



Development and evaluation of extruded ready-to-eat snack from optimized rice, kersting's groundnut and lemon pomace composite flours

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Abstract Composite flour comprising rice, kersting's groundnut and lemon pomace were produced. The percentage blends of the composite flours based on the proximate composition and functional properties were optimized using optimal mixture design of response surface methodology (RSM). The optimum blends were subjected to further analyses (pasting properties and Mixolab). The overall best blend was selected for extrusion. The extrusion process was optimized using central composite design of RSM. The variables were moisture content, screw speed and temperature while the dependent variables were lateral expansion, residence time, throughputs, water absorption index and water solubility index. The microbial analysis as well as the sensory evaluation of the extrudates was also evaluated. The result showed that addition of kersting's groundnut had positive effect on the protein content while lemon pomace had positive effect on both fibre and protein contents. Blend with highest rice flour had the best pasting properties. The Mixolab results had C1 stage similar to wheat flour while it had no C2–C5 stages. The optimum blend for extrusion was 97 °C barrel temperature 12% moisture and 90 rpm screw speed which present the best lateral expansion, water absorption index and water solubility index. All the snacks had high general acceptability.

Keywords Composite flour · Extrusion · Response surface methodology · Rice flour · Mixolab

Introduction

Worldwide, consumption of ready-to-eat convenient and inexpensive gluten-free snacks from cereals, tubers and legumes is increasing (Awolu et al. 2016b). This was aimed at diversification of the consumption of wheat-based flour production due to incidences of celiac disease and economic purposes (Awolu et al. 2015, 2016a). Celiac disease is a common complex disease caused by a dietary intolerance to gluten proteins found in all wheat types and closely related cereals such as barley and rye (Heap and Van Heel 2009). Apart from the growth in the number of celiac patient in the society, the production of gluten-free composite flour has been adopted as a means of addressing the high cost of wheat importation in many developing countries, and development of products that are locally sourced raw (Heap and Van Heel 2009). The major source of gluten-free flours for the production of snacks is the cereals, which are essential components of the daily diets (Laila et al. 2011). Nutritionally, cereals are important sources of carbohydrates, dietary fiber and vitamins (Katina et al. 2005). However, flours used in the production of gluten-free ready-to-eat snack are major challenge for food technologist due to their poor baking properties, low nutritional quality, poor mouth feel and flavor. In order to improve the nutritional and baking quality of the flours, different protein sources were being added (Katina et al. 2005). Apple pomace had been added to wheat based composite flour to further enhance its protein and crude fibre contents alongside improving its functional and pasting properties (Awolu et al. 2016b). Kersting's

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groundnut, an underutilized legume, rich in essential minerals, protein and amino acids has also been utilized in the production of rice-cassava based composite flour (Awolu et al. 2015).

The aim of this study was to develop a composite flour comprising rice, kersting's groundnut and lemon pomace flours; optimised the proximate composition and functional properties of the composite flour using response surface methodology and produced extruded snack from the optimum blends. The screw speed, barrel temperature and moisture contents of the extrusion process were also optimized.

Materials and methods

Materials

Igbemo rice was sourced from Igbemo-Ekiti, Ekiti state. Kersting's groundnut (*Kerstingiella geocarpa* Harms.) was sourced from Oyingbo market, Lagos. Lemon fruits were sourced at Oja-Oba, Akure, Ondo State.

Experimental design for the development of flour blends

For the optimisation of the proximate and functional properties, the optimal mixture model design of response surface methodology (Design expert 8.0.3.1, trial version) was used. The independent variables were rice flour (70.30–85.00%), kersting's groundnut flour (10.00–20.00%) and lemon pomace (5.00–10.00%) while the dependent variables were the proximate and functional properties. For the extrusion process, central composite design (CCD) was used for the experimental design. The independent variables were barrel temperature (BT; 51.40–108.58 °C), moisture content (M; 6.54–28.00 g/100 g) and screw speed (SS; 79.77–120 rpm) while the dependent variables were throughputs (T), lateral expansion (LE), residence time (RT), water absorption index (WAI) and water solubility index (WSI) of the extrudates.

Preparation of rice flour

The rice flour was produced according to the method adopted by Laila et al. (2011) with some modifications. Exactly 5 kg of rice grains were first sorted to remove stones, rice bran and dirt, washed in warm water to reduce microbial load, and sun dried. The dried rice grains were reduced into smaller particles with an attrition mill, made to pass through 200 µm sieve in order to obtain the desired flour particles, stored in a sealed polythene bag at room temperature for further use.

Preparation of kersting's groundnut flour

The method of Chikwendu (2007) was adopted with slight modifications. Exactly 2.5 kg of kersting's groundnut seeds were sorted to remove stones, defective seeds and other extraneous materials. The sorted seeds were parboiled at 100 °C for 30 min, manually dehulled and cooked for another 2 h to deactivate trypsin inhibitors, protease and other antinutrients present in the legume. The cooked seeds were then oven (Gen-Lab Oven-model DGH-9101.1SA) dried at 60 °C for 8 h. The dried seeds were milled to fine powder using an attrition mill, sieved using a 200 µm aperture sieves and stored in a sealed polythene bag at room temperature for further use.

Preparation of lemon pomace flour

Lemon pomace was produced according to the method described by Krzysztof et al. (2007). Fresh lemon fruits were washed with warm water to remove tough dirt and dust from the fruits. The washed fruit was pulverized with a sharp knife and a Kenwood blender (BL-237) was used to blend them into slurry. The juice was extracted from the slurry using a muslin cloth. The wet lemon pomace was oven dried with a Gen-lab (Oven model DHG-9101.1SA) hot air oven at 60 °C for 18 h. The blender was then used to grind the dried pomace into flour.

