# *Original Research Article*

**Proximate Composition, Functionality and Pasting Properties of Orange Flesh Sweet Potato and Red Bambara Groundnut Flour Blends for Snacks Formulation**

**Abstract**

Successful use of non-wheat flours for snacks production depends on their functional and pasting properties. The use of orange fleshed sweet potato and red Bambara groundnut flour blends for snack production have not been fully explored. The objective of this work was to formulate flour blends using orange fleshed sweet potato and red Bambara groundnut and to evaluate their proximate compositions and processing properties for possible application in the production of high protein and pro-vitamin A enriched snacks for consumers especially children in developing countries. Flour blends were formulated in ratio 60:40, 50:50, 40:60, 30:70 (orange fleshed sweet potato to red banbara groundnut). The protein and fat increased from 12.95±0.05% (60:40) to 16.87±0.02% (30:70) and 2.17±0.03% (60:40) to 3.05±0.04% (30:70) respectively. Ash and carbohydrate decreased from 2.52±0.04% (60:40) to 2.27±0.05% (30:70) and 60.38±0.44% (30:70) to 69.09±0.30% (60:40). The water absorption capacities for the flour blends ranged between 28.03±0.17% and 50.40±0.40%. Oil absorption capacity was between 16.70±0.12% and 31.40±0.13%. Swelling capacities was highest in 30:70 (2.48±0.06%) and lowest in 60:40 (2.13±0.07%). Solubility was between 9.27±0.59% and 11.67±0.70%. Bulk density ranged between 0.77±0.01 g/ml and 0.87±0.02g/ ml. Peak, breakdown, setback and final viscosities increased from 92.88±3.47 to109.34±0.23; 20.33±3.66 to 21.75±1.17; 32.16±0.84 to 44.59±0.25 and 102.71±1.00 to 132.00±1.06 RVU respectively. This study indicate that the 50% sweet potato and 50% red bambara groundnut flour blend will make a better product judging from its functional and pasting properties compared to other blends but will require a little more energy to cook.

**Keywords:** Orange fleshed sweet potato, bambara groundnut, proximate, functionality, pasting properties



## INTRODUCTION

Most snack food products are primarily produced from wheat flour. However, the use of non-wheat flour in snack foods and baked products is recently being practiced in many countries of the world for some social, cultural, economic, agronomical and nutritional/ health reasons. The increasing incidence of celiac disease or allergic reactions/ intolerances to wheat gluten in Europe has caused food markets to be filled with wheat-less breads [13]. In Nigeria and many other countries in the world, snack food products especially *chin-chin*, meat pie, dough-nuts, cookies, scones, buns and bakery products such as breads and biscuits are still being mostly produced from one hundred percent wheat flour. Flour can be made from locally available raw materials that are more nutritious, cheap and readily available [16]. The use of non-wheat flour mixed with flour from high protein food sources for making snack foods and other bakery products in Nigeria and many other developing countries may be justified from nutritional, economical, and agronomic perspectives. Wheat is grown in temperate countries and Nigeria's climatic conditions are not quite adaptable for growing enough wheat for its needs.

The main ingredient contained in wheat flour which conferred on it the ability to produce the visco-elastic dough and firm gel is gluten. Roots and tubers, other cereals and legumes are lacking in this protein only found in wheat. In order to produce dough with similar properties to that of wheat flour we need to select a flour blend that will possess the ability to form a firm gel. In this wise we will need to formulate flour blends by using a combination of plant food protein sources and starches that will have similar effects as gluten. The successful use of plant protein sources as food ingredients depends to a large extent on their contribution to the overall beneficial qualities they impact to the manufactured food and this depend to a large extent on their functional properties. Functional properties are the properties, which define the consumers' acceptability of products made from such food ingredients. These are the characteristics which defines how suitable a food ingredient will be for the intended purpose. Functional characteristics are required to evaluate and possibly help to predict how new proteins, fat, fibre and carbohydrates may behave in specific systems as well as demonstrate whether or not such protein can be used to simulate or replace conventional protein [18; 8]. In selecting raw materials for use as alternatives for wheat flour we need to consider the suitability of the material for the intended purpose and its availability and cost implications.

