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FUNCTIONAL, PASTING AND SENSORY PROPERTIES OF COMPLEMENTARY FOOD FROM ORANGE FLESHED SWEETPOTATO- ROASTED AFRICAN YAM BEAN-TIGERNUT COMPOSITE FLOUR USING RESPONSE SURFACE METHODOLOGY

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Abstract: *This study investigated the functional, pasting and sensory properties of complementary food from blends of orange fleshed sweet potato, roasted African yam bean and tigernut composite flour using response surface methodology. Orange fleshed sweetpotato root, roasted African yam bean and tigernut seed were blended into composite flours based on D-optimal mixture design resulting into fourteen experimental runs. The Orange fleshed sweetpotato, roasted African yam bean and tigernut flour blends were analyzed for their functional and pasting properties using standard laboratory procedures. The composite flours were optimized using D-optimal of the mixture design. The optimized composite flours were used to prepare complementary food and sensory properties (taste, colour, aroma, thickness and overall acceptability) were evaluated using nine point Hedonic scale of preference. The bulk density, water absorption capacity, swelling power, dispersibility, least gelation capacity and wettability ranged from 0.82-0.85g/ml, 300.00-359.00%, 6.00-6.51%, 60.20-65.99%, 2.72-3.69% and 22.71to 40.81% respectively. Significant differences ($p<0.05$) were observed in the pasting properties of orange fleshed sweetpotato, roasted African yam bean and tigernut flour blends. However optimized complementary prepared from the different composite flours were all accepted by the panelists except complementary food prepared from 82.95% orange fleshed sweetpotato, 10.26% roasted African yam bean and 6.78% tigernut composite flour blend.*

Keywords: Complementary food, Orange fleshed sweet potato, roasted African yam bean, tigernut flour

1. Introduction

Complementary foods are foods given to infants in addition to breast milk when breast milk nutrients become insufficient for their energy and growth needs [1, 2]. In developing West African countries such as Nigeria, the introduction of complementary food typically starts between the ages of four to six months (i.e. after six months of exclusive breast feeding). The complementary food is usually in form of semi-liquid porridge prepared from staple cereals such as sorghum, maize and millet or tubers such sweet potato, cocoyam, irish potato etc.

It has however been observed that during this period, infants between the ages of 6-11 months are given complementary foods two-four times daily which make it the major source of nutrients for the infants. Complementary feeding is needed for both nutritional and developmental reasons, and is an important phase in the transition from milk feeding to family foods. The development of nutritious complementary foods from local and readily accessible raw materials has received considerable attention in many developing countries [2]. This is in response to the need of a highly nutritious food for infants.

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Orange fleshed sweetpotato is a conventionally bio-fortified crop with β-carotene contents of 30 – 100 ppm [4]. Orange fleshed sweetpotato has considerable antioxidant activity and can potentially improve vitamin A level in growing children in developing countries [5, 6, 7]. It is rich in carotenoids and β-carotene (containing 24.2 – 73.9mg/100 g of β-carotene on dry basis), a precursor of vitamin A [8] which protects the body from several diseases, such as night blindness and other serious diseases. Orange fleshed sweetpotato roots are source of fibre, starch, sugar, vitamin A, iron, calcium and several other minerals [9, 7].

African yam bean (AYB) (*Sphenostylis stenocarpa*) has been observed by researchers [10, 11] to be one of the less utilized legumes that are gradually going into extinction; this was reported to be probably due to the long cooking time and its taste. It was however suggested to be used in the preparation of other plant based products which can be imitated milk, milk shake, flours, candy, gruel and cheese. Adewale et al. [12] and Idowu [11] observed and reported that the vast genetic and economic potentials of AYB have been recognized most especially in reducing malnutrition among Africans but the crop has not received adequate research attention. AYB is highly nutritious with protein, mineral and fibre contents. Its protein content is reported to be similar to that of some commonly consumed legumes and its amino acid (such as lysine, tryptophan) is comparable and even better than those of cowpea, soy bean and pigeon pea according to [13]. Ade-omowaye et al. [14] and Soetan et al. [15] reported that AYB contain several bioactive compounds such as polyphenols and flavonoids which are beneficial to consumers for the maintenance of a good and healthy lifestyle.

Tigernut (*Cyperus esculentus*) is a high dietary fibre tuber crop which could be utilized in the treatment and prevention of many disease including colon cancer, coronary heart diseases, heart diseases, obesity and gastro intestinal disorder as reported by [16] and [17]. Its flour has been observed to be rich source of quality oil, vitamin E and some useful minerals such as iron and calcium which are essential for body growth and development [18, 19]. Due to its high amino acids contents, tigernut has inherent nutritional and therapeutic advantage which could serve as a good alternative to cassava in baking [20] and other food processes.

In many developing countries, traditional weaning foods are prepared mainly from cereals such as maize, sorghum [21] and millet. These cereal crops have been reported to be poor in protein quantity and quality. It has also been reported by [22] and [23] that high cost, viscous nature of commercially available complementary foods and poor hygiene of food handlers are the major constraints in the provision of complementary food of adequate nutrients for children. It is, therefore necessary to study ways and means of developing inexpensive but equally nutritious complementary food that may be within the reach of the under privilege, using locally available cereals, legumes and easy means of technologies in its production. The formulation of nutritious complementary foods from local and readily available raw materials such as orange flesh sweetpotato, African yam bean and tigernut is expected to provide protein based weaning foods that are of high quality and inexpensive.

Hence, the overall objective of this study was to determine the functional, pasting and sensory properties of complementary food from orange fleshed sweetpotato, roasted African yam bean and tigernut composite flour using response surface methodology

2. Materials and Methods

Materials

Orange fleshed sweetpotato roots were obtained from the research farm of Federal University of Agriculture, Abeokuta while African yam bean and tigernut (yellow variety) were purchased from Kuto market, Abeokuta, Ogun State, Nigeria

Production of orange fleshed sweetpotato flour

The orange fleshed sweetpotato flour was produced according to the standard method of Singh et al. [24] described by Alawode et al. [2]. The orange fleshed sweetpotato tubers were peeled and cut into thin slices manually with sharp knives. The sweetpotato slices were soaked in 1% potassium metabisulphite solution for a period of five minutes to avoid browning and to also intensify its colour. They were dried in a cabinet dryer set at 55 °C for 24 hours. The dried orange fleshed sweet potato chips were then milled into flour using the laboratory hammer mill and the milled flour sieved using 250 µm screen to obtain the flour. The flour was packaged in a sealed plastic film and stored in a properly closed plastic container till further use.