Proximate composition determination of the composite flour

The moisture content (950.46B, p. 39.1.02), crude protein (981.10, p. 39.1.19), fat (960.39 (a), p. 39.1.05), ash content (920.153, p. 39.1.09) and crude fiber of the composite flour blends were determined according to the standard methods of AOAC (2003).

Determination of functional properties of the composite flour

The water absorption capacity (WAC) and oil absorption capacity (OAC) were determined using the procedure of Sathe and Salunkhe (1984) as modified by Adebawale et al. (2005), bulk density (BD) by method of Sathe et al. (1982), swelling index (SI) by the method of Ukpabi and Ndimele (1990) and dispersibility by method described by Kulkarni et al. (1991).

Determination of pasting properties

Three blends of the composite flour were selected and subjected to rapid visco-analysis. Xanthan gum (0.5 g) was added to each of the samples and properly mixed. The flour

sample (3 g) was mixed with 25 ml distilled water in the canister of a rapid visco- analyzer (RVA, model 3D; Newport Scientific, Sydney, Australia) monitored with RVA control software and operated. Based on the result of pasting characteristics, two samples were chosen for rheological (Mixolab) analysis.

Determination of rheological behaviour of dough

Mixolab ('Chopin+', Chopin Technologies, France) was used according to standard methods (AACC 54-60.01). Mixolab consisted of heating/cooling cycle after constant mixing at 80 rpm. The analyses were carried out at constant water absorption. The dough characteristics were determined when mixing at constant temperature and during heating/cooling cycles.

Extrusion

Extrusion was carried out using a single screw extruder fabricated locally by NASOD Engineering Limited, Ogun State, Nigeria. The configuration of the extruder is length to diameter (L/D) ratio of 304:18.5, 18 mm screw diameter, 2 horsepower (HP) and 304 mm barrel length. The extrusion conditions were barrel temperature (A; 51.40–108.58 °C), moisture content (B; 6.54–28.00 g/100 g) and the screw speed (C; 79.77–120 rpm).

Microbial analysis on freshly prepared extrudates

About 25 g of samples was dissolved into 225 ml peptone water and was homogenized. Serial dilutions were performed and 1 ml of the dilution was poured into the media plates, Nutrient Agar (NA), Deoxycholate agar (DCA) and Potato Dextrose Agar (PDA) respectively. The plates were left to set and thereafter incubated at 37 °C for 24 h for both NA and DCA plates while PDA were incubated at 25 °C for 5 days (FAO 1992). After the incubation periods, plates were brought out and colonies were counted using colony count.

Sensory evaluation of the ready-to-eat snacks

The sensory attributes of the ready to eat breakfast snack was assessed by thirty trained sensory panelists. The panelists scored the samples using the 9 point Hedonic scale with respect to color, taste, texture, appearance, and overall acceptability. The scores were ranked and subjected to statistical analysis (Ihekoronye and Ngoddy 1985).

Statistical analysis

Analyses on proximate composition, functional properties and extrusion were carried out in triplicate. The data obtained in the experiment were analyzed using the Response Surface Methodology (RSM) so as to fit the quadratic polynomial equation generated by the Design-Expert software version 8.0.3.1 (Stat-Ease Inc., Minneapolis, USA). RSM is a statistical tool for products and processes optimization. All other analyses were statistically analyzed using IBM SPSS 22 version. In order to correlate the response variable to the independent variables, multiple regressions was used to fit the coefficient of the polynomial model of the response. The quality of the fit of model was evaluated using analysis of variance (ANOVA).

Results and discussion

Proximate composition and functional properties of the composite flour

The results of the proximate composition and functional properties are presented in Table 1. The moisture content of the composite flour ranged from 6.20 to 6.81 g/100 g. Singh et al. (2005) reported that the moisture content of flour should be within the acceptable limit of not more than 10% for long term storage of flour. The R-squared and the adjusted R-squared values were 0.3496 and 0.0244 respectively. Low R-squared and the adjusted R-squared values of moisture content are good for flour production since it signifies that the independent variables (raw materials) do not support moisture. The final equation showing the effect of the component on moisture content is shown in Eq. (1).

$$\text{Moisture} = 6.44 + 6.68B + 1.49C + 0.71AB + 7.58AC + 6.13BC \quad (1)$$

The ash content of the flours ranged from 0.98 to 1.81 g/100 g. An ash content of 1.16 and 1.68 g/100 g have been reported for composite flour consisting up to 60–77% wheat flour, plantain flour and tigernut flour by Bamigbola et al. (2016). In addition, Awolu et al. (2016b) reported ash content between 0.7 and 2.79 g/100 g for composite flour consisting wheat flour, amaranth flour, brewer spent grain flour and apple pomace flour. The ash content increased significantly ($p \leq 0.05$) as the levels of lemon pomace increased. The ANOVA indicated that the model and linear mixture model were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.7546 and 0.7168 respectively. The contour plot for the ash content is shown in Fig. 1a while the final equation is shown in Eq. (2).