Sweet potato (*Ipomoea batatas* L.) has high starch content like other tropical root crops like yam, but unlike any other root and tuber crop, is very rich in carotene and pro-vitamin A [4]. It is fat-free food containing protein, vitamins and minerals. According to [17] sweet potato is expected to play a vital role in combating the food shortages and malnutrition that may increasingly occur as a result of population growth and pressure on land utilization. Its production efficiency of edible energy and protein is outstanding in the developing world [28]. The potential of sweet potato as poverty alleviation, highly nutritional crop with growing importance in the prevention of malnutrition in children, are not in doubt [29].

Bambara groundnut (*Voandzeia subterranean* L.) is the third most important crop after peanut (*Arachis hypogea*) and cowpeas (*Vigna unguiculata*) in Africa but it has low status as it is seen as a snack or food supplement but not a lucrative cash crop [11]. It has the potential to improve malnutrition and boost food availability. The seed makes a complete food, as it contains sufficient quantities of proteins, carbohydrates, and lipids [7]. The gross energy value of Bambara groundnut seed is greater than that of other common pulses such as cowpea, lentil and pigeon pea [12]. Bambara groundnut contains higher amount of lysine than other legumes, while the seed contain more methionine than any other grain legume [1]. Despite all the advantages of Bambara groundnut in the area of food security and its industrial potentials, its use as an industrial raw material is still at very low ebb [16]. Proximate composition of flour blends from orange flesh sweet potato and red bambara groundnut have been documented by [23].

The objective of this study was to expand the utilization of orange flesh sweet potato and red Bambara groundnut, both cheap and ready available crops in developing countries, by value addition through usage as flour blends in snacks production.

## Materials and Methods

### *Materials.*

Fresh roots of orange-fleshed sweet potato (OFSP) variety, Umuspo 3 were harvested from an experimental farm of the Nigerian Root Crops Research Institute (NRCRI) in Agbamu village, Kwara State, Nigeria at 16 weeks of planting. Red bambara groundnuts (RBG) were obtained from a local dealer in Auchi Kingdom, Edo State, Nigeria.

***Preparation of flours***

Sweet potato and Bambara groundnut flours were prepared according to the method of [26].

***Formulation of flour blends***

The flour blends were formulated according to the ratio 60:40, 50:50, 40:60, and 30:70 (OFSP: RBG).

***Proximate composition***

The proximate analyses of the flours from the four varieties of the sweet potato were carried out using the methods of [6]. The reported values are means of three (3) determinations

***Functional properties***

***Bulk density (BD):*** The bulk density of flour samples were conducted using the methods of [20] and [25]. The experiment was conducted in triplicate and calculated as.

$$Bulk\ density\ (g/cm3)\ = \frac{W2 - W1}{Vol. of\ sample}$$

***Water absorption capacity (WAC):*** The water absorption capacities were determined using the method of [30]. Fifteen (15) ml of distilled water was added to 1.0g of the sample in a 25 ml centrifuge tube and agitated on a vortex mixer for 2 minutes. It was then centrifuged at 4000 rpm for 20 minutes. The supernatant was decanted and discarded. The adhering drops of water were removed and the tube reweighed again.

$$WAC\ = \frac{Weight\ tube + sediment - Weight\ of\ empty\ tube}{Weight\ of\ sample}$$

***Oil absorption capacity (OAC):*** To 1 g of the samples, 5 ml of refined oil was added in a 25 ml centrifuge tube and agitated on a vortex mixer for 2 minutes. It was then centrifuged at 4000 rpm for 20 minutes. The supernatant was decanted and discarded. The adhering drop of oil were removed and the tube reweighed again.

$$OAC\ = \frac{Weight\ tube + sediment - Weight\ of\ empty\ tube}{Weight\ of\ sample}$$

***Swelling capacity (SC):*** The swelling capacities of all flour samples were determined by the method described by [33]. It involved weighing 1g of the flour into 50 ml centrifuge tube. 50ml of distilled water is added and mixed gently. The slurry is then heated in a water bath at 60, 70, 80, 90, and 100$^{o}$C respectively for 10 minutes. The solution was gently shaken during the heating process to prevent clumping of the starch and the solution was centrifuged at 3,000rpm for 10 minutes. The supernatant was decanted and dried to determine the amount of soluble solid and dissolved and was used to calculate the solubilities. The weight of the sediment was recorded and moisture content of the sediment gel was determined.

$$Swelling\ Capacity\ = \frac{weight\ of\ the\ wet\ mass\ of\ sediment}{weight\ of\ dry\ matter\ in\ the\ gel}$$

***Solubility:*** The supernatant (dissolved starch) decanted is poured into a tarred evaporating dish and put in air oven at 100$^{o}$C for 4 hours. Water solubility index was determined from the amount of dried solids recovered by evaporating the supernatant, and is expressed as gram dried solids per gram of sample.