Production of roasted African yam bean flour

The modified method described by Idowu [11] and Okolie et al. [25] was used for roasted African yam bean seed. The African yam bean seeds were cleaned to remove extraneous elements such as stones, deformed bean and pest-infested beans. The seeds were washed and steeped in tap water for 72 hours and dehulled. The dehulled seeds were dried in the cabinet dryer at 60°C for 24 hours and then roasted using a gas cooker until the seeds were cracked. The seeds were dry milled after cooling into flour using the laboratory hammer mill and then sieved with 250 µm screen. The flour was packaged in an air tight plastic film and stored in a tightly closed plastic container until further use.

Production of tigernut flour

Tigernut flour was produced by the method described by Ade-Omowaye et al. [26] and Oke et al. [27]. After removing stones, pebbles, and other unknown materials from the tigernut (*Cyperus esculentus*), they were washed under running tap water. The cleaned nuts were then dried in a cabinet dryer at 60°C for 72 hours. The Dried nuts were milled in a laboratory hammer mill and sample was sieved (using 250µm screen) to obtain the flour. The tigernut flour was packed and sealed in a airtight polyethylene bags until further use.

Flour blends formulation

D-Optimal mixture design was used for the design of experiment with three independent variables, including orange fleshed sweetpotato flour, roasted African yam bean flour and tigernut flour using Design expert (Version 6.0.8). The levels of each variable were established based on a series of preliminary experiments resulting in a total of 14 experimental runs (Table 1). Flour from orange fleshed sweetpotato, roasted African yam bean and tigernut were blended together using Phillips blender (model HR-1702) and packaged in polythene bags at ambient temperature (26±2 °C) until further analysis.

Functional properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Bulk density
The bulk density of the composite flour was determined using the method described by Akpapunarn and Markakis [28] and Ohizua et al. [29]. Approximately ten grams of the composite flour was adequately weighed into a 50 ml graduated measuring cylinder. The composite flour was packed by tapping the cylinder gently on the bench top up to 10 times from a height of 5cm. The volume of the composite flour was thereafter recorded.

$$Bulk\ density\ \left(\frac{g}{ml}\right) = \frac{Weight\ of\ sample}{volume\ of\ sample\ after\ tapping}$$

Table 1:
Orange fleshed sweetpotato, roasted African yam bean and tigernut formulations using D-optimal mixture design

Runs	OFSP	RAFB	TF
1	80.00	15.00	5.00
2	82.50	10.00	7.50
3	80.83	10.83	8.33
4	80.00	10.00	10.00
5	83.33	10.83	5.83
6	80.83	13.33	5.83
7	85.00	10.00	5.00
8	85.00	10.00	5.00
9	80.00	10.00	10.00
10	80.00	15.00	5.00
11	80.00	12.50	7.50
12	80.00	12.50	7.50
13	82.50	12.50	5.00
14	81.67	11.67	6.67

OFSP: Orange Fleshed Sweetpotato, RAFB- Roasted African Yam Bean, TF: Tigernut Flour

Swelling power (SP)
The swelling power was determined using the method described by Oke et al. [17]. Composite flour of absolutely one gram was weighed into a 50ml centrifuge tube. After which 50ml of distilled water was added and mixed gently together. The mixture was heated in a water bath at 90 ºC for 15 minutes with gentle stirring to prevent clumping of the flour. Thereafter, 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 then determined to get dry matter content of the gel.

$$Swelling\ power = \frac{Weight\ of\ wet\ mass\ sediment}{Weight\ of\ dry\ matter\ in\ gel}$$

Water absorption capacity (WAC)
The method described by Onwuka [30] was used for the determination of the water absorption capacity of the composite flour. About one gram of the composite flour was weighed into a 15 ml centrifuge tube and suspended in 10 ml water. It was vigorously shaken on a platform tube rocker for 1 minute at room temperature. The sample was allowed to stand for about 30 minutes and centrifuged at 1200 x g for 30 minutes. The volume of free water was then read directly from the centrifuge tube.

$$Water\ absorption\ capacity\ (\%) = \frac{Amount\ of\ water\ added - free\ water}{Weight\ of\ sample \times density\ of\ water \times 100}$$

Dispersibility

The method described by Kulkarni et al. [31] and Ohizua et al. [29] was adopted for the determination of the dispersibility of the composite flour. About ten grams of each sample was suspended in 200 ml measuring cylinder and distilled water was added up to 100 ml mark. It was then stirred vigorously and allowed to settle for 3 hr. The volume of the settled particles was thereafter recorded and subtracted from 100. The difference was reported as percentage dispersibility.

$$Dispersibility\ (\%) = 100 - Volume\ of\ settled\ particle$$

Wettability

The method described by Onwuka [30] and Iwe et al. [32] was adopted for the determination of the wettability of the composite flours. One gram of each flour sample was weighed and added into a 25 ml graduated measuring cylinder of 1cm diameter. Finger was then placed over the open end of each cylinder, inverted and clamped at a height of 10cm from the surface of a 600 ml beaker containing 500ml distilled water. The finger was then removed and the test sample was allowed to dump. The value of the wettability was recorded as the time required for the sample to become completely wet.

Least gelation concentration (LGC)

This was determined according to the method described by Coffman and Garcia [33]. Sample suspensions of between 2-20% (w/w) were prepared in distilled water and the dispersions were transferred into a test tube. It was heated in a boiling water bath for about 1 h, followed by a rapid cooling in a cold water bath. The test tubes were further cooled at 4 ºC for 2 h. The least gelation concentration of the sample was determined as the concentration when the sample from the inverted test tube did not slip or fall.

