***Original Research Article***

**Chemical Composition, Pasting and Functional Properties of *Sorghum bicolor*, *Phaseolus lunatus* and *Xanthosoma sagittifolium* Flour Blends for Complementary Food Production**

**ABSTRACT**

**Aim:** The work aimed at producing composite flour from blends of sorghum, lima beans and cocoyam flour to address micro and macronutrient deficiencies, improve functional properties and as value addition to the utilization of local crops.

**Methodology:** Composite flour was produced from sorghum (*Sorghum bicolor*), lima bean (*Phaseolus lunatus*) and cocoyam (*Xanthosoma sagittifolium*) flour blends at different ratios; 100:0:0:0 (control), 0:80:15:5, 0:70:20:10, 0:60:25:15, 0:50:30:20 and 0:40:35:25 respectively. Each blend was evaluated for proximate, mineral compositions, functional and pasting properties.

**Results:** The proximate results showed that the protein content for all flour blends ranged from 7.26-10.75%. SLC1 and SLC3 had significant (p<0.05) higher protein content than the control sample (9.65%). The FAO/WHO minimum required protein level of 10% was only met by these two flour blends. Due to their low moisture content (10.13–10.94%), all the flour blends might have a longer shelf life and maximum storage capacity as compared to the control (11.51%). The sodium (45.1-52.4 g/100g) and calcium (88.4-103.5 g/100g) contents of the flour blends are significantly (p<0.05) higher than that of the control (2.4 and 40.8 g/100g). The oil absorption capacity (OAC) increased significantly (p<0.05) from 8.03 to 9.39 g/ml with the highest OAC from sample SLC3 (9.39 g/ml). The OAC of flour is important as it improved the mouth feel and retains the flavour. There was improved pasting properties with composite flours compare to 100% wheat flour. Sample SLC2 (50% sorghum, 30% lima bean, 20% cocoyam) had the highest peak, trough, setback and final viscosity indicating better thickening, heat stability, and gelling potential. The SLC2 formulation (50% sorghum, 30% lima bean, 20% cocoyam) consistently exhibited superior pasting characteristics

**Conclusion:** That composite flour blends have demonstrated better potential in replacing wheat flour for baking applications.

***Keywords:*** proximate, composite, pasting, thickening, formulation

**1. Introduction**

The increase in the consumption of wheat-based products, especially biscuits and bread have been reported in Nigeria and other sub-Saharan Africa nations, due to advancing prosperity, urbanization and recent increase in population (Ojinnakin, 2015). However, wheat, a temperate-cereal crop that is very scarce and if available, very expensive to meet the daily needs of most producers for confectionery products in Nigeria (Oluwalana *et al.,* 2012). The use of locally sourced, underutilized and nutritionally rich indigenous crops have been explored and exploited for use in Nigeria to produce some readily available confectionery products (Igbabul *et al.,* 2014). Past studies had reported the use of composite flours from locally available cereals, legumes and root crops (Udomkun *et al.*, 2019; Igbabul *et al.,* 2014; Oluwalana *et al.,* 2012). Biscuits contribute to over 33% of the total production of bakery products; for instance, 79% of the biscuits are manufactured by the small-scale bakery industry (Ashenafi, 2017). The composite flour-made biscuits from indigenous crops, without the wheat cereal, are expected to meet the demands of most celiac patients, thereby contributing to the improved health status of these individual (Kumar *et al.,* 2024). In the latest development, locally available cereals like rice, maize or corn and tubers (cocoyam, yam and cassava) with plantain inclusive, have been used to replace certain percentage of wheat flour without adversely affecting the quality (colour, taste and nutritional values) of non-wheat flours (Ezeibe & Robinson, 2024). In Nigeria, a lot of under exploited plant food crops such as lima bean, cocoyam and sorghum with promising nutritional potentials exist as potential functional ingredients for nutritional and food industry purposes (Adebo, 2023; Ikhajiagbe *et al.,* 2022). These crops are abundantly available as they are cultivated on a large-scale production with suitability to be used as components in composite flour production. It is certain that there would always be constant production of bakery products throughout the year and with the availability of composite flour. This will go a long way, as it will help to alleviate the problems arising from the cost of importing wheat flour. Moreover, the availability of that raw material would encourage researchers and improve techniques on the production and formulation of the composite flour. It is therefore reasonable to attempt to produce bakery products from the flour obtained from these crops (Oladunmoye *et al.,* 2010). This study aimed to produce composite flour from blends of sorghum (*Sorghum bicolor*), lima bean (*Phaseolus lunatus*) and cocoyam (*Xanthosoma sagittifolium*) flours while examining their proximate composition, mineral content, functional and pasting properties for future value-addition to the local crops’ usage.