***Least gelation capacity (LGC):*** The modified method of [9] was used. Flour dispersions were made in test tubes with deionized water in concentrations of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v). The dispersions were heated in a water bath (Buchi water bath B-480, Switzerland) at 80$^{o}$C for 1 hour, followed by rapid cooling under running cold water. The test tubes were set at 4$^{o}$C for 2 hours. The least gelation concentration was then determined as the concentration at which the samples from the inverted tube did not fall or slip.

***Pasting properties:*** The pasting profiles of the flours were studied using a Rapid Visco-Analyzer (RVA) of Newport Scientific Pty. Ltd, Warri wood, Australia (perten Instrument), Model RVA Super 4 at the Multipurpose Laboratory, University of Ibadan, with the aid of a thermocline for windows version 1.1 software (1998). RVA was connected to a PC where the pasting properties and curves are recorded directly. Data were analyzed using ANOVA at $\alpha_{0.05.}$

**Results and discussion**

***Proximate Composition of Flour Blends***

The proximate composition of the flour blends is depicted in Table 1. The moisture contents ranged between 6.24±0.37% and 6.75±0.13%. The value obtained for 30:70 OFSP: RBG was the highest, followed by 50:50, 40:60, the lowest being 60:40. The moisture contents were between 6.24±0.37% and 6.75±0.13%. This is within the ranges 4.31±0.03 – 8.70±0.20% and 5.14±0.02 – 6.75±0.04% reported by [3] and [4] for composite flour made from wheat, breadfruit and cassava starch and fermented pumpkin seed, sorghum, maize-based *agidi* respectively. But the values were found to be less than the ranges 8.00±0.01 – 8.50±0.10; 9.90 – 11.31%; 8.84±0.32 – 9.20±0.03%; 8.17 – 12.10% and 12.40 – 12.90%; recorded by [24], [25], [17] and [27] respectively for flour blends made from different sources. Moisture content plays an important role in flour storage and shelf stability of food products. According to [17] flour and flour products with less than 14% are highly stable from moisture-dependent deterioration during storage and will be more resistant to microbial proliferation. This implies that the moisture contents of the flour blends in this study are within the acceptable limit for effective storage for further processing with no risk of microbial invasion. The protein content for the blends increased significantly from 12.95±0.05% to 16.87±0.02%, the value for the 30:70 blend being significantly higher than all other samples at $p \leq 0.05$ levels. The trend observed here is that the higher the level of substitution of RBG flours the higher the protein content, the 60:40 being least in protein content. This was expected as RBG contain more protein than OFSP and therefore the synergistic effects of protein complementation. The range obtained in this experiment is in consonance with documented ranges 3.91 – 17.01 and 7.37±0.08 – 22.25±0.47% obtained by [24]) and [5] but higher than 6.81±1.59 – 9.34±0.14% and 1.86±0.02 – 9.52±0.01% recorded by [3] and [25] respectively. [7] and [17] reported higher ranges 14.70±0.10 – 28.87±0.25 and 12.86 – 28.13% for wheat and groundnut protein concentrate flour blends and FARO 44 rice, African yam bean and brown cowpea seeds composite flour respectively.

Amounts of fat were generally low and ranged between 2.17±0.03 and 3.05±0.04. This could be as a result of the fact that tubers and legumes store their energy as starch instead of as lipids [17]. The fat contents increased significantly as the rate of substitution of RBG increases. The value for the 30:70 (3.05±0.04%) was highest and least in 60:40 (2.17±0.03%). The range recorded in this study is lower than 5.56±0.15 – 8.84±0.18, 3.56 – 5.79 and 7.50±0.64 – 10.81±0.07% reported by [27], [17] and [5] but far higher than 0.55±0.01 – 0.90±0.01; 0.51 – 2.01 and 0.50±0.20 – 0.82±0.13% documented by [23], [23] and [3] respectively. The low fat contents is of storage advantage for longer shelf-life of flour and flour products and makes them suitable raw materials in various food formulations [23]; [34] because of the expected rancidity occurring in fats and fatty foods.