Pasting properties of orange fleshed sweetpotato- roasted African yam bean-tigernut composite flour

These were determined with the aid of a Rapid Visco Analyzer (RVA instrument). Absolutely three grams of each sample were weighed into a dried empty canister and 25ml of distilled water was dispensed into the canister containing the sample, the suspension was mixed properly to avoid lumps formation and the canister was fitted into the rapid visco analyzer. A paddle was placed into the canister and immediately automatically plotting the characteristic curve as the process proceeds. The parameters estimated in the process were peak viscosity, setback viscosity, final viscosity, trough, breakdown viscosity, pasting temperature and time to reach peak viscosity.

Preparation of orange fleshed sweetpotato- roasted African yam bean-complementary food

Complementary foods from orange fleshed sweetpotato- roasted African yam bean-tigernut composite flour were prepared according to the method described by Opara et al. [34] with little modification in the addition of boiled water. Complementary foods in form of gruels were prepared by reconstituting 60 g of each of the composite flours in 100 mL of clean water. About 60 mL of boiled water was added to the suspension to produce hot gruel, and this was brought to a boil for 5 min, cooled, and served to a panel of 25 members.

Sensory evaluation of complementary food from orange flesh sweetpotato-African yam bean-tigernut

Complementary foods in form of gruels were served to 25 members of panel comprising majorly of mothers among students and members of staff of Moshood Abiola Polytechnic, Abeokuta. They were asked to score the gruels on a 9-point hedonic scale of preference where 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely. Sensory qualities evaluated were: taste, colour, aroma, thickness and overall acceptability [35]

Statistical analysis

Data except sensory scores were obtained in triplicate and subjected to statistical analysis using SPSS version 21.0. The means, analysis of variance and the difference between the mean values were evaluated at $p<0.05$ using Duncan multiple range test. The investigation of the optimization procedure was done using Design expert version (6.0.8) software which was used to predict the effects of the variation of composite flour. The statistical parameters, including the adjusted coefficients of determination (adjusted R^2), coefficient of determination (R^2) and regression (F value) were used to evaluate and select the best-fitting mathematical method [36]. The design was expressed by the polynomial regression equation to generate the model as shown below:

$$Y_i = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 - \beta_{11}X_1^2 + \beta_{22}X_2 + \beta_{33}X_3^2 + \beta_{44}X_4^2 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{34}X_3X_4$$

Where Y_i is the predicted response; β_o, β_i, and β_{ii} are the linear coefficient and interaction coefficient. The suitable polynomial equations for the design, such as linear, quadratic, or special cubic models, were chosen according to the fittest model. In order to view the interaction of the response variables and the factor variables, the mixture design space and three-dimensional (3D) surface plots of the fitted polynomial regression were generated.

3. Results and Discussion

Functional properties of orange fleshed sweetpotato- roasted African yam bean-tigernut composite flour

Functional properties of orange fleshed sweetpotato- roasted African yam bean-tigernut composite flour are shown in Table 2. Bulk density depicts the behaviour of the material in dry mixes and is an important parameter that can determine packaging requirement of the product [37, 38]. The bulk density of the orange flesh sweetpotato - African yam bean-tigernut composite flour ranged from 0.82 to 0.85g/ml. As presented in the regression table (table 3), the interaction effect of orange flesh sweetpotato, roasted African yam and tigernut flour were not significantly ($p>0.05$) affected which might be due to the differences in the particle size since the composite flours were prepared using the same processing equipment. However, Adebowale et al. [39] and Adegunwa et al. [40] reported that bulk density of flour is usually affected by its particle size and also by density of the flour blend which always have significant application in packaging, transportation and raw material handling. The low bulk density of the composite flour observed in this study would be of advantage in the formulation of complementary food. This is due to the fact that low density has been reported [41, 2] to be of advantage in the formulation of easily digestible food.

Table 2:
Functional properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

OFSP	RAFB	TF	Bulk Density (g/ml)	Water Absorption Capacity (%)	Swelling Capacity (%)	Dispersibility (%)	Least Gelation Capacity (%)	Wettability (Sec.)
80.00	15.00	5.00	0.841^{g}	306.50^{b}	5.67^{c}	63.78^{d}	3.55^{d}	37.61^{e}
82.50	10.00	7.50	0.848^{h}	329.50^{de}	5.73^{d}	64.78^{f}	3.36^{c}	28.75^{c}
80.83	10.83	8.33	0.834^{d}	359.00^{g}	5.82^{e}	63.98^{d}	2.82^{a}	22.81^{a}
80.00	10.00	10.00	0.821^{a}	334.50^{e}	5.09^{b}	65.99^{g}	3.15^{bc}	26.69^{b}
83.33	10.83	5.83	0.834^{d}	340.50^{f}	6.19^{g}	60.20^{a}	3.69^{d}	40.81^{f}
80.33	13.33	5.83	0.836^{e}	300.00^{a}	5.00^{a}	63.98^{d}	3.05^{b}	29.58^{c}
85.00	10.00	5.00	0.834^{d}	318.50^{c}	5.79^{e}	65.19^{c}	3.23^{bc}	32.63^{d}
85.00	10.00	5.00	0.834^{d}	318.50^{c}	5.79^{e}	65.19^{c}	3.23^{bc}	32.63^{d}
80.00	10.00	10.00	0.821^{a}	334.50^{e}	5.09^{b}	65.99^{g}	3.15^{bc}	26.69^{b}
80.00	15.00	5.00	0.841^{g}	306.50^{b}	5.67^{c}	63.78^{d}	3.55^{d}	37.61^{e}
80.00	12.50	7.50	0.834^{d}	327.50^{d}	5.05^{ab}	64.38^{e}	2.72^{a}	22.71^{a}
80.00	12.50	7.50	0.834^{d}	327.50^{d}	5.05^{ab}	64.38^{e}	2.72^{a}	22.71^{a}
82.50	12.50	5.00	0.828^{c}	305.00^{ab}	6.51^{h}	62.49^{b}	3.62^{d}	37.39^{e}
81.67	11.67	6.67	0.825^{b}	320.50^{c}	6.12^{f}	63.40^{c}	3.19^{bc}	36.60^{e}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); OFSP: Orange fleshed sweetpotato flour, RAFB-roasted African yam bean flour, TF: Tigernut flour,