**2. Materials and Methods**

**2.1 Collections and preparation of composite flours**

Sorghum, Lima bean and cocoyam tubers used in this study were purchased from Bisi Market, Ado-Ekiti, Nigeria. The white variety sorghum grains were sorted steeped in water; at 30 ℃ for 15 mins. The water was drained off completely and dried using hot air oven at 70 ℃. After drying, the grains were cooled at room temperature while the dried sorghum grains were then grounded into flour and sieved using a sieve with mesh size of 500 µm. The processed flour was subsequently kept in an air-tight polythene container for further use. The cocoyam was **s**ubjected to sorting, then washing to remove field soil, surface micro-organism, insecticide and pesticides residue. The periderms were peeled off manually using knife and fully immersed in clean water because peeling under water reduces the rate of enzymatic browning. Each cultivar was sliced-flaked using knife (thickness of 1 mm). The slices were treated prior to drying (50 ℃) using hot air oven to obtain a constant weight of cocoyam after drying. The dried materials were allowed to cool, milled, sieved and stored for further use.

The Lima bean was obtained from Bisi Market, Ado-Ekiti Nigeria, sorted to remove foreign materials like stones, debris, sands and shafts. It was then blanched in hot water at the temperature of 75 ℃ for 3 hours for ease dehulling. After the soaking process, the hulls were removed from the bean seed, drained and dried in hot air oven at 60 ℃. The dried dehulled bean is then milled into fine particles (flour) and stored for final use. Three different flours were now formulated into composite flour blends as shown in Table 1:

**Table 1:** Formulation of the flour blends (%)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Wheat flour**  **(WF)** | **Sorghum flour**  **(SF)** | **Lima bean flour**  **(LMF)** | **Cocoyam flour**  **(CF)** |
| **Control** | 100 | ─ | ─ | ─ |
| **SLC5** | ─ | 80 | 15 | 5 |
| **SLC4** | ─ | 70 | 20 | 10 |
| **SLC3** | ─ | 60 | 25 | 15 |
| **SLC2** | ─ | 50 | 30 | 20 |
| **SLC1** | ─ | 40 | 35 | 25 |

**(Source: Obomeghei, *et al.* 2021)**

**2.2 Proximate Composition of Composite Flour Blends and biscuit**

The proximate composition of the composite flour blends was determined according to the standard methods as described by AOAC (2012) while the carbohydrate content was calculated.

**2.3 Determination of mineral compositions**

Mineral contents of samples were determined by atomic absorption spectrometry, flame photometry and spectrophotometry according to the methods of AOAC (2016).

**2.4 Determination of pasting properties of composite flour**

The pasting properties of the samples were determined using the Rapid Visco Analyzer (ViscoMan, RVA-D-47055, Frankfurt, Germany).

**2.5 Determination of functional properties of flour blends**

The swelling power was determined according to the methods of (Oladunmoye *et al.,*2010).Water and oil absorption capacity and bulk density were also determined as describe by Klunklin and Savage, (2018). The pH of the samples was measured directly using a digital pH meter (Jenway England) after calibration with freshly prepared buffer solution.

**2.6 Statistical analysis**

All determination reported in this study were carried out in triplicates, a mean value and standard deviation were calculated. One way ANOVA was also performed using SPSS version 23.0 and separation of mean values using Duncan multiple range test at p<0.05.

**3. Results and Discussion**

**3.1 Proximate composition of the composite flour**

Table 1 shows the results of the proximate composition of sorghum, lima bean and cocoyam composite flour blends. The moisture content of the flour blends decreased significantly (p<0.05) compared with the control sample (100% wheat flour) from 10.94-10.13% as the incorporation lima-bean and cocoyam flour increased in which the control sample had the highest moisture content of (11%). The low moisture content in this study would enhance the storability and keeping quality of the products.

The flour blends showed significant increase (p<0.05) in protein content ranging from 7.26 – 10.72 % with increase in the incorporation of lima bean flour. Samples SLC1 and SLC3 had higher protein content than the control sample (wheat flour), which might be due to higher proportion of Lima beans (21.46 g/100g raw) in the flour blends. There was no observed significance difference between in the protein contents of sample SLC5 (9.60%) and the control sample (9.65%), this could as result of the low substitutional level of the lima bean and the cocoyam flour in the blends. This corroborated what was reported by Okpala and Okoli, (2011).

Total ash content ranged between 1.56 ─ 1.88%. The percentage ash content of the flour blends was significantly (p ≤0.05) higher than that of the control which could be as result of the incorporation of both the lima beans and cocoyam flour, although there was no observable difference in the ash content among the blends. Ash content is indicative of the amount of minerals in any food sample. The increase in total ash content in sample SCL5 is an indication of high mineral content in sorghum and cocoyam flour.