The ash contents ranged between 2.27±0.05% and 2.52±0.04%. The value recorded for the 60:40 was found to be significantly higher than all other values, followed by the 50:50 sample, then 40:60 and lastly by 30:70 sample. Significant differences do not exist among the values for 50:50, 40:60 and 30:70 flour blends. The ash content of food stuff is an index of the mineral elements contained in the food sample. It gives an indication of the inorganic constituent after the removal of the organic matters and moisture (17]. The ash content decreased significantly as rates of substitution of RBG increases. The range for ash recorded in this study is in harmony with the ranges (1.94±0.005 – 3.86±0.005 and 0.51 – 3.18%) documented by [25] and [23] but are higher than 1.05±0.01 – 1.13±0.08, 1.00 – 1.97, 0.10±0.08 – 1.54±0.12 and 1.43±0.07 – 1.61±0.03 % reported by [3], [17], [5] and [23] respectively.

The fiber contents increased from 7.02±0.12 to 9.67±0.23%. The amount for 30:70 blend is significantly higher while the amount for 60:40 blend is significantly lower than all other samples. Crude fiber retards the release of glucose into the blood stream and reduces the intercolonic pressure thereby decreasing the risk of colon cancer [14]. The crude fiber contents rises steadily as rates of substitution of RBG increases. This is expected as crude fiber content for RBG flour is far higher than that of OFSP flour [22]. The range of crude fiber recorded in this study is far higher compared to 0.92±0.10 – 1.23±0.01, 0.75 – 2.67, 1.08±0.01 – 5.55±0.02, 2.24±0.76 – 4.81±0.20, 3.21 – 6.27 and 1.19±0.02 – 2.25±0.22% reported by Ocheme *et al* (2018), [23], [25], [3], [17] and [5] respectively.

The carbohydrate contents were 69.09±0.30, 66.33±0.26, 63.75±0.46 and 60.38±0.44% respectively for 60:40, 50:50, 40:60 and 30:70 blends. All the results recorded were found to be significantly different from each other at $p \leq 0.05$ levels. The high carbohydrate contents gives an indication that food products manufactured from these flour blends will be very good sources of calories. The carbohydrate contents of the flour blends was inversely proportional to the amount of RBG substituted as expected since carbohydrates content is higher in OFSP flour than in RBG flour [22].

Table 1: Proximate Composition of Flour Blends (%)

| Parameter | 60:40 | 50:50 | 40:60 | 30:70 |
|---|---|---|---|---|
| Moisture | $6.24 \pm 0.37^{a}$ | $6.68 \pm 0.04^{a}$ | $6.64 \pm 0.00^{a}$ | $6.75 \pm 0.13^{a}$ |
| Protein | $12.95 \pm 0.05^{a}$ | $14.14 \pm 0.18^{b}$ | $15.57 \pm 0.02^{c}$ | $16.87 \pm 0.02^{d}$ |
| Fat | $2.17 \pm 0.03^{a}$ | $2.29 \pm 0.02^{b}$ | $2.54 \pm 0.09^{c}$ | $3.05 \pm 0.04^{d}$ |
| Ash | $2.52 \pm 0.04^{a}$ | $2.38 \pm 0.08^{ab}$ | $2.33 \pm 0.04^{b}$ | $2.27 \pm 0.05^{b}$ |
| Fiber | $7.02 \pm 0.12^{a}$ | $7.98 \pm 0.01^{b}$ | $8.84 \pm 0.19^{c}$ | $9.67 \pm 0.23^{d}$ |
| Carbohydrate | $69.09 \pm 0.30^{a}$ | $66.33 \pm 0.26^{b}$ | $63.75 \pm 0.46^{c}$ | $60.38 \pm 0.44^{d}$ |

Values with same superscript along rows are not significantly different at $p \leq 0.05$



***The functional properties of flour blends***

The functional properties for the flour blends are presented in Table 2. The functionality of starch plays important roles in the control of moisture, texture, viscosity, consistency, mouth-feel and shelf-life of manufactured food products [35]. The water absorption capacities increased from 28.03±0.17% to 50.40±0.40%. The value for the 60:40 blend is significantly higher than the values for the 40:60 and 30:70 blends but not significantly different from the 50:50 blend. WAC denotes the maximum amount of water that a food material can absorbed and retain under formulation condition. Imbibition of water is an important functional trait in foods such as paste. According to [32] WAC is a critical function of protein in various food products. WAC is a reflection of protein-water interaction in food systems and is therefore influenced greatly by protein content [34]. But high water absorption capacity has also been attributed to loosely associated amylose and amylopectin whereby the association of hydroxyl groups to form hydrogen and covalent bonds between starch chains lowers water absorption capacity [10] and [12]. The differences observed here could be due to the differences in water binding sites available in the various flours [36]. The high WAC obtained for the 60:40 (50.40±0.40%) and 50:50 (43.93±0.29%) flour blends may be due to the possession of large numbers of water-binding sites compared to 40:60 (36.17±0.22%) and 30:70 (28.03±0.17%) flour blends.