Table 3:
Regression coefficient of functional properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Parameters	Bulk Density	WAC	Swelling Capacity	Dispersibility	Least Gelation Capacity	Wettability
A (X_1)	0.88	320.26	5.80	62.89	3.28	33.39
B(X_2)	4.88	303.20	5.55	64.01	3.52	36.81
C(X_3)	0.87	337.12	5.15	66.01	3.12	25.86
AB	-8.47	-25.06	2.73	-6.12	0.94	20.99
AC	1.23	52.51	1.87	-2.66	0.69	8.05
BC	-8.30	38.73	-1.31	-2.38	-2.70*	-34.96
R^2	0.4432	0.6570	0.7263	0.6958	0.8650	0.7867
Adj R^2	0.095	0.4426	0.5552	0.5057	10.26	0.6534
F-value	1.27	3.06	4.25	3.66	0.7807	5.90

*Significant at $p<0.05$; A (X_1) – Orange fleshed sweetpotato flour, B (X_2)-roasted African yam bean flour, C (X_3) – Tigernut flour, WAC: Water absorption capacity; A- Main effect of orange fleshed sweetpotato flour, B-Main effect of roasted African yam bean flour, C- Main effect of tigernut flour, AB- Interaction effect of orange fleshed sweetpotato and roasted African yam bean flour, AC- Interaction effect of orange fleshed sweetpotato and tigernut flour, BC- Interaction effect of roasted African yam bean and tigernut flour, R^2- Coefficient of determination

The surface plot for the effect of bulk density on orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour is illustrated in Figure 1.

Water absorption capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged from 300.00 to 359.00%. The regression coefficient is shown in Table 3 where it was observed that the quadratic model developed for water absorption capacity has the coefficient of determination (R^2) of 0.6570 and F-value of 3.06. The regression coefficient showed that the main effect and the interaction effect of orange fleshed sweetpotato, roasted African yam bean and tigernut flour were not significantly ($p>0.05$) affected. Figure 2 shows the response surface plots for the water absorption capacity of composite flour from orange flesh sweetpotato, roasted African yam bean and tigernut flour. Water absorption capacity signifies the ability of a product to associate with water under limited water conditions [42]. The values obtained for water absorption capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour varies from each other, this might be due to the differences in the protein and starch contents of the flour blends [43, 44]. However, Fekria et al. [45] reported that flours with high water absorption capacity have more hydrophilic constituents such as polysaccharides.

Swelling power (SP) is the ability of the flour to absorb water and hold it in the swollen flour granule [38]. The swelling capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged between 6.00 and 6.51%. As shown in the regression table, the quadratic model developed for swelling capacity has the coefficient determination (R^2) of 0.7263 and F-value of 4.25. The regression table revealed that when tigernut flour was held constant, increase in orange flesh sweetpotato and roasted African yam bean caused an increase in the swelling capacity; this could be due to high amylose content likely to be present in the starch granules of orange fleshed sweetpotato flour. This implies that the composite flour will produce a thick viscous gruel in the preparation of complementary food [2]. The surface plot for the effect of swelling power on orange flesh sweetpotato-roasted African yam bean-tigernut composite flour is illustrated in Figure 3. Dispersibility is the ability of the flour blends to reconstitute in water. The dispersibility of composite flour from orange fleshed sweetpotato-roasted African yam bean-

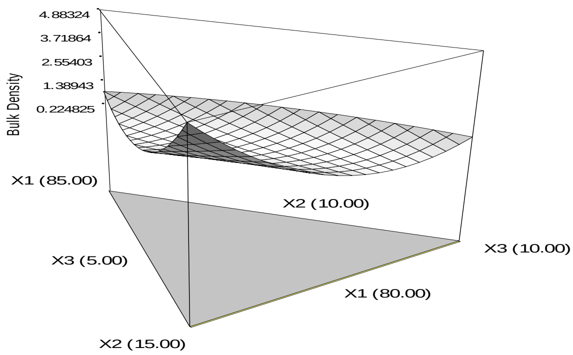

Fig. 1: 3D surface plot showing the effect of flour blends on bulk density of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flours

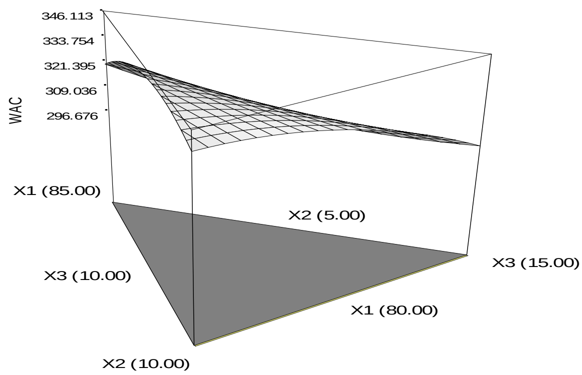

Fig. 2: 3D surface plots showing the effect of flour blends on water absorption capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

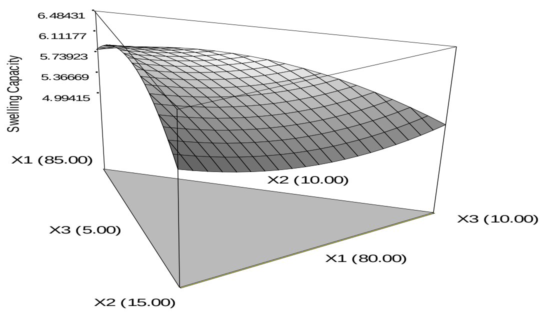

Fig. 3: 3D surface plot showing the effect of flour blends on swelling capacity of orange fleshed sweetpotato- roasted African yam bean-tigernut composite flour

tigernut ranged between 60.20 and 65.99% The regression of coefficient has shown in Table 3 shows that the coefficient of determination (R^2) and F-value for dispersibility is 0.6958 and 3.66 respectively. The regression table shows that the main and the interaction effect were not significantly ($p>0.05$) affected on dispersibility of the flour blends. According to Kulkarni et al. [31] and Alawode et al. [2] the higher the dispersibility, the better the flour reconstitutes in water. However, the values of dispersibility obtained in this study for orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour are high, this implies they will easily reconstitute to give fine consistency of dough during mixing [39; 29] The surface plot for the effect of dispersibility on the composite flour is presented in Figure 4.