Table 1 Proximate composition and functional properties of composite flour

Run	Variables (g)			Proximate composition (g/100 g)						Functional properties					
	A (g)	B (g)	C (g)	Moisture	Ash	Protein	Fibre	Fat	CHO	WAC (%)	OAC (%)	WSI (%)	DSP (%)	SC (%)	BD (g/cm ³)
1	79.84	10.16	10.00	6.40	1.81	7.51	3.71	4.00	66.57	3.00	1.45	8.00	74.00	14.00	0.75
2	75.00	20.00	5.00	6.20	1.25	12.99	2.89	4.28	67.39	3.80	1.60	9.50	84.90	18.00	0.88
3	83.50	11.50	5.00	6.50	1.05	8.56	2.80	4.00	72.09	3.00	1.20	8.00	72.50	14.00	0.79
4	70.30	20.00	9.70	6.30	1.76	12.57	3.34	4.30	62.03	3.75	1.55	9.50	84.00	18.00	0.86
5	76.98	15.75	7.25	6.46	1.70	9.12	3.21	4.27	67.98	3.20	1.40	8.50	82.80	15.00	0.81
6	79.84	10.16	10.00	6.47	1.30	8.43	3.62	4.00	66.18	3.00	1.50	8.00	74.00	14.00	0.75
7	82.28	10.00	7.71	6.30	1.48	8.41	3.70	4.00	68.4	3.00	1.55	8.00	72.20	14.00	0.75
8	75.00	20.00	5.00	6.81	1.30	12.8	2.90	4.44	66.75	3.80	1.60	9.00	84.90	18.00	0.84
9	85.00	10.00	5.00	6.40	0.98	8.41	2.68	4.01	72.52	2.80	1.20	8.00	73.10	14.00	0.73
10	73.16	19.07	7.76	6.62	1.68	12.72	3.18	4.36	63.67	3.60	1.40	9.00	83.50	18.00	0.83
11	82.28	10.00	7.71	6.80	1.60	8.46	3.72	4.11	67.60	3.00	1.50	8.00	72.20	14.00	0.74
12	85.00	10.00	5.00	6.41	1.06	7.99	2.66	4.00	72.88	3.15	1.20	8.00	73.10	14.00	0.73
13	80.31	14.68	5.00	6.43	1.32	9.55	2.52	4.20	70.98	3.25	1.40	8.50	83.20	15.00	0.79
14	77.44	12.55	10.00	6.41	1.80	9.00	3.78	4.10	64.91	3.10	1.40	8.00	74.10	15.00	0.74
15	73.56	16.43	9.99	6.30	1.74	11.62	3.09	4.19	63.10	3.20	1.25	8.50	83.40	16.00	0.83
16'	70.30	20.00	9.70	6.30	1.76	12.63	3.30	4.24	62.07	3.80	1.60	9.00	84.80	18.00	0.89

A—rice Flour; B—kersting’s groundnut; C—lemon pomace; CHO—carbohydrate

WAC water absorption, OAC oil absorption capacity, WSI water solubility index, DSP dispersibility, SC swelling capacity, BD bulk density

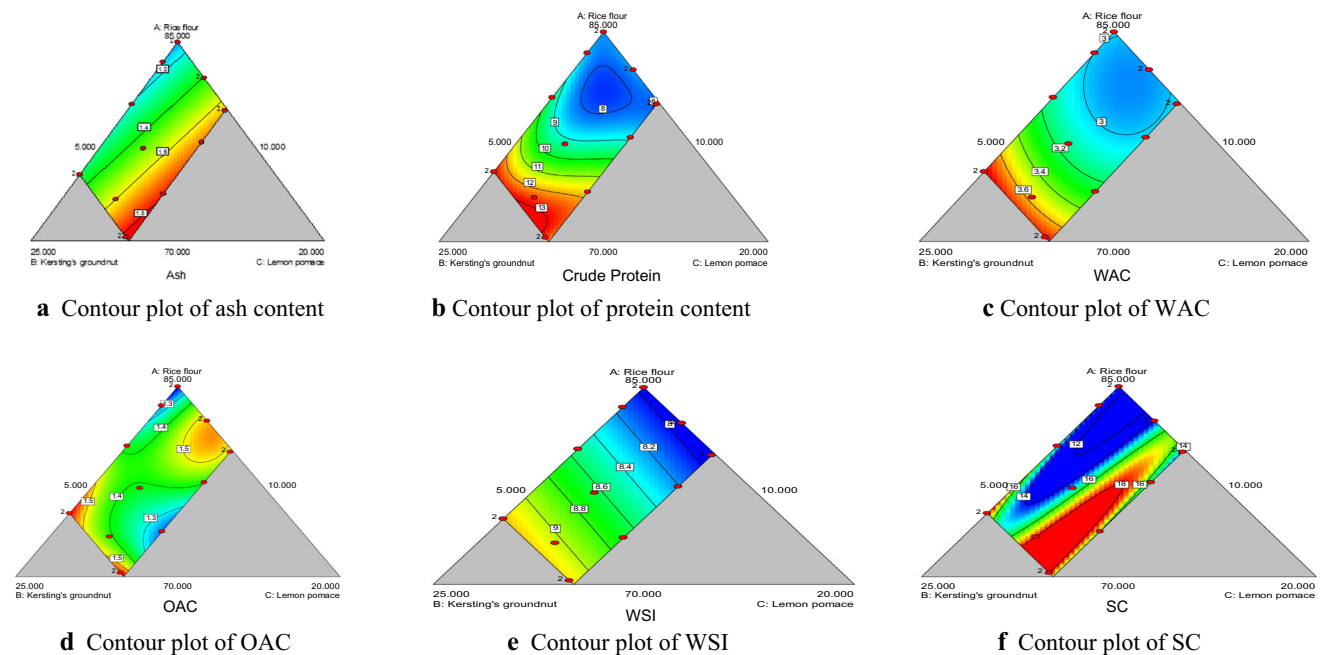


Fig. 1 **a** Contour plot of the ash content. **b** Contour plot for the crude fibre. **c** Contour plot for water absorption capacity. **d** Contour plot for oil absorption capacity. **e** Contour plot for water solubility index.