The OAC ranged between 16.70±0.12% and 31.40±0.13%. The value for the 60:40 was significantly higher than all other samples followed by the 50:50, 40:60 and lastly 30:70 in that order. Liquid retention is an index of the ability of proteins to absorb and retain oil/ water which in turn influences the texture and mouth feel characteristics of the food. OAC is an important functional property which improves the mouth feel while still retaining the flavor of the food products [3]. The range recorded in this work (0.31±0.001 – 0.17±0.001g/ml) was lower than 0.46 – 1.48g/ml documented by [15]. The LGC decreased from 3.50±0.00% to 2.80±0.40%. The

value for the 60:40 flour blend is significantly lower than all the other values but the values for the rest samples are not significantly different from each other. LGC is referred to as the least concentration of flour needed for the formation of a good gel in a stated volume of water [23; 25]. This implies that flours with the lowest LGC possess highest gelling capacities. The 60:40 blend had the lowest least gelation capacity (2.80±0.40%) while the other blends had 3.50±0.00%. Increasing substitution of RBG does not necessarily affect the least gelation capacity. The values recorded in this study are far lower than the values 8 – 14% reported by [23], 12.00±0.02 – 13.00±0.04% documented by [3] and 42.33±2.52 – 48.33±2.89% recorded by [5]. The ability of the flour blends in this study to form gel at lower concentrations was clearly demonstrated with very low LGC which is of processing advantage.
The SC of the flour blends were between 2.13±0.07% and 2.48±0.06%. The value for 60:40 is significantly lower than the value for all other samples. There are no significant differences among the rest samples. SC is measure of the hydration capacity of starches and is used to provide evidence for associative absorption forces within starch granules [34]. SC of starch is directly associated with the amylopectin content because the amylase is a diluents and inhibitor of swelling [31]. According to [19] some species of starch which contain amylose-lipid complexes exhibit swelling capacity retardations. The SC was found to increase with increase in the amount of RBG substituted in the blend and decreases as RBG decreases. This could mean that amylose-lipid complexes may be present in OFSP flours resulting in decrease in swelling capacity as OFSP increases and increases as RBG increases. This decrease may also be as a result of starch and protein interaction because of their attraction due to opposite charge [25].

The solubility for the flour blends increased from 9.27±0.59% to 11.67±0.70%. Significant difference does not exist among the values for the 60:40 and the 50:50 blends and also significant difference does not exist among the values for the 40:60 and the 30:70 blends. The value for the bulk densities were between 0.77±0.01 g/ml and 0.87±0.02g/ ml. The value for the 60:40 flour blend was found to be significantly less than all other samples. Significant differences do not exist among other samples. High BD denotes high sink ability of flours which will aid wetting and ability to disperse. The high bulk densities recorded in this study indicates high dispersibility of all the flour blends. This implies that all the flour blends will reconstitute to consistent dough easily in mixing operations. This result is in consonance with the range 0.71 – 0.92 reported by [23] for unripe banana, pigeon pea and sweet potato flour blends and similar to 0.83±0.00 – 0.85±0.10 recorded by [3] for wheat, breadfruit and cassava composite flour. But the values are however, higher than 0.66±0.01 – 0.68±0.01 reported by [16] for wheat and groundnut protein concentrate, 0.65±0.017 – 0.71 documented by [5] for maize, sorghum, pumpkin seed composite flours and 0.71 – 0.74 reported by [24] for wheat-acha-cowpea. The high bulk densities obtained in this study also signified that the blends are heavy and so less quantity of these flours can be packed in a stated volume.