The least gelation concentration is a measure of the minimum amount of flour blends that is needed to form a gel in a measured volume of water [29]. The least gelation capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged from 2.72 to 3.69%. The quadratic model developed for the least gelation capacity has the coefficient of determination (R^2) and F-value of 0.8650 and 10.26 respectively. It was observed from the regression table that the interaction effect of African yam bean and tigernut flour had a negative significant ($p<0.05$) effect on the least gelation capacity of the composite flour. When tigernut was held constant, an increase in orange fleshed sweetpotato and roasted African yam bean caused an increase in the least gelation capacity. This could be as a result of roasted African yam bean which serve as a protein source, increases the protein concentration thereby enhancing the interaction among the binding forces which in turn increases the gelling ability of the flour [46]. However, it was reported by Adebowale et al. [47] that gelation takes place more readily at higher protein concentration because of greater intermolecular contact during heating and that high protein solubility is always necessary for gelation. Figure 5 shows the surface plot for the effect of least gelation capacity on the orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour.

Wettability is the measure of the rate at which flour samples get wetted in water. The wettability of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged from 22.71 to 40.81%. The regression coefficient presented in Table 3 shows that the quadratic model developed for wettability has the coefficient of determination (R^2) of 0.7867 and F-value of 5.90 respectively. The interaction effect of roasted African yam bean and tigernut flour were significantly ($p<0.05$) affected negatively as shown in Table 2. Wettability of flour is an important indicator of instant characteristics of dried flours. In this study, it was observed that the wettability of the composite flour samples was observed to be high which is an indication of a slight reduction in instant characteristic of the flour as reported by Udensi et al. [48] to be an indication for change in flour characteristic. Figure 6 shows the surface plot for the effect of wettability on the orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Pasting properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

The pasting properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour are presented in Table 4.

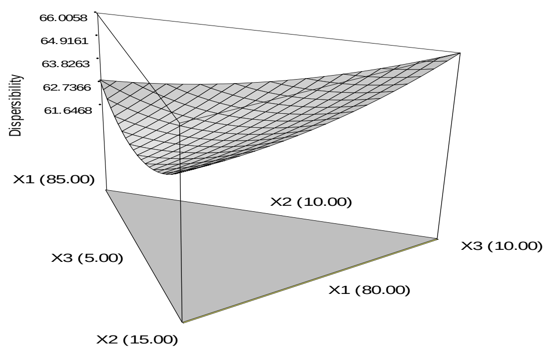

Fig. 4: 3D surface plot showing the effect of flour blends on dispersibility of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

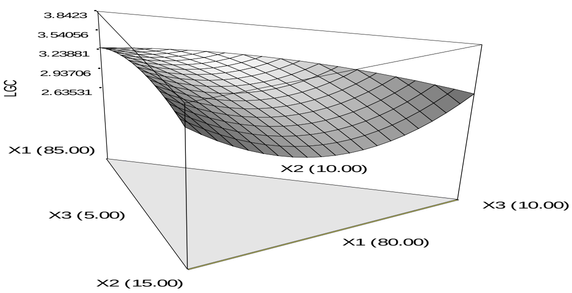

Fig. 5: 3D surface plot showing the effect of flour blends on least gelation capacity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

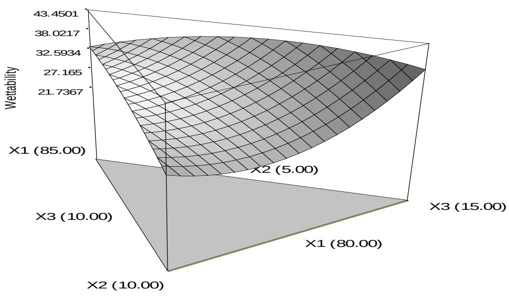

Fig. 6: 3D surface plot showing the effect of flour blends on wettability of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

The peak viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged from 718.00 to 864.5RVU. From the regression table 5, the quadratic model developed for peak viscosity has the coefficient determination (R^2) of 0.9621 and F-value of 40.92 respectively. The regression table shows that interaction effects of orange fleshed sweetpotato and roasted African yam bean, roasted African yam bean and tigernut flour had a negative significant ($p<0.05$) effect on the peak viscosity of the composite flour. When tigernut flour was held constant, increase in orange fleshed sweetpotato and roasted African yam bean caused a decrease in the peak viscosity. Peak viscosity is indicative of the strength of the pastes which are formed from gelatinization during processing in food application [49]. Peak viscosity is often correlated with final product quality. It is the maximum viscosity developed during or soon after heating [50, 42]. It reflects the ability of starch to swell freely before their physical breakdown [51]. It has been suggested that high peak viscosity contributes to good texture of paste, which basically depends on high viscosity and moderately high gel strength [50]. The relatively high peak viscosity exhibited by orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour is an indication that the flour may be suitable for products requiring high gel strength and elasticity. Figure 7 shows the surface plot for the effect of peak viscosity on the orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Trough is the minimum viscosity after the initial peak and occurs after the commencement of the sample cooling [42]. The trough viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour ranged from 713.00 to 840.00RVU.