$$\text{Ash} = 1.12A + 1.42B + 2.73C \tag{2}$$

The crude protein of the flour samples ranged between 7.51 and 12.99 g/100 g. The protein content increased

f Contour plot for swelling capacity. WAC water absorption capacity, OAC oil absorption capacity, WSI water solubility index, SC swelling capacity

significantly ($p \leq 0.05$) as the level of kersting’s groundnut incorporation increased. Awolu et al. (2015) reported an increase in protein content of rice, cassava and kersting’s groundnut composite flour as the kersting’s groundnut flour

incorporation increased. Protein content of between 9.9 and 11.5 g/100 g were reported for composite flour consisting wheat flour, amaranth flour, brewer spent grain and apple pomace (Awolu et al. 2016b). The ANOVA indicated that the model and model term [linear mixture, AB, AB (A–B)] were significant ($p \leq 0.05$). The R-squared and the adjusted R-squared values were 0.9975 and 0.9937 respectively while the contour plot is shown in Fig. 1b. High R-squared and the adjusted R-squared values indicated that the model is highly fit. The final equation showing the effects of the variables on the responses is shown in Eq. (3).

$$\begin{aligned} \text{Crude protein} = & 8.23A + 18.07B - 1.48C - 8.37AB \\ & + 13.43AC + 2.53BC - 159.18A^2BC \\ & - 8.39AB^2C + 298.34ABC^2 \end{aligned} \quad (3)$$

The fat content of the flours ranged from 4.00 to 4.44 g/100 g. Fats are flavor retainers in foods. Wheat flour had been reported to have 1.33 g/100 g fat content. The fat content decreased significantly ($p \leq 0.05$) in the composite flour as the level of rice flour and lemon pomace increased. The ANOVA indicated that only the model and model term (Linear mixture) were significant ($p \leq 0.05$).

The crude fibre values ranged from 2.52 to 3.78 g/100 g. Kersting's ground and lemon enhanced the crude fibre content of the composite flour. Chang et al. (2015) reported that lemon pomace contained 63.85% crude fiber. Crude fibre contents of 0.7–2.79 g/100 g was reported for composite flour consisting wheat, amaranth grain, brewer spent grain and apple pomace flours. The ANOVA result indicated that the model and model terms (linear mixture, AB, AB(A–B)) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared were 0.9975 and 0.9937 respectively. The final equation showing the effects of the component on crude fiber content is shown in Eq. (4).

$$\begin{aligned} \text{Crude Fiber} = & 2.66A + 8.85B + 19.81C - 13.81AB \\ & - 29.57AC - 43.33BC + 68.92ABC \\ & + 11.01 AB (A - B) \\ & + 24.63AC (A - C) + 5.77 BC (B - C) \end{aligned} \quad (4)$$

The carbohydrates content of the flours ranges between 62.03 and 72.98 g/100 g. The carbohydrate content recorded in this report suggests that it could be used in managing protein-energy malnutrition. The ANOVA indicated that the model and model term (linear mixture component, AB, AC, A²BC, ABC²) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared are 0.9945 and 0.9882 respectively.

The WAC of the composite flour ranged from 2.80 to 3.80%. Water absorption capacity values increased

significantly ($p \leq 0.05$) as the levels of kersting's groundnut flour increased. This could be as a result of the ability of the protein in the material to prevent fluid loss from a product during food storage or processing (Kiosseoglou and Paraskevopoulou 2011). A WAC of 2.81–2.90% has been shown to be desirable in composite flours for the development of sausage and bread (Kisambari et al. 2015). The ANOVA indicated that the model and model terms (linear mixture and AB) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.9369 and 0.9053 respectively. The contour plot is shown in Fig. 1c.

The bulk density (BD) of the composite flour ranged from 0.73 to 0.89 g/cm³. Bulk density increased significantly ($p \leq 0.05$) as kersting's groundnut incorporation increased. Bulk density is an indication of the porosity of a product and a function of flour wettability which influences packaging design. It could be used in determining the required type of packaging material (Iwe and Onalope 2001). Bulk density between 0.76 and 0.82 g/cm³ has been found to be desirable in composite flour for the development of food products (Chandra et al. 2015). The ANOVA indicated that the model and model term (linear Mixture Component) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.9001 and 0.8847 respectively. Dispersibility of the flour ranged from 72.20 to 84.80%. The dispersibility increased significantly ($p \leq 0.05$) as kersting's groundnut increased. Dispersibility measures ease of reconstitution of flour in water (Adebowale et al. 2012). Values of 73.50–78.00% and 73.50–76.50% were reported for wheat-millet flour and sorghum-wheat flour respectively (Adegunwa et al. 2011; Adebowale et al. 2012). The ANOVA showed that the model and model term (linear mixture) were significant ($p \leq 0.05$). The R-squared and adjusted R-squared values were 0.9542 and 0.9018 respectively.