Table 2: Functional Properties of Flour Blends (Sweet potato: Bambara)

| Parameter (%) | 60:40 | 50:50 | 40:60 | 30:70 |
|---|---|---|---|---|
| WAC | 50.40±0.40[a] | 43.93±0.29[ab] | 36.17±0.22[b] | 28.03±0.17[b] |
| OAC | 31.40±0.13[a] | 26.47±0.11[b] | 21.60±0.88[c] | 16.70±0.12[d] |
| LGC | 2.80±0.40[a] | 3.50±0.00[b] | 3.50±0.00[b] | 3.50±0.00[b] |
| SC | 2.13±0.07[a] | 2.24±0.06[ac] | 2.36±0.06[bc] | 2.48±0.06[bc] |
| Solubility | 9.27±0.59[a] | 10.73±0.27[a] | 11.00±0.70[ab] | 11.67±0.70[b] |
| BD (g/ml) | 0.77±0.01[a] | 0.83±0.03[ab] | 0.87±0.02[b] | 0.82±0.01[b] |

Values with same superscript along rows are not significantly different at $p \leq 0.05$

***Pasting properties for the flour blends***

The results obtained for the pasting properties for the flour blends are presented in Table 3. The peak viscosities for the flour blends increased from 92.88±3.47 to 109.34±0.23 RVU. There were significant differences between the 60:40 sample and the values obtained for all other samples in this study. The values for the 50:50, 40:60 and 30:70 blends were found not to be significantly different at $p \leq 0.05$ levels. Peak viscosity indicates the highest value of viscosity attained in a heating cycle by gelatinized starches and it measures the ability of flours to form pastes. It appears that, the higher the RBG flour in the blend the higher the peak viscosity. The peak viscosities obtained in this experiment are within the range 66.29 – 348.92RVU reported by [21] and similar to 105.80 – 123.24RVU recorded by [3]. Ocheme [14], [25], [17] and [5] documented higher values of 913±0.07 – 1,379±20, 161.95±0.05 – 213.73±0.57, 128.50±0.01 – 213.83±0.01 and 133.58 – 237.58 RVU respectively. Peak viscosity is said to be closely related the degree of starch damage in flours. This implies that starch damage is higher in RBG than in OFSP flour resulting in increased peak viscosity with increase in RBG flour in the blends. High peak viscosity is an index of the relative suitability of the flour blends for products that requires high elasticity and strength [25].

The trough viscosities ranged between 70.55±0.18 and 87.67±0.23 RVU. Significant differences exist among the values obtained, with the value of the 30:70 blend being significantly higher and the value for the 60:40 blend being significantly lower than the value for all other samples at $p \leq 0.05$ levels. Trough viscosity is a measure of the ability of paste to withstand breakdown during cooling. According to [17] trough viscosity is the point at which viscosity gets to its minimum value during heating or cooling processes. The value of trough viscosities increases as RBG substitution increases. The values recorded in this study are within the range 17.71 – 263.96RVU obtained by [23] for unripe banana, pigeon pea and sweet potato flour blends but lower than the ranges 536±0.00 - 759±30.5 and 100.36±0.05 – 150.68±0.02 RVU reported by [16] and [25].

The breakdown viscosities or pasting stability were between 20.33±3.66 and 21.75±1.17 RVU. Significant differences do not exist among the values obtained in this study. All the samples exhibited similar breakdown stability ratios (trough/peak), with 50:50, 40:60 and 30:70 flour blends having the highest stability ratio (0.80) and the 60:40 flour blend having 0.76 stability ratio. Starches with low break down or low pasting stability have weak cross-linking within the granules of the flour. The values obtained in this study are higher than the values obtained by [22] for Orange flesh sweet potato flour (0.20 RVU), yellow flesh sweet potato flour (0.40 RVU), purple flesh sweet potato flour (0.18 RVU) and white flesh sweet potato flour (0.71RVU). Also [34] obtained 0.64 RVU (white flesh), 0.65 RVU (light yellow), 0.58 RVU (yellow), 0.64 RVU (light orange) and 0.35 RVU (deep orange). This implies that the flour blends from orange flesh sweet potato and Bambara groundnuts are expected to withstand shear at high temperatures better than the unblended flours.