The fat content ranged from 2.20–2.26%. There was a significant reduction in the fat content with the incorporation of lima beans and cocoyam which was a better signal of shelf-life longevity in the blends, as samples with high fat content are proxy to rancidity increased significantly with increase in lima bean flour substitution.

The crude fibre content ranged from 2.32–2.50%. The crude fibre content of the control was significantly lower compared to other samples, increasing order of substitution showed no significant difference. However, the value obtained in this research work (2.32–2.50%) was lower to what was reported by Ikujenlola, et al.(2013) for malted quality protein maize and defatted fluted pumpkin flour blends.

The carbohydrate content ranged between 72.55-75.49% on the other hand showed significant (p<0.05) increase with increase in cocoyam flour up to 25% in the blends. This corroborated what was reported by Okoye et al (2021) for Sorghum-African yam beans

**Table 2**: Proximate composition of the composite flour **(%)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Moisture** | **Crude protein** | **Total ash** | **Fat** | **Crude fibre** | **Carbohydrate** |
| Control | 11.51a±0.04 | 9.65b±0.03 | 1.56c±0.03 | 3.41a±0.03 | 1.63b±0.03 | 72.24c±0.12 |
| SLC5 | 10.94a±0.22 | 9.60b±1.00 | 1.88a±0.07 | 2.22b±0.67 | 2.32a±0.20 | 73.61bc±0.05 |
| SLC4 | 10.93a±0.22 | 7.26d±1.00 | 1.73ab±0.07 | 2.20b±0.67 | 2.38a±0.20 | 75.49a±0.24 |
| SLC3 | 10.72a±0.22 | 10.75a±1.00 | 1.71ab±0.07 | 2.26b±0.67 | 2.37a±0.20 | 72.55c±0.23 |
| SLC2 | 10.65a±0.22 | 8.56c±1.00 | 1.58c±0.24 | 2.21b±0.67 | 2.50a±0.20 | 74.51ab±0.24 |
| SLC1 | 10.13b±1.00 | 10.75a±1.00 | 1.65ab±0.07 | 2.25b±0.67 | 2.47a±0.20 | 72.76bc±0.05 |

Values with the same letters in the same column are not significantly (p≤0.05) different.

**Control** = 100%Whear flour (WF), **SLC5** = 80% Sorghum flour (SF) + 15% Limabean flour (LMF) + 5% Cocoyam flour (CF), **SLC4** = 70% Sorghum flour (SF) + 20% Limabean flour (LMF) + 10% Cocoyam flour, **SLC3 =** 60% Sorghum flour +25% Limabean flour (LMF) +15%CF, **SLC2**= 50% Sorghum flour (SF) +30% Limabean flour (LMF) +20%CF, **SLC1**= 40% Sorghum flour (SF) +35% Limabean flour (LMF) +25% Cocoyam flour (CF)

**3.2 Mineral composition of the composite flour**

Table 3 showed the mineral composition of the composite flour. The composite flour at each level of substitution has higher sodium (45.10-52.40 mg/100g) and calcium (88.40-103.50 mg/100g) contents compare with the control sample (2.40 and 40.80 respectively). The results could be because of the moderate percentage of lima bean added the composite as further increase in lima beans and cocoyam flour could lead to reduction of these minerals content. Control sample (100 % wheat) had the highest potassium content. This could be as a result of the inherent potassium level in wheat which is higher than that in the individual components of the composite flour. A low range of copper contents (0.06-0.15 mg/100g) was observed in all the composite compare with the control (0.49 mg/100g) while the least value of the copper was noticed the in the composite with highest percentage of lima-beans flour. This denotes that the flours are safe for consumption and application in food industry. Contrarily, the potassium content for sample SLC1 (66.50 mg/100g), SLC2 (70.40 mg/100g), SLC3 (75.10 mg/100g) and that of iron content for sample SLC1 (2.04 mg/100g), SLC2 (2.19 mg/100g), SLC3 (1.38 mg/100g) were lower than what was obtained for the control sample (435.6 mg/100g) and (4.32 mg/100g) respectively. The value obtained for Iron in this study (1.38-4.32 mg/100g) is higher than 0.42 mg/100g reported by Malomo et al.(2011) for wheat-breadfruit composite flour.