The oil absorption capacity (OAC) ranged from 1.20 to 1.60%. Oil absorption capacity increased significantly ($p \leq 0.05$) as kersting's groundnut flour increased. Oil absorption capacity of 1.87–2.08% is desirable in composite flour to improve mouth feel, palatability and shelf life particularly in bakery or meat products where fat absorptions are desired (Aremu and Akintayo 2006). The ANOVA showed that the model and model terms (linear mixture, AC, BC, AB²C) were significant. The R-squared and the adjusted R-squared value were 0.9369 and 0.9053 respectively while the contour plot is shown in Fig. 1d. The final equation is shown in Eq. (5).

$$\begin{aligned} \text{OAC} = & 1.19A + 1.180B - 2.35C + 0.011AB + 6.60AC \\ & + 5.29BC - 3.02A^2BC - 25.21AB^2C \\ & + 7.14ABC^2 \end{aligned} \quad (5)$$

Water solubility value ranged from 8.00 to 9.50%. The WSI values increased significantly ($p \leq 0.05$) in flour blends with increasing kersting’s groundnut flour incorporation. Water solubility index of 8.84–9.92% has been reported to be desirable in composite flour for proper granule swelling (Adebowale et al. 2012). The ANOVA showed that the model and linear mixture term were significant ($p \geq 0.05$). The R-squared and the adjusted R-squared value were 0.9077 and 0.8935 respectively. The contour plot (Fig. 1e) also showed that the addition of kersting’s groundnut had positive effect in WSI of the composite flour.

The swelling capacity of the flours ranged between 14.00 and 18.00 g/cm. Chandra et al. (2015) reported that values of 16.00–22.30 ml are desirable for the swelling capacity of composite flour. The ANOVA showed that the model and model terms [linear mixture, AB, AC, BC, ABC, AC (A–C) and BC (B–C)] were significant ($p \leq 0.05$). The R-squared and adjusted R-squared were 0.9997 and 0.9992 respectively. The final equation is shown in Eq. (6) while the contour plot is shown in Fig. 1f.

$$\begin{aligned}
 SC = & 13.97A + 22.19B - 879.52C - 6.91AB \\
 & + 1612.40AC + 1593.86BC - 1584.06ABC \\
 & - 1.17AB(A - B) - 816.90AC(A - C) \\
 & - 804.06BC(B - C)
 \end{aligned} \tag{6}$$

Pasting characteristics

The optimum blends, meaning the blends with the best proximate and functional properties were used for the evaluations of pasting rheological properties. The optimum blends are, Runs 2, 7 and 14. The results of the pasting properties of the optimum blends (2, 7 and 14) are presented in Table 2. Peak viscosity of the composite flour decreased significantly ($p \leq 0.05$) as the level of kersting’s groundnut increased in the flour blends while it significantly ($p \leq 0.05$) increased with increased rice flour. Peak viscosity is often correlated with the final product quality

and also provides an indication of the viscous loads likely to be encountered during mixing (Adebowale et al. 2005).

The Trough ranged from 103.37 to 119.13 RVU. Composite flour with highest lemon pomace flour (run 14) had the least trough while sample with highest rice flour (run 7) had the highest trough. Decrease in the holding period of composite flour has been reported by to be due to the presence of lipids from legumes (Tharise et al. 2014). Trough is a measure the ability of paste to withstand breakdown during cooling

The breakdown viscosities of the composite flour ranged from 27.32 to 28.43 RVU. The breakdown viscosity is an indication of breakdown or stability of the starch gel during cooking (Arisa et al. 2013). Flour with lower breakdown viscosity had been reported to possess higher capacity to withstand heating and shearing during cooking. The sample with the highest rice flour (run 7) also had the least breakdown viscosity, hence, better stability capacity during cooking.

In addition, the breakdown viscosity of the sample with highest kersting’s groundnut (run 2) had no significant difference from that of run 7. This showed that both rice (cereal) and kersting’s groundnut (legume) enhanced composite flour stability. Jimoh and Olatidoye (2009) reported that break down viscosity below 53.50 RVU is desirable in composite flours. Higher breakdown viscosities of 34.67–46.92 RVU was reported for plantain and bambara groundnut composite flour by Arisa et al. (2013) hence, the breakdown viscosity reported in this study suggests that the paste of the composite flour would have a high stability against retrogradation.

Setback viscosity ranged between 138.19 and 164.40 RVU. Setback viscosity is associated with cohesiveness of the composite flour and shows the potential for retrogradation in food product. In this instant, sample with highest rice flour had the highest setback viscosity. Run 7 also had the highest final viscosity. The results of the pasting properties clearly showed that rice flour promotes pasting characteristics of the composite flour.

Table 2 Pasting properties of the optimized composite flour

Sample	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (Min)
Runs 2	128.25 ± 0.34 ^c	115.36 ± 0.33 ^b	27.92 ± 0.13 ^b	256.49 ± 0.43 ^b	138.19 ± 2.80 ^a	7.00 ± 0.00 ^{ns}
Runs 7	154.74 ± 0.68 ^a	119.13 ± 0.12 ^a	27.32 ± 0.48 ^b	277.28 ± 0.42 ^a	164.40 ± 0.38 ^a	7.00 ± 0.00 ^{ns}
Runs 14	131.37 ± 0.32 ^b	103.55 ± 0.48 ^c	28.43 ± 0.52 ^a	241.12 ± 0.19 ^c	158.26 ± 0.28 ^b	7.00 ± 0.00 ^{ns}