Table 4:
Pasting properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

OFSP	RAFB	TF	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak Time (Mins.)	Pasting Temp (ºC)
80.00	15.00	5.00	864.50[c]	840.00[c]	24.50[b]	1188.50[c]	348.50[c]	5.73[ab]	84.85[a]
82.50	10.00	7.50	823.50[bc]	804.50[bc]	19.00[ab]	1131.00[bc]	326.50[abc]	5.34[a]	83.98[a]
80.83	10.83	8.33	788.50[abc]	783.00[abc]	5.00[ab]	1100.00[abc]	317.00[abc]	5.74[ab]	84.83[a]
80.00	10.00	10.00	779.50[abc]	778.00[abc]	1.50[a]	1087.50[abc]	309.50[abc]	6.47[bc]	85.65[a]
83.33	10.83	5.83	818.50[bc]	798.00[bc]	20.00[ab]	1129.50[bc]	331.00[bc]	5.87[abc]	84.00[a]
80.33	13.33	5.83	776.50[abc]	770.50[abc]	6.00[ab]	1085.00[abc]	314.50[abc]	6.47[bc]	85.70[a]
85.00	10.00	5.00	838.50[bc]	811.00[bc]	26.50[b]	1159.50[c]	347.50[c]	5.33[a]	85.68[a]
85.00	10.00	5.00	838.50[bc]	811.00[bc]	26.50[b]	1159.50[c]	347.50[c]	5.33[a]	85.68[a]
80.00	10.00	10.00	779.50[abc]	778.00[bc]	1.50[a]	1087.50[abc]	309.50[abc]	6.47[bc]	85.65[a]
80.00	15.00	5.00	864.50[c]	840.00[c]	24.50[b]	1188.50[c]	348.50[c]	5.73[ab]	84.85[a]
80.00	12.50	7.50	718.00[a]	713.00[a]	5.00[ab]	1001.00[a]	288.00[a]	6.70[c]	84.38[a]
80.00	12.50	7.50	718.00[a]	713.00[a]	5.00[ab]	1001.00[a]	288.00[a]	6.70[c]	84.38[a]
82.50	12.50	5.00	799.50[abc]	793.50[abc]	6.00[ab]	1108.00[abc]	314.50[abc]	6.34[bc]	85.60[a]
81.67	11.67	6.67	752.50[ab]	742.50[ab]	10.00[ab]	1036.00[ab]	294.00[ab]	6.60[c]	85.18[a]

Mean values with different superscripts within the same column are significantly different (p <0.05); OFSP: Orange fleshed sweetpotato flour, RAFB-Roasted African yam bean flour, TF – Tigernut flour, Temp-Temperature

The regression coefficient shown in Table 5 revealed that the quadratic model developed for trough has the coefficient of determination (R^2) of 0.9452 and F-value of 27.62 respectively. The regression table shows that interaction effects of orange fleshed sweetpotato and roasted African yam bean, roasted African yam bean and tigernut flour were significantly ($p<0.05$) affected negatively. Figure 8 shows the response surface plots for the trough viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour. The high trough viscosity obtained in this study is an indication that the paste can withstand breakdown during cooling because Oke et al. [17] reported that the higher the trough viscosity, the greater the ability of the paste to withstand breakdown during cooling

Breakdown is a measure of the ease with which the swollen granules can be disintegrated [52]. The breakdown of composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut ranged between 1.50 and 26.50RVU. From the regression table, the regression of coefficient shows that the coefficient of determination (R^2) and F-value for breakdown is 0.9703 and 52.50 respectively as shown in Table 5. The regression shows that interaction effects of orange fleshed sweetpotato and roasted African yam bean, roasted African yam bean and tigernut flour were significantly ($p<0.05$) affected negatively while interaction effect of orange fleshed sweetpotato and tigernut flour was significantly ($p<0.05$) affected positively.

Increase in orange fleshed sweetpotato and roasted African yam bean led to decrease in the breakdown when tigernut flour was held constant.

Table 5:
Regression coefficient of pasting properties of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Parameters	Peak	Trough	Breakdown	Final viscosity	Setback	Peak time	Pasting Temperature
A (X_1)	839.26	811.13	27.12	1160.04	347.89	5.34	85.49
B(X_2)	863.15	839.30	23.86	1187.70	348.39	5.74	84.94
C(X_3)	782.77	781.51	1.26	1092.56	311.04	6.39	85.66
AB	-210.37*	-134.12*	-74.65*	-264.11*	-127.93*	3.77*	2.30
AC	83.35	59.16	25.78*	65.03	7.93	-2.27*	-6.29*
BC	-411.59*	-379.73*	-32.01*	-538.75*	-158.89*	2.46*	-2.52
R^2	0.9621	0.9452	0.9703	0.9407	0.9343	0.8904	0.6321
Adj R^2	0.9384	0.9110	0.9517	0.9037	0.8933	0.8219	0.4021
F-value	40.92	27.62	52.50	25.40	22.76	13.00	2.75

*Significant at $p<0.05$; A (X_1) – Orange fleshed sweetpotato flour, B (X_2)-Roasted African yam bean flour, C (X_3) – Tigernut flour, WAC: Water absorption capacity; A- Main effect of orange fleshed sweetpotato flour, B-Main effect of Roasted African yam bean flour, C- Main effect of tigernut flour, AB- Interaction effect of orange fleshed sweetpotato and roasted African yam bean flour, AC- Interaction effect of orange fleshed sweetpotato and tigernut flour, BC- Interaction effect of roasted African yam bean and tigernut flour, R^2- Coefficient of determination

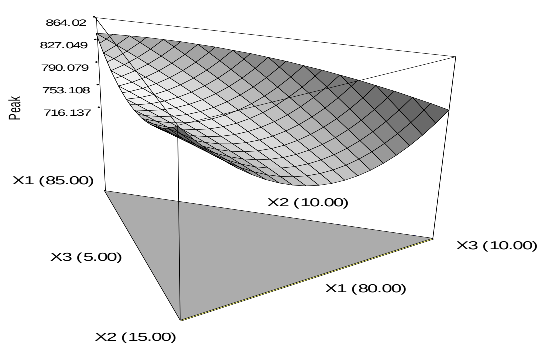

Fig. 7: 3D surface plot showing the effect of flour blends on peak viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