**Table 3: Mineral composition of the composite flour (mg/100g)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Samples** | **Sodium** | **Calcium** | **Potassium** | **Copper** | **Iron** | **Manganese** |
| SLC1 | 45.10 | 88.40 | 66.50 | 0.06 | 2.04 | 0.42 |
| SLC2 | 45.50 | 95.00 | 70.40 | 0.09 | 2.19 | 0.52 |
| SLC3 | 50.20 | 101.70 | 75.10 | 0.15 | 1.38 | 0.55 |
| SLC4 | 52.40 | 103.50 | 81.80 | 0.07 | 2.43 | 2.43 |
| SLC5  Control | 46.80  2.40 | 90.30  40.80 | 65.20  435.6 | 0.10  0.49 | 1.70  4.32 | 1.70  4.88 |

**Control** = 100%Whear flour (WF), **SLC5** = 80% Sorghum flour (SF) + 15% Limabean flour (LMF) + 5% Cocoyam flour (CF), **SLC4** = 70% Sorghum flour (SF) + 20% Limabean flour (LMF) + 10% Cocoyam flour, **SLC3 =** 60% Sorghum flour +25% Limabean flour (LMF) +15%CF, **SLC2**= 50% Sorghum flour (SF) +30% Limabean flour (LMF) +20%CF, **SLC1**= 40% Sorghum flour (SF) +35% Limabean flour (LMF) +25% Cocoyam flour (CF)

**3.3 Functional property of the composite flour**

The result presented in Table 4 showed the functional properties of the composite flour and that of the control. Water absorption capacity reflects the amount of water that the flour can absorb and retain. Water absorption capacity (WAC) increased significantly with increase in the substitutional level of cocoyam and Lima bean flour in the blends, which ranged between 6.10 and 6.33 g/ml. Higher water absorption values were attributed to the higher content of starch and fiber (Klunklin and Savage, 2018; Culetu *et al.,* 2021).

The oil absorption capacity (OAC) increased significantly from 4.04 to 9.39 g/ml in which the highest value was observed in sample SLC3 (9.39 g/ml). The OAC of flour is important as it improves the mouth feel and retains flavour of developed food product (Suzauddula *et al.,* 2021). The higher OAC suggested the presence of non-polar amino acids in the flour blends as a result of the addition of Lima bean flour (Palupi *et al.,* 2021). Protein concentration and their conformational properties in foods have been reported to also influence its OAC (Malomo and Aluko, 2015). Thus, the composite flour from sorghum, lima bean and cocoyam could be useful as functional ingredient in foods such as whipped toppings, sausages and sponge cakes with its high oil absorption capacity.

Bulk density represents a measure of flour heaviness (Adanse *et al.*, 2021). The bulk density value ranged between 0.837 and 1.005(g/ml3)but it decreased significantly as the substitutional levels of cocoyam and Lima bean flour increases with the values ranging between 0.837 to 1.005 (g/m3). Bulk density is generally affected by the particle size and density of flour, and it is very important in determining the packaging requirement, material handling and application in wet processing in food industry (Awuchi *et al.,* 2019). The values obtained in this research work were higher than what was reported for breadfruit and soybean composite flour (2.30-3.87 g/ml) by Ijarotimi and Aroge, (2005) but lower than 9.48-13.21 g/ml as reported for pigeon pea flours (Okpala and Okoli, 2011).

Swelling index is an indication of the water absorption index of the granules during heating (Malomo and Aluko, 2015). The swelling capacity increased significantly with increase in cocoyam and lima bean flour substitutional level, which ranged from 0.222-0.262 %. The swelling capacity of flours depends on size of particles, types of variety and types of processing methods (Dereje *et al.,* 2020). Addition of cocoyam and lima bean flour to the sorghum flour increased the hydrophilic groups in the composite flour leading to increased solubility index (Adebayo and Oladunjoye, 2024). Thus, the flour would be useful in food systems that need water for its preparation such as the confectionaries.

The pH of flour samples decreased significantly (p<0.05) from 6.18 - 5.48 with the control sample having the highest value (6.18). The decreased pH levels of the formulated ratios could aid their prolonged storage life of the composite. This is because, the acidic products have been reported to be more shelf stable than their non-acidic counterpart (Tireki, 2021). The increase in acidity is of great significance as it was reported it reduces the incidence of diarrhea in infants consuming fermented maize porridge (Adavachi, 2017).

**Table 4**: Functional property of the composite flour

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Samples** | **Water absorption capacity (g/ml)** | **Oil absorption capacity (g/ml)** | **Bulk density (g/m3)** | **Swelling index (%)** | **pH** |
| Control | 4.34d±0.32 | 4.04e±0.21 | 1.84a±0.12 | 0.15b±0.06 | 6.18a±0.15 |
| SLC5 | 6.30a±0.20 | 8.23c±0.12 | 1.01c±0.11 | 0.23a±0.13 | 5.48c±0.9 |
| SLC4 | 6.10c±1.00 | 8.03d±0.15 | 1.01c±0.11 | 0.26a±0.42 | 5.60bc±0.18 |
| SLC3 | 6.23b±0.05 | 9.39a±1.00 | 0.84b±0.11 | 0.23a±0.13 | 5.68b±0.18 |
| SLC2 | 6.20b±0.50 | 8.41b±0.12 | 0.84b±0.11 | 0.22a±0.45 | 5.77b±0.18 |
| SLC1 | 6.30a±0.20 | 8.20c±0.12 | 0.92b±0.11 | 0.25a±0.42 | 6.08a±1.00 |

Values with the same letters in the same column are not significantly (p≤0.05) different.