Values are mean ± standard deviation of triplicate samples

Values on vertical row with the same superscript are not significantly different at $p \leq 0.05$

Runs 2—rice flour (75.0 g), kerstings groundnut flour (20.0 g), lemon pomace flour 5.00 g)

Runs 7—rice flour (82.28 g), kerstings groundnut flour (10.0 g), lemon pomace flour (7.71 g)

Runs 14—rice flour (77.44 g), kerstings groundnut flour (12.55 g), lemon pomace flour (10.0 g)

Rheological properties

The rheological properties of the rice-based composite flour and the control (wheat flour) are shown in Fig. 2a, b respectively. It was observed that the rice based composite flour had a longer dough development time (DDT) of 1.97 min when compared with the control (wheat flour) which had 1.73 min DDT. The development time is related to the time necessary to hydrate all compounds (Rosell and Marco 2016). The water absorption for the rice-based composite flour and the control were 55.0% and 57.3% respectively. Water absorption indicates the potential of protein molecules to absorb water, hence, an indicator of baking quality (Van Lili et al. 1995). Protein, starch, damaged starch, pentosans contents as well as gluten strength had been reported to enhance water absorption of flours (Vizitiu and Danciu 2011). The control had

better water absorption. The torque for the composite flour and the control were 5.71 Nm and 1.14 Nm respectively. The water absorption capacity has been defined as the hydration needed to obtain a maximum dough consistency of 1.1 Nm on chopin + protocol (which is equivalent to 500 BU line on farinograph). The implication is that the composite flour may not be good material for bread production, whereas it can be useful in other baked products.

The control had values for the other phases of the Mixolab. The C2 phase defines protein weakening as a function of shear stress and temperature, C3 defines the starch gelatinization, C4 is the hot gel stability, while the

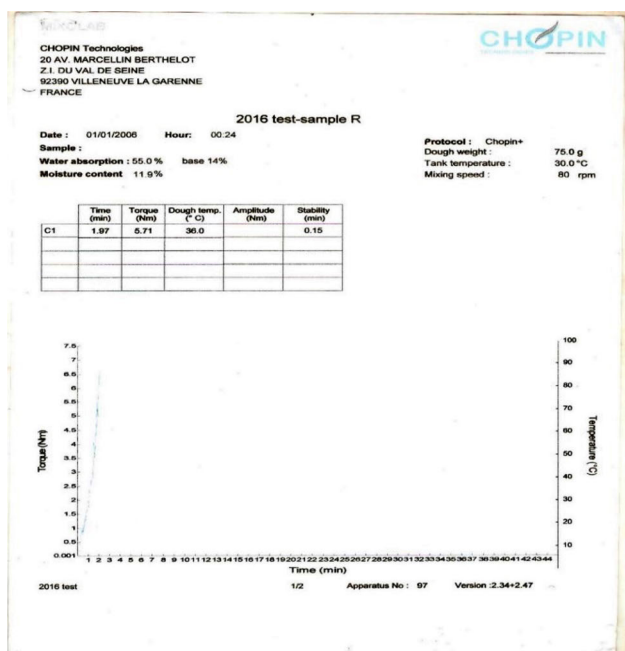
C5 is the starch retrogradation in the cooling phase (Pastukhov and Dogan 2014).

Extrusion characteristics of extrudates

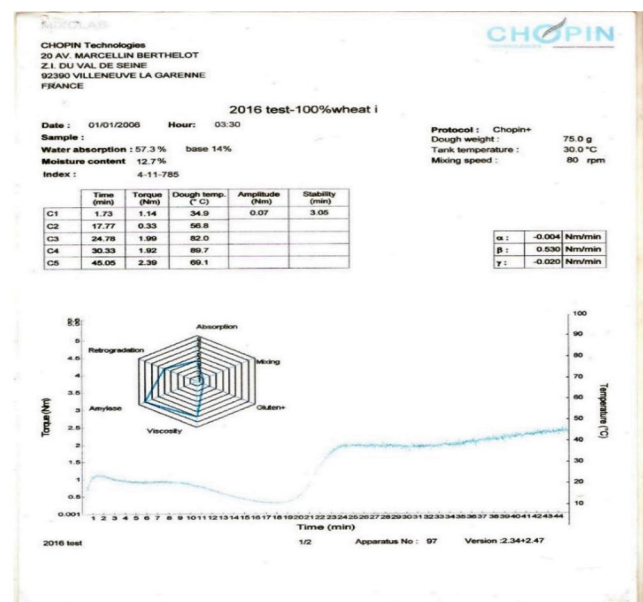
The result of the extrusion process is presented in Table 3. The lateral expansion ranged from 0.01 to 0.04%. Lateral expansion increased significantly ($p \leq 0.05$) as temperature increased. The increase may be due to extrudate expansion which occurs at high temperature and low moisture extrusion cooking (Shimelis et al. 2015). Similar result showed rise in lateral expansion of extruded meat analogue from bambara groundnut with rise in temperature (Akegbejo and Oluwatoyin 2010).

The residence time of the extrudate ranged between 1.2 and 4.4 s. High moisture contents increases the residence time of extrudates, and vice versa. In addition, a moderate moisture (around 20%) and high screw speed (greater than 100 rpm) significantly ($p \leq 0.05$) increased the residence time. It has been reported that the dough becomes heavy as it absorbs water making it to move slowly inside extruder (Siew-Yooge and Kathryn 1996). Contrariwise, high screw speed at low moisture content resulted in lower residence time. Short residence time will prevent proper cooking of the extrudates. However, high temperature and moderately high screw speed will cook the dough well.