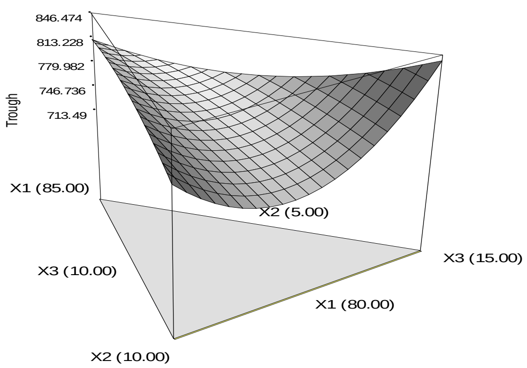

Fig. 8: 3D surface plot showing the effect of flour blends on trough viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

However, Adebowale et al. (47) and Oke et al. (17) reported that the higher the breakdown in viscosity, the lower the ability of starch sample to withstand heating and shear stress during cooking. This implies that large values of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour in this study indicate little breakdown of sample starches [42]. Figure 9 shows the response surface plot for the effect of breakdown viscosity on the orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

The final viscosity indicates the consistency at which the cooked paste of the flours is likely to be consumed [52]. The final viscosity of composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut ranged between 1001.00 and 1188.50 RVU. The quadratic model developed for the final viscosity content has the coefficient of determination (R^2) and F-value of 0.9407 and 25.40 respectively. It was observed from the regression table that the interaction effects of orange fleshed sweetpotato and roasted African yam bean, roasted African yam bean and tigernut flour were significantly ($p<0.05$) affected negatively. When roasted African yam bean was held constant, increase in orange fleshed sweetpotato and tigernut flour caused an increase in the final viscosity. The variation in the final viscosity for orange flesh sweetpotato-African yam bean-tigernut composite flour might be due to the sample kinetic effect of cooling on viscosity and the re-association of starch molecules in the samples [53]. The final viscosity is an important parameter in predicting the final textural quality of food [54]. Figure 10 shows the response surface plot for the effect of final viscosity on composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut. The setback viscosity is an index of retrogradation or re-ordering of the starch molecules. It has been correlated with texture of the food products [55; 17]. The setback of composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut ranged between 288.00 and 348.50RVU. From the regression table, the quadratic model developed for setback has the coefficient of determination (R^2) of 0.9343 and F-value of 22.76 as shown in Table 5. The interaction effects of orange fleshed sweetpotato and roasted African yam bean, roasted African yam bean and tigernut flour were significantly ($p<0.05$) affected negatively as shown in Table 5. At a constant African yam bean, while orange flesh sweetpotato and tigernut flour increases, the setback increases. The setback value obtained in this study was high, this implies the higher the setback value, the higher the rate of retrogradation [47]. Soluble amylose is largely responsible for retrogradation during setback. The response surface plot for setback on composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut is depicted in Figure 11. Peak time is the time at which the peak viscosity occurred in minutes and it is a measure of the cooking time of the flour [17]. The peak time of composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut ranged between 5.33 and 6.70mins. The response surface plots for peak time on orange fleshed sweetpotato-African yam bean-tigernut composite flour are shown in Figure 12. The regression table revealed that increase in orange fleshed sweetpotato and roasted African yam bean when tigernut flour was held constant which led to increase in the peak time of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour, which is an indication of more processing time in the composite flour. The pasting temperature is the temperature at which the viscosity starts to rise [49]. The pasting temperature of composite flour from orange fleshed sweetpotato-roasted African yam bean-tigernut ranged between 83.98 and 85.68 ºC as shown in Table 4. From the regression table (table 5), the quadratic model developed for pasting temperature has the coefficient of determination (R^2) of 0.6321 and F-value of 2.75. The interaction effect of orange fleshed sweetpotato and tigernut flour had a negative significant ($p>0.05$) effect on the pasting temperature of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour. At an increase in orange flesh sweetpotato and African yam bean and at a constant tigernut flour, the pasting temperature increase which is an indication of the gelatinization time during processing [17]. A higher pasting temperature implies higher water binding capacity and higher gelatinization [56]. The response surface plots for pasting temperature on orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour are shown in Figure 13.

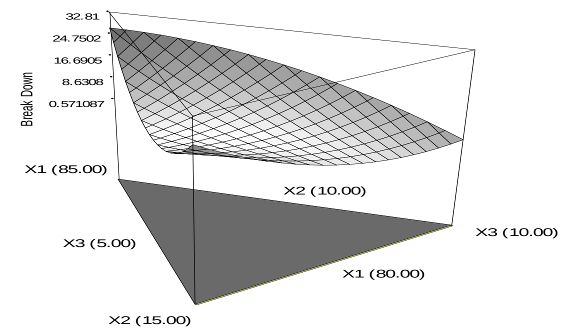

Figure 9: 3D surface plot showing the effect of flour blends on breakdown viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

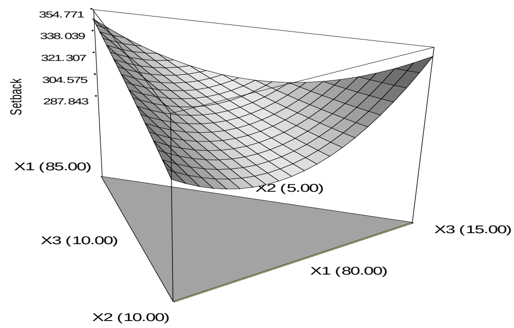

Figure 11: 3D surface plot showing the effect of flour blends on setback viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

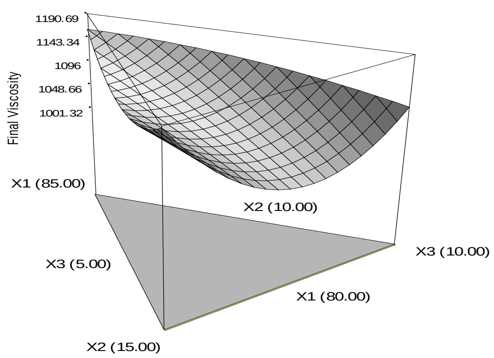

Figure 10: 3D surface plot showing the effect of flour blends on final viscosity of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