**Control** = 100%Wheat flour (WF), **SLC5** = 80% Sorghum flour (SF) + 15% Limabean flour (LMF) + 5% Cocoyam flour (CF), **SLC4** = 70% Sorghum flour (SF) + 20% Limabean flour (LMF) + 10% Cocoyam flour, **SLC3 =** 60% Sorghum flour +25% Limabean flour (LMF) +15%CF, **SLC2**= 50% Sorghum flour (SF) +30% Limabean flour (LMF) +20%CF, **SLC1**= 40% Sorghum flour (SF) +35% Limabean flour (LMF) +25% Cocoyam flour (CF)

**3.4 Pasting property of the composite flour**

Pasting characteristics are crucial since they are utilized to project the flour samples' pasting behaviours and skills (Offia-Olua, 2014). The pasting property of sorghum, lima bean and cocoyam composite flour blends was presented in Table 4. It shows that the peak viscosity ranged from 323 to 556 RVU and the final viscosity ranged from 629 to 1277 RVU of the flour blends were higher than of the control (145.45 and 170.13 RVU respectively). Formulation SLC2 (50% Sorghum flour (SF)+30% Limabean flour (LMF) +20%CF) had the highest peak viscosity which was significantly (p<0.05) higher than that of the control (100% wheat) and the other composite flours. The value obtained in this research (556 RVU) was significantly (p<0.05) higher than what was reported by Orisa and Udofia, (2020) for wheat, cowpea, acha and *Moringa oleifera* leaf powder (385.79 RVU). The relatively high peak viscosity of the composite flours as compared to 100% wheat flour indicates that the flours will form a thick paste, hence may be suitable for products requiring low gel strength and elasticity (Orisa and Udofia, 2020). Awoyale et al. (2020) reported that peak viscosity is the ability of starches to swell freely before their physical breakdown and it indicates the strength of the pastes formed during gelatinization.

Trough viscosity also known as holding period, is the point at which viscosity reaches its minimum during heating or cooling process (Eke-Ejiofor *et al.,* 2021). Trough value of the samples ranged from 84.54 to 501.00 RVU with the control sample showing the lowest value (84.54 RVU) while the formulation SLC2 had the highest trough viscosity (501.00 RVU). High trough viscosity of the composite flours may be attributed to the gradual increase in the substitution with the lima beans and cocoyam flour. The high trough viscosity indicates that the composite flours can withstand high-heat treatments during processing than 100% wheat flour which had the lowest trough viscosity. These values were higher than values 39.60-59.19 RVU reported for wheat and walnut flour blends (Offia-Olua, 2014).

The breakdown viscosity of cooked pastes indicates their stabilities to shearing during cooking (Obomeghei *et al.,* 2021). Starches with low breakdown or low pasting stability have weak cross-linking within the granules of the flours. The breakdown viscosity of the flours ranged from 26.00 to 61.00RVU with formulationsample SLC4 and that of the control showing the lowest and highest values, respectively. There was a significant (p<0.05) difference in the breakdown viscosity across the composite of the flours. Breakdown viscosity of the composite flours was significant (p<0.05) lower compared to the control. The low break down viscosity of the composite flour could be attributed to the inclusion of sorghum, lima-beans and cocoyam flour. The lower the break down viscosity of flours, the higher its stability under hot conditions (Ojo *et al.,* 2017). The result from this study suggests that the flour blend with sorghum, lima-beans and cocoyam flour will be more stable and able to withstand heating as compared to 100% wheat flour.

The final viscosities of the complementary flour blends ranged from 170.13 to 1277.00 RVU. Final viscosity of sample SLC2 (50% SF:30% LBF:20% CF) was significantly higher (p<0.05) than all other flour samples and the control. The high final viscosity of sample SLC2 could be attributed to 30% limabeans substitutional level. Liang and King, (2003) stated that final viscosity of flours is important in determining their ability to form gel during processing. Hence, the thickening and gelling property of the flours will increase with substitution with increased levels of lima-beans and cocoyam flour in the blends.

The values of final viscosity reported in this study were higher than the range 102.71 to 132.00 RVU reported by Obomeghei and Ebabhamiegbebho, (2020) for orange fleshed sweet potato and Bambara groundnut flour blends and was also higher than the final viscosity which ranged between 95.51 and 252.09 RVU as reported by Offia-Olua, (2014) for wheat and walnut flour blends. Final viscosity is the most used parameter for the quality of a starch-based sample. High final viscosity gives an indication of the strength of the flour to form a viscous paste or firm gel after cooking and cooling and paste or gel resistance to shear force during stirring (Obomeghei and Ebabhamiegbebho, 2020; Olaleye *et al.,* 2020). This implies that the sample SLC2 with final viscosity of 1277.00 RVU will form a firm or viscous gel than all other samples.