The water solubility index ranged between 10.00 and 12.92%. Water solubility index is often used as an indicator of degradation of molecular components (Shimelis et al.



a Mixolab of Composite flour (run 7)



b Mixolab of control (100% wheat)

Fig. 2 a Mixolab of Composite flour (run 7). b Mixolab of control (100% wheat)

Table 3 Extrusion characteristics and microbial analysis of extrudate

Run	Variables			Extrusion characteristics					Microbial analysis (10^5 cfu/g)		
	BT (°C)	M (%)	SS (rpm)	T (g/s)	LE (%)	RT (s)	WAI (%)	WSI (%)	TVC	Yeast and mould	Salmonel
1	97.00	12.00	120.0	0.17	0.02	2.60	3.6	12.01	0.60	Nil	Nil
2	63.00	12.00	90.00	0.16	0.01	3.58	2.6	12.92	1.40	Nil	Nil
3	80.00	20.00	130.2	0.13	0.01	3.55	3.2	10.0	0.80	1.00	Nil
4	51.40	20.00	105.0	0.16	0.02	4.31	3.0	10.0	3.00	3.00	Nil
5	97.00	12.00	90.00	0.39	0.04	4.41	3.6	12.0	0.80	Nil	Nil
6	63.00	28.00	120.0	0.16	0.01	2.01	2.6	10.2	2.00	3.00	Nil
7	80.00	20.00	79.77	0.36	0.04	3.51	3.4	12.01	1.00	Nil	Nil
8	63.00	12.00	120.0	0.18	0.02	2.38	2.8	10.1	1.50	2.00	0.10
9	80.00	20.00	105.0	0.18	0.02	2.50	3.6	12.01	0.75	Nil	Nil
10	80.00	20.00	105.0	0.16	0.02	2.50	3.6	12.01	0.80	Nil	Nil
11	108.6	20.00	105.0	0.18	0.02	2.66	3.2	12.01	1.00	Nil	Nil
12	80.00	20.00	105.0	0.18	0.02	2.50	3.6	12.01	1.00	Nil	Nil
13	80.00	20.00	105.0	0.18	0.02	2.50	3.6	12.01	0.75	Nil	Nil
14	80.00	33.45	105.0	0.24	0.03	2.38	3.6	12.01	1.80	3.00	0.20
15	97.00	28.00	120.0	0.13	0.01	4.46	3.4	12.34	1.80	2.00	Nil
16	80.00	20.00	105.0	0.18	0.02	2.50	3.4	12.56	0.80	Nil	Nil
17	97.00	28.00	90.00	0.19	0.02	3.41	3.6	11.89	1.80	2.00	Nil
18	80.00	20.00	105.0	0.18	0.02	2.50	3.6	10.98	1.00	Nil	Nil
19	63.00	28.00	90.00	0.17	0.02	3.68	2.4	10.01	2.00	3.00	Nil
20	80.00	6.54	105.0	0.24	0.03	1.20	2.4	10.81	0.60	Nil	Nil

BT barrel temperature, *M* moisture content, *SS* screw speed, *T* throughput, *LE* lateral expansion, *RT* residence time, *WAI* water absorption index, *WSI* water solubility index, *TVC* total viable count

2015). Extrudates with low moisture content and high temperature had higher WSI. The water absorption index (WAI) measures the extent of water retention by the protein granules and indicates the degree of exposure of the internal structure of the protein granules to the action of water (Ruales and Nair 1993). The water absorption index (WAI) ranged from 2.4 to 3.6%. Extrudates with high temperature and screw speed had high WAI.

Microbial analyses of extrudates

The total viable counts (TVC) of the ready-to-eat snacks presented in Table 3 ranged from 0.60 to 3.00×10^5 cfu/g. WHO (1994) reported the maximum allowable limits of Total Viable Counts (TVC) permissible in cooked foods to be 10^4 cfu/g, while salmonella and yeast and mould should be absent from cooked foods. Simultaneous high temperature (≥ 80 °C) and low moisture ($\leq 20\%$) produced safe snack with low TVC and absent yeast, mould and salmonella, Similar values of 0.5–1.8 cfu/g was reported for the extrusion of rice, cassava and kersting’s groundnut composite flours by Awolu et al. (2015). The snack with the lowest TVC count was extruded with a moisture content of 12 g/100 g under a temperature of 97 °C and screw speed

of 120 rpm, confirming reports by Awolu et al. (2015) and Temple et al. (1996) that low temperature and low moisture content reduced microbial activity of snacks. Salmonella thrive at low temperature and high moisture contents as found on runs 8 and 14 snacks. Hema et al. (1994) reported the presence of microbial load in snacks extruded at low temperature.

Sensory qualities of extrudates

Sensory quality attributes of extrudates are presented in Table 4. Values obtained for all extrudates were generally acceptable by consumers. There was no significant difference ($p \leq 0.05$) in taste of the ready-to-eat snack. This may be attributed to the constant level of ingredients added to different runs before extrusion. The appearance score of the snacks ranged from 6.33 to 8.00, with runs 11, 12, 14, 15, 16 and 19 having the highest score while run 20 had the lowest appearance score. There was no significant difference ($p \geq 0.05$) in the texture of most snacks. Runs 10, 12,13,16,18 and 20 were generally accepted as the best extrudates.