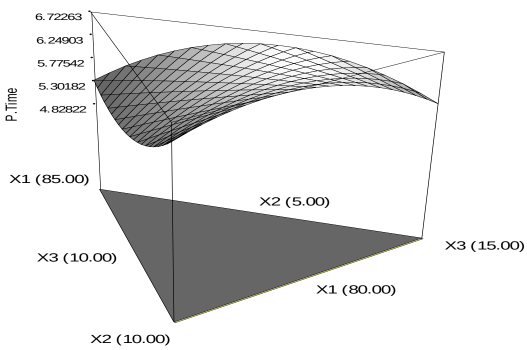

Figure 12: 3D surface plot showing the effect of flour blends on peak time of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

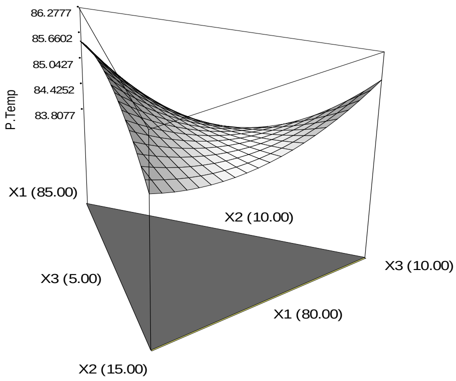

Figure 13: 3D surface plot showing the effect of flour blends on pasting temperature of orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Optimization of orange fleshed sweet potato, Roasted African yam bean and tigernut composite flour for complementary food

The composite flour was optimized based on some important properties attributed to complementary food. Bulk density, water absorption capacity, swelling capacity, dispersibility, least gelation capacity, wettability, peak, trough, breakdown, final viscosity, setback, peak time and pasting temperature were the major quality parameters studied in this research which were also the criteria based on desirability concept as well as their main quality parameters serving as the constraints to process optimization. The solution to the optimized orange flesh sweet potato, African yam bean and tigernut composite flour for complementary food is presented in Table 6

Table 6

Solution to optimization of orange fleshed sweetpotato, roasted African yam bean and tigernut flour blends for complementary food

No	OFSP	RAFB	TF	BD	WAC	SWC	DISP	LGC	Peak	Trough	BD	FV	SB	P.Time	P.Temp	Desirability
1	80.00	14.88	5.12	4.603	304.74	5.512	64.00	3.454	851.99	829.38	22.61	1173.3	343.94	5.81	84.90	0.718-Selectd
2	81.15	10.00	8.85	1.090	342.55	5.632	64.82	3.282	810.47	798.77	11.76	1119.5	320.89	5.75	84.51	0.628
3	81.06	10.00	8.94	1.077	342.32	5.602	64.90	3.272	808.62	797.65	11.03	1117.7	320.15	5.79	84.57	0.628
4	82.95	10.26	6.78	0.928	336.28	6.012	63.26	3.364	823.64	808.20	20.23	1132.8	329.46	5.42	84.22	0.656

OFSP: Orange fleshed sweetpotato; RAFB: Roasted African yam bean, TF: Tigernut flour, BD: Bulk density, WAC: Water absorption capacity, SWC: Swelling capacity, DISP: Dispersibility, LGC: Least gelation capacity, BD: Breakdown viscosity, FV: Final viscosity, SB: Setback, P.Time: Peak Time, P.Temp: Pasting Temperature

Sensory score for complementary food from optimized orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

Sensory scores for optimized and control complementary food quality attributes (taste, colour, aroma, thickness and overall acceptability) are shown in Table 7. There were significant ($p<0.05$) differences in all the attributes evaluated. The scores for taste, colour, aroma, thickness and overall acceptability ranged from 6.15 to 6.60, 6.60 to7.10, 5.25 to 6.60, 5.70 to 7.00 and 5.65 to 7.30 respectively. Complementary food prepared from 100% orange fleshed sweetpotato flour and optimized complementary food prepared from 81% orange fleshed sweetpotato flour, 10% roasted African yam bean flour and 8.85% tigernut flour had the highest degree of likeness followed by complementary food prepared from 81.06% orange flesh sweetpotato flour, 10% African yam bean flour and 8.94% tigernut flour while complementary food prepared from 82.95% orange fleshed sweetpotato flour, 10.26% roasted African yam bean flour and 6.78% tigernut flour had the lowest degree of likeness. Hence optimized complementary prepared from orange fleshed sweetpotato-African yam bean-tigernut composite flour were all accepted by the panelist except complementary food prepared from 82.95% orange fleshed sweetpotato flour, 10.26% roasted African yam bean flour and 6.78% tigernut flour.

4. Conclusion

This study revealed that characterization of orange fleshed sweetpotato, roasted African yam bean and tigernut composite flour was significantly affected by the functional and pasting properties. However, acceptable complementary food can be obtained at an optimized condition of 81.15% orange fleshed sweetpotato, 10% African yam bean and 8.85% tigernut flour.

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6. Declaration of interest No potential conflict of interest was reported by the authors concerning this work.

Table 7:
Sensory score for complementary food from optimized orange fleshed sweetpotato-roasted African yam bean-tigernut composite flour

OFSP	RAYB	TF	Taste	Colour	Aroma	Thickness	Overall Acceptability
100	0	0	6.55^{a}	7.10^{a}	6.30^{b}	6.85^{b}	7.30^{ac}
80.00	14.88	5.12	6.60^{a}	6.75^{a}	6.60^{b}	7.00^{b}	6.65^{ac}
81.15	10.00	8.85	6.15^{a}	6.60^{a}	6.05^{ab}	6.90^{b}	7.00^{bc}
82.95	10.26	6.78	6.20^{a}	6.70^{a}	5.25^{a}	5.70^{a}	5.65^{a}
81.06	10.00	8.94%	6.25^{a}	6.60^{a}	6.45^{b}	6.20^{ab}	6.30^{ab}

Mean values with different superscripts within the same column are significantly different ($p<0.05$); OFSP: Orange fleshed sweetpotato flour, RAFB-Roasted African yam bean flour, TF – Tigernut flour

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