Setback viscosity indicates resistance to retrogradation (Offia-Olua, 2014). Setback viscosities of the

flour samples ranged from 85.59 RVU in 100% wheat flour to 776.00 RVU in formulated sample SLC2. It was observed that set back viscosity of the composite flours were significantly higher (p<0.05) than the control (100% wheat flour) owing to the substitution level of lima-bean and cocoyam flour in the flour blends. This indicates that 100% wheat flour had a higher possibility of retrogradation than those formulated with sorghum, Lima-bean and cocoyam flour. The high set back viscosity in the composite flours with 50% sorghum: 30% limabeans:20% cocoyam flour could be as a result of the high fibre content, as fibre is a good water absorption component that gives good stabilizing effects on foods (Adegunwa *et al.,* 2017). However, the current setback values obtained in this study (85-776) is higher than 70-400 reported by Malomo et al. (2011) for wheat-breadfruit composite flour. Hence, the composite flours should undergo starch modification prior usage in the food processing industries.

Peak time is a measure of the cooking time (Eke-Ejiofor *et al.,* 2018). The result showed that the peak time of the flour blends ranged from 5.95 to 7.00 min. Peak time of the composite flours were significantly (p<0.05) similar and higher than that of 100% wheat flour. This is mainly attributed to the substitution with sorghum, lima-bean and cocoyam flour. Similar observation was also noted by Eke-Ejiofor et al. (2018) who reported an increase in peak time of acha-defatted soybean and groundnut flour blends (5.33-6.71 min) as substitution with defatted soybean and groundnut flours increased.

Pasting temperature gives an indication of the minimum temperature required to cook or gelatinize flour. It is the temperature at which the viscosity of the sample starts to rise. The combination of pasting temperature and pasting time is a measure of the energy cost of the operation. The pasting temperature of the blends ranged from 61.95 to 94.50 ℃. The highest pasting temperature was recorded for sample SLC1 (94.35 ℃) and SLC5 (94.50 ℃) respectively while the lowest was noticed in the control sample (61.95 ℃). This indicates that it can form a paste in hot water below the boiling point. Pasting temperature of the flour samples were significantly (p<0.05) increased with starting the substitution level with sorghum. Lima-beans and cocoyam flour but reduced with further increased in the lima-beans flour in sample SLC4 to SLC2. This study corroborated what was reported for acha-defatted soybean and groundnut flour blends (81.30-94.32 ℃) by Eke-Ejiofor et al. (2018) and is below the boiling temperature of water.

**Table 5**: Pasting property of the composite flour

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Samples** | **Peak viscosity (RVU)** | **Trough (RVU)** | **Breakdown (RVU)** | **Final viscosity (RVU)** | **Setback (RVU)** | **Peak time (mins)** | **Pasting**  **Temperature (℃)** |
| CONTROL | 145.54e | 84.54e | 61.00a | 170.13e | 85.59e | 5.95b | 61.95d |
| SLC5 | 323.00d | 293.00d | 30.00c | 719.00d | 426.00c | 7.00a | 94.50a |
| SLC4 | 356.00c | 330.00c | 26.00d | 740.00c | 410.00c | 7.00a | 92.85b |
| SLC3 | 504.00b | 473.00b | 31.00c | 1001.00b | 526.00b | 7.00a | 88.85c |
| SLC2 | 556.00a | 501.00a | 55.00b | 1277.00a | 776.00a | 7.00a | 88.75c |
| SLC1 | 334.00d | 301.00d | 33.00c | 692.00d | 391.00d | 7.00a | 94.35a |

**Control** = 100%Wheat flour (WF), **SLC5** = 80% Sorghum flour (SF) + 15% Limabean flour (LMF) + 5% Cocoyam flour (CF), **SLC4** = 70% Sorghum flour (SF) + 20% Limabean flour (LMF) + 10% Cocoyam flour, **SLC3 =** 60% Sorghum flour +25% Limabean flour (LMF) +15%CF, **SLC2**= 50% Sorghum flour (SF) +30% Limabean flour (LMF) +20%CF, **SLC1**= 40% Sorghum flour (SF) +35% Limabean flour (LMF) +25% Cocoyam flour (CF)

**4. Conclusions**

The incorporation of cocoyam and Lima-beans flour as composite flours with sorghum in place of wheat flour shows a promising opportunity to enhance the nutritional and functional properties of food products. This research work not only improved the protein and ash content but also boosts essential mineral such as calcium and sodium. The enhanced functional properties of the composite flour showed a closed similarity to the well-known wheat flour commonly used for confectionary products. Higher peak, final, trough, and setback viscosities were observed in the pasting properties of the blend of sorghum, lima bean, and cocoyam flours when compared to 100 % wheat flour. This suggests that the blend may be more appropriate for food products that need firm gels and thermal stability. These underutilized crops can improve sustainability and economic through reduction in the dependence on wheat flour and promoting local crop production, supporting local farmers and industries, encourage environmentally friendly practices and reducing reliance on resource intensive crops.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.).

