groundnut flour, 11.67% cassava starch); CBC2- (69.17% cocoyam flour, 16.67% bambara groundnut flour, 14.17% cassava starch); CWC1- (60% wheat, 30% cocoyam, 10% bambara groundnut flours); CWC2 - (72% wheat, 19% cocoyam, 9% bambara groundnut flours).

The same trend observed in peak viscosity was repeated in breakdown and final viscosities. Breakdown viscosity is a measure of degree of starch disintegration or the hot paste stability of the starch (Bakare et al., 2015). Lower breakdown viscosity indicated higher paste stability (Bakare et al., 2015). Cocoyam-based flour (CBC1) had lowest breakdown viscosity which could be as a result of the higher content of bambara groundnut (a legume) present. On the other hand, wheat-based flour had higher final viscosity meaning it will form firmer gel after cooking and cooling.

Setback viscosity and peak time displayed trends similar to those of peak viscosity, breakdown and final viscosity for the wheat-based composite flours. Cocoyam-based composite flour with lower starch content (CBC1) had higher setback and peak time than sample CBC2. It had been established

that the the higher the setback value, the lower the retrogradation during cooling of the products made from the flour (Ikegwu, et al., 2010).
The pasting temperature was higher in wheat-based samples (CBW1 and CBW2) than in the cocoyam-based composte flours (CBC1 and CBC2). Pasting temperature is a measure of the minimum temperature required to cook the composite beyond its gelatinization point. High pasting temperature is a reflection of high water-binding capacity, high gelatinization tendency, and low swelling property of starch-based flour (Adebowale et al., 2008).

Farinogragh property for the selected optimised flour blends
The result of the farinograph of the wheat-based and cocoyam-based flour samples are shown in Figure 4a and 4b respectively.

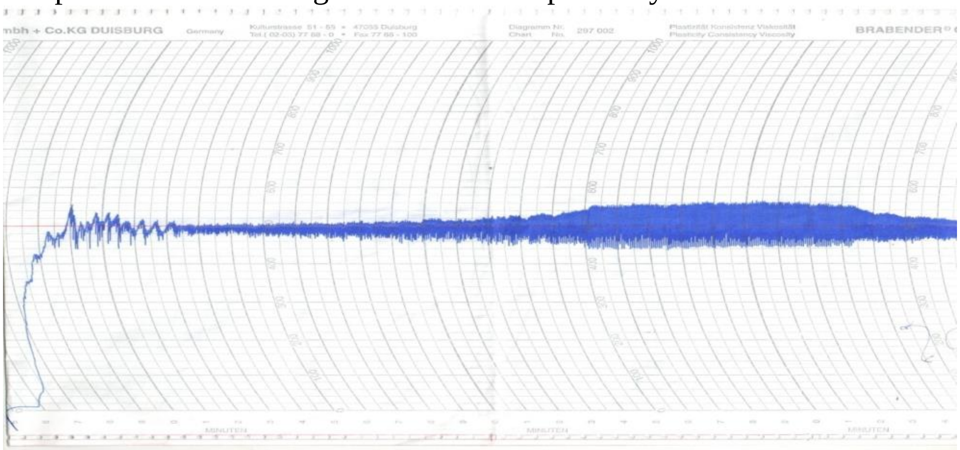

Figure 4a: Farinograph of wheat-based flour sample (CBW2)
CWC2 - (72% wheat, 19% cocoyam, 9% bambara groundnut flours)

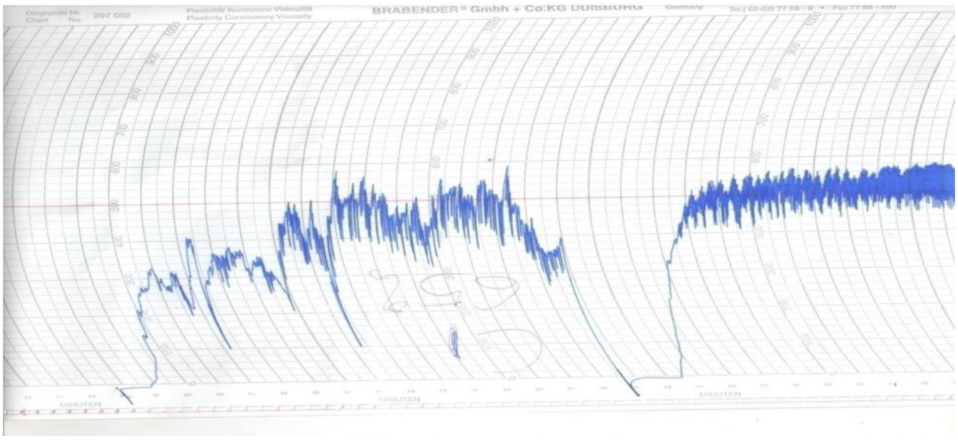

Figure 4b: Farinograph of cocoyam-based flour sample (CBC1)
CBC1- (70% cocoyam flour, 18.33% bambara groundnut flour, 11.67% cassava starch)

The wheat-based sample had better dough development time (shorter time to get to the 500-BU line), dough stability and mixing tolerance index. DDT is an indication of the rate of flour hydration Dough stability indicates the strength of the dough; the higher dough stability the stronger the dough. Most commercial bread flours have bene reported to have 10 min stability value. The mixing tolerance index (MTI), which is a measure of weakening area, is the difference in between the top of the curve and the top of the curve measured 5 min after the peak is reached (Mohamed et al., 2006). The greater the MTI value, the greater is the weakening area. The result indicted that cocoyam-based flour had greater weakening areas than wheat-based sample. Mixing tolerance index had been shown to influence baking quality.

CONCLUSIONS

A gluten-free cocoyam-based composite flour with rich in nutritional (protein, fibre and minerals) quality were produced. Samples CBC1 (70% cocoyam, 18.333% bambara groundnut and 11.667% cassava starch flours) and CBC2 (69.167% cocoyam, 16.667% bambara groundnut and 14.167% cassava starch) had the overall best protein, crude fibre, ash, moisture and minerals contents in addition to having the best functional characteristics.

The incorporation of starch into the composite flour enhanced the functional, pasting and farinographic characteristics of the composite flour. The pasting characteristics of the cocoyam-based flour was similar to that of 70% wheat-based composite flour.

The cocoyam-based composite at 69% and above could actually replace composite flour with 70% wheat-based composite flour in the production of baked products requiring good functional and pasting characteristics. The farinographic evaluation indicated that the cocoyam-based composite flour could replace soft wheat flour (100%) used in the production of biscuits and cookies as .

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