The setback viscosity for the flour blends increased from 32.16±0.84 to 44.59±0.25RVU. There is no significant difference between the values for the 40:60 and the 30:70 flour blends but the values are significantly higher than the 50:50 value which is also significantly higher than the 60:40 value. High set back viscosity is an index of the magnitude of swelling power of a flour sample. It is also an indication of higher tendency to undergo retro gradation after heating and cooling. Higher setback implies lower retro gradation of products during cooling. The values obtained in this study indicates that the 30:70 and the 40:60 flour blends have lower tendency to undergo retro gradation than the 50:50 and 60:40 flour blends. The results are noted to be similar to ranges 22.88 – 89.71 RVU and 33.50±0.01 – 124.08±0.00 RVU reported by [23] and [17]. The final viscosities for the flour blends ranged between 102.71±1.00 and 132.00±1.06 RVU. The value for the 30:70 flour blend was found to be significantly higher and the value for the 60:40 flour blend significantly lower than the values for the rest samples at $p \leq 0.05$ levels. Final viscosity is the most commonly used determinant for the quality of a starch based sample. A high final viscosity gives an indication of the ability of the flour to form firm gel. This implies that the 30:70 (132.00±1.06 RVU) flour blend will form a firmer gel than the 60:40 (102.71±1.00 RVU) flour blend. The values documented in this study are within the range 35.25 – 353.67RVU obtained by [23; 21] for unripe banana, pigeon pea and sweet potato flour blends but lower than 123.58±0.01 – 247.33±0.01RVU reported by [17] for FARO 44 rice, African yam bean and brown cowpea seeds composite flour.

The pasting times ranged between 4.37±0.05 and 5.13±0.00 minutes. There was no significant difference among the values for 50:50, 40:60 and 30:70 blends, but these values were significantly higher than the values for the 60:40 blend at $p \leq 0.05$ levels. The pasting temperatures were between 80.21±0.49$^0$C and 81.52±1.17$^0$C. Significant differences do not exist among the values obtained in this study at $p \leq 0.05$ levels. Pasting temperature denotes the minimum temperature needed to cook a flour sample while pasting time refers to the minimum time required to achieve the cooking. The combination of both is a measure of the energy cost. A higher pasting temperature implies higher water-binding capacity and higher gelatinization. Apart from the 50:50 flour blend which had a pasting temperature of 81.52$^0$C, all other samples were noticed to begin gelatinization at about 80$^0$C. This means that the 40:60, 30:70 and 60:40 will cook at about 80$^0$C and the 50:50 flour blend at about 82$^0$C. But the 60:40 blend will cook faster while the 30:70 blend will take more time to cook than all other samples. It is clear that the 60:40 will consume less energy and the 30:70 more energy to cook.

Table 3: Pasting Properties of Flour Blends (RVU)

| Parameter | 60:40 | 50:50 | 40:60 | 30:70 |
|---|---|---|---|---|
| Peak viscosity | $92.88\pm3.47^{b}$ | $102.63\pm2.89^{a}$ | $106.33\pm2.47^{a}$ | $109.34\pm0.23^{a}$ |
| Trough | $70.55\pm0.18^{c}$ | $81.88\pm2.41^{b}$ | $84.59\pm1.29^{ab}$ | $87.67\pm0.23^{a}$ |
| Breakdown | $20.33\pm3.66^{a}$ | $20.75\pm0.47^{a}$ | $21.75\pm1.17^{a}$ | $21.46\pm0.30^{a}$ |
| Final viscosity | $102.71\pm1.00^{c}$ | $120.30\pm2.99^{b}$ | $129.17\pm1.06^{a}$ | $132.00\pm1.06^{a}$ |
| Setback | $32.16\pm0.84^{c}$ | $32.42\pm0.12^{b}$ | $44.59\pm0.25^{a}$ | $44.34\pm0.83^{a}$ |
| Pasting time (min) | $4.37\pm0.05^{c}$ | $5.04\pm0.05^{ab}$ | $5.00\pm0.00^{b}$ | $5.13\pm0.00^{a}$ |
| Pasting temp ($^{0}C$) | $80.38\pm0.18^{a}$ | $81.52\pm1.17^{a}$ | $80.21\pm0.49^{a}$ | $80.29\pm0.49^{a}$ |

Values with same superscript along rows are not significantly different at $p \leq 0.05$

***Conclusion***

This study shows that nutritious snack food products can be successfully prepared from orange flesh sweet potato and red Bambara groundnut both cheap and readily available tropical crops. The formulated flour blends contained high protein and may also be rich in pro-vitamin A. This study revealed the variations in the functional and pasting properties that exist among the flour blends. The study further indicated that the 50% sweet potato and 50% red Bambara groundnut flour blend will make a better product judging from its functional and pasting properties compared to other blends tested. This study gives an indication that 100% wheat flour could conveniently be replaced by flour blends from orange fleshed sweet potato and red bambara groundnut flours.



**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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