**Reference**

Adanse, J., Bigson, K., Dare, N. J., & Glago, P. (2021). Proximate and Functional Properties of Water Lily

(*Nymphaea Lotus*), Coconut (*Cocos Nicifera*) and Wheat (*Titricum Aestivum*) Flour Blends. *J Food Tech Food Chem*, *3*(1), 104-121.

Adavachi, W. M. (2017). The role of fermented maize-based products on nutrition status and morbidity

of children 6-59 months old in Western Kenya (Doctoral dissertation, University of Nairobi).

Adebayo, A. I., & Oladunjoye, A. O. (2024). Proximate, structural, textural, sensory and microbiological

properties of non-gluten extrudate using Sorghum (*Sorghum bicolor L. Moench*) and a sprouted legume (*Phaseolus lunatus L.*). *Food Science and Technology International* ;0(0). doi:[10.1177/10820132241289157](https://doi.org/10.1177/10820132241289157)

Adebo, J. A. (2023). A review on the potential food application of lima beans (Phaseolus lunatus L.), an

underutilized crop. *Applied Sciences*, *13*(3), 1996.

Adegunwa, M. O., Adelekan, E. O., Adebowale, A. A., Bakare, H. A., & Alamu, E. O. (2017). Evaluation

of nutritional and functional properties of plantain (*Musa paradisiaca L.*) and tigernut (*Cyperus esculentus L.*) flour blends for food formulations. *Cogent Chemistry*, *3*(1), 1383707.

AOAC. (2016). Official methods of analysis of the association of official analytical chemists (21st ed.).

https://www.aoac.org/official-methods-of-analysis-21st-edition.

Ashenafi, A. (2017). An Assessment on The Practice of New Product Development: The Case of Kality

Food Sc Biscuit (Doctoral Dissertation, St. Mary's University).

Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and

flours. *International Journal of Advanced Academic Research*, *5*(11), 139-160.

Culetu, A., Susman, I. E., Duta, D. E., & Belc, N. (2021). Nutritional and functional properties of gluten-

free flours. *Applied Sciences*, *11*(14), 6283.

Dereje, B., Girma, A., Mamo, D., & Chalchisa, T. (2020). Functional properties of sweet potato flour and

its role in product development: a review. *International Journal of Food Properties*, *23*(1), 1639-1662.

Eke-Ejiofor, J. N., Ojimadu, A. E., Wordu, G. O., & Ofoedu, C. E. (2021). Functional properties of

complementary food from millet (*Pennisetum glaucum*), African yam bean (*Sphenostylis stenocarpa*), and Jackfruit (*Artocarpus heterophyllus*) flour blends: A comparative study. *Asian Food Science Journal*, *20*(9), 45-62.

Ezeibe, N. F., & Robinson, N. (2024). Development of Plantain and Cocoyam Bread and Assessment of Its

Nutritional Value to the Elderly. *Sch Bull*, *10*(8), 214-218.

Igbabul, B. D., Amove, J. and Okoh, A. (2014). Quality evaluation of composite bread produced from

wheat, defatted soy and banana flours. *International Journal of Nutrition and Food science*. 3(5): 471-476.

Igbabul, B. D., Idikwu, H.O. and Inyang, C.U. (2012). Effect of fermentation on some functional properties of *Mucuna sloanei* and *Detarium microcarpum*. *J. of food Technol*., 10(3): 83-86.

Ijarotimi, S.O., and Aroge, F. (2005). Evaluation of the Nutritional Composition, Sensory and Physical

Properties of a Potential Weaning Food from Locally Available Food Materials Breadfruit (*Artocarpus Altilis*) and Soybean (*Glycine Max*). *Pol.J. Food Nutr. Sci*. 14 (4), 411–415

Ikhajiagbe, B., Ogwu, M. C., Ogochukwu, O. F., Odozi, E. B., Adekunle, I. J., & Omage, Z. E. (2022). The

place of neglected and underutilized legumes in human nutrition and protein security in Nigeria. *Critical Reviews in Food Science and Nutrition*, *62*(14), 3930-3938.

Ikujenlola A. Victor, Oguntuase S. O., Omosuli S. & Vincent (2013). Physico-Chemical Properties of

Complementary Food from Malted Quality Protein Maize (*Zea mays L.*) and Defatted Fluted Pumpkin Flour (*Telfairia occidentalis Hook, F*), *Food and Public Health*, 3 (6), 323-328

doi: 10.5923/j.fph.20130306.09

Klunklin, W., & Savage, G. (2018). Biscuits: A substitution of wheat flour with purple rice flour. *Advances*

*in Food Science and Engineering*, *2*(3), 81-97.