Table 4 Sensory attributes of extrudates

Runs	Taste	Appearance	Texture	Color	General acceptability
Runs 1	6.66 ± 2.31 ^{ns}	7.33 ± 0.58 ^{abc}	7.33 ± 0.58 ^{ab}	7.00 ± 0.71 ^{ab}	7.08 ± 0.63 ^{abc}
Runs 2	5.66 ± 1.57 ^{ns}	7.33 ± 0.58 ^{abc}	7.33 ± 0.58 ^{ab}	5.33 ± 1.00 ^{bc}	6.42 ± 0.63 ^{abc}
Runs 3	5.33 ± 2.30 ^{ns}	7.66 ± 0.58 ^{abc}	7.67 ± 0.58 ^{ab}	4.33 ± 2.52 ^c	6.25 ± 0.75 ^{abc}
Runs 4	5.33 ± 2.30 ^{ns}	7.33 ± 0.58 ^{abc}	7.33 ± 0.58 ^b	7.67 ± 0.58 ^a	6.92 ± 0.52 ^{abc}
Runs 5	5.66 ± 1.53 ^{ns}	7.00 ± 0.00 ^{abc}	7.00 ± 0.00 ^{ab}	6.67 ± 0.58 ^a	6.58 ± 0.38 ^{abc}
Runs 6	6.66 ± 2.31 ^{ns}	7.67 ± 0.58 ^{abc}	7.67 ± 0.58 ^{ab}	6.00 ± 1.73 ^{ab}	7.00 ± 0.66 ^{abc}
Runs 7	5.66 ± 1.53 ^{ns}	7.47 ± 0.50 ^{abc}	7.26 ± 0.64 ^c	7.33 ± 1.73 ^{abc}	6.93 ± 0.51 ^{abc}
Runs 8	6.33 ± 0.83 ^{ns}	6.67 ± 0.23 ^{bc}	5.60 ± 0.91 ^{ab}	6.00 ± 0.58 ^a	6.15 ± 0.61 ^{ab}
Runs 9	6.26 ± 2.05 ^{ns}	7.73 ± 0.46 ^{abc}	7.53 ± 0.81 ^{ab}	7.80 ± 0.72 ^a	7.33 ± 0.58 ^{ab}
Runs 10	6.66 ± 2.31 ^{ns}	7.67 ± 0.58 ^{abc}	7.33 ± 0.58 ^{ab}	7.33 ± 0.35 ^a	7.25 ± 0.91 ^a
Runs 11	5.66 ± 1.53 ^{ns}	8.00 ± 0.00 ^{ab}	8.00 ± 0.00 ^{ab}	8.00 ± 0.58 ^a	7.42 ± 0.38 ^{abc}
Runs 12	5.33 ± 2.31 ^{ns}	8.00 ± 0.00 ^{ab}	7.68 ± 0.58 ^{ab}	7.67 ± 0.00 ^a	7.17 ± 0.29 ^a
Runs 13	6.66 ± 2.31 ^{ns}	7.67 ± 0.58 ^{abc}	7.67 ± 0.58 ^{ab}	7.66 ± 0.58 ^a	7.42 ± 0.52 ^a
Runs 14	5.66 ± 1.53 ^{ns}	8.00 ± 0.00 ^{ab}	8.00 ± 0.00 ^{ab}	8.00 ± 0.58 ^a	7.42 ± 0.38 ^{abc}
Runs 15	4.00 ± 0.00 ^{ns}	8.00 ± 0.00 ^{abc}	8.00 ± 0.00 ^{ab}	8.00 ± 0.00 ^a	7.00 ± 0.00 ^{abc}
Runs 16	5.33 ± 2.31 ^{ns}	8.00 ± 0.00 ^a	7.33 ± 0.58 ^{ab}	7.33 ± 0.00 ^a	7.00 ± 0.43 ^a
Runs 17	4.00 ± 0.00 ^{ns}	7.00 ± 2.65 ^c	7.33 ± 0.58 ^b	7.33 ± 0.58 ^{ab}	6.42 ± 0.80 ^{abc}
Runs 18	5.33 ± 2.31 ^{ns}	7.00 ± 1.00 ^{abc}	7.33 ± 0.58 ^{ab}	7.33 ± 0.58 ^a	6.75 ± 0.90 ^a
Runs 19	5.33 ± 2.31 ^{ns}	8.00 ± 1.00 ^{abc}	7.67 ± 0.58 ^{ab}	7.67 ± 0.58 ^a	7.17 ± 1.01 ^{abc}
Runs 20	6.33 ± 2.08 ^{ns}	6.33 ± 2.52 ^{abc}	7.67 ± 1.15 ^a	7.00 ± 0.58 ^{ab}	6.83 ± 1.18 ^a

Values are mean ± standard deviation

Values on vertical row with the same superscript are not significantly different at $p \leq 0.05$

Conclusion

The study has shown that composite flour consisting of rice flour (75.00 g), kersting's groundnut flour (20.00 g) and lemon pomace (5.00 g) had good and acceptable protein, crude fiber and mineral contents, thus, a better nutritional quality than 100% wheat flour. The addition of xanthan gum to the composite flour enhanced the functional and pasting characteristics but not the Mixolab properties. The composite flour might therefore be useful in production of other baked products minus bread. The optimum conditions for a ready-to-eat extruded snack were 97 °C barrel temperatures, 12 g/100 g moisture, 90 rpm screw speed. The snacks were generally acceptable and safe.

Compliance with ethical standards

Conflict of interest Authors declare there are no conflict of interest.

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