Malomo, S.A. & Aluko, R.E. (2015). A comparative study of the structural and functional properties of

isolated hemp seed (*Cannabis sativa L*.) albumin and globulin fractions. *Food Hydro.*, 43, 743-752.

Malomo, S.A., Eleyinmi, A.F., & Fashakin, J.B. (2011). Chemical composition, rheological properties and

bread making potentials of composite flours from breadfruit, breadnut and wheat. *Afr. J. Food Sci*. 5(7), 400 – 410.

Obomeghei, A. A., Ebabhamiegbebho, P. A., Olorunda, A. O., & Olapade, A. A. (2020). Quality of Chin-

Chin from Blends of Bambara Groundnut (*Vigna subterranean (L) Verdc.*) and Pro-Vitamin A Fortified Sweet Potato (*Ipomoea batatas (L) Lam*). *Nigerian Food Journal*, *38*(1).

Obomeghei, A. A., Olapade, A. A., & Ebabhamiegbebho, P. (2021). Comparison of the functional and

pasting characteristics of millet (*Pennisetum Glaucum*), African yam bean (*Sphenostylis Stenocarpa Hoechst Ex. A. Rich*) and tiger nut (*Cyperus Esculentus*) flour blends for complementary food production. *EAS Journal of Nutrition and Food Sciences*, *3*(2), 42-49.

Offia-Olua, B. I. (2014). Chemical, functional and pasting properties of wheat (*Triticumspp*)-walnut

(*Juglansregia*) flour. *Food and Nutrition Sciences*, *5*(16), 1591-1604.

Ojinnaka, M. C. and Nnorom, C. C. (2015). Quality Evaluation of Wheat-Cocoyam Soybean Cookies.

*Nigerian Journal of Agriculture, Food and Environment*. 11(3): 123-129.

Ojo, M. O., Ariahu, C. C., & Chinma, E. C. (2017). Proximate, functional and pasting properties of cassava

starch and mushroom (*Pleurotus pulmonarius*) flour blends. *American Journal of Food Science and Tech.*

Okoye, J. I., Egbujie, A. E., & Ene, G. I. (2021). Evaluation of complementary foods produced from

sorghum, soybean and irish potato composite flours. *Science World Journal*, *16*(3), 206-211.

Okpala, L. C., & Okoli, E. C. (2011). Formulation and evaluation of cookies containing germinated pigeon

pea, fermented sorghum and cocoyam flour blends using mixture response surface methodology. *Advance Journal of Food Science and Technology*, *3*(5), 366-375.

Oladunmoye, O. O., Akinoso, R., & Olapade, A. A. (2010). Evaluation of some physical–chemical

properties of wheat, cassava, maize and cowpea flours for bread making. *Journal of Food Quality*, *33*(6), 693-708.

Olaleye, H., Oresanya, T., & Temituro, E. O. (2020). Quality assessment of weaning food from blends of

sorghum, mung beans and orange fleshed sweet potato blends. *Eur. J. Nutr. Food Safety*, *12*(6), 42-52.

Oluwalana, I.B., Malomo, S.A. and Ogbodogbo, E.O. (2012). Quality assessment of bread from sweet

potato-wheat composite flour. *Int. J. Biol. Chem. Sci*., 6 (1), 65- 76.

Orisa, C. A., & Udofia, S. U. (2020). Functional and pasting properties of composite flours from Triticum

durum, Digitaria exilis, Vigna unguiculata and Moringa oleifera Powder. *Asian Food Sci. J*, *19*, 40-49.

Palupi, H. T., Estiasih, T., & Sutrisno, A. (2021). Characterization of nutritional and functional properties

of Lima bean flour *(Phaseolus Lunatus L*.). In *IOP Conference Series: Earth and Environmental Science* 924 (1), 012033.

Suzauddula, M., Hossain, M. B., Farzana, T., Orchy, T. N., Islam, M. N., & Hasan, M. M. (2021).

Incorporation of oat flour into wheat flour noodle and evaluation of its physical, chemical and sensory attributes. *Brazilian Journal of Food Technology*, *24*, e2020252.

*Technology*, *5*(1), 11-18.

Tireki, S. (2021). A review on packed non-alcoholic beverages: Ingredients, production, trends and future

opportunities for functional product development. *Trends in Food Science & Technology*, *112*, 442-454.

Udomkun, P., Tirawattanawanich, C., Ilukor, J., Sridonpai, P., Njukwe, E., Nimbona, P., & Vanlauwe, B.

(2019). Promoting the use of locally produced crops in making cereal-legume-based composite flours: An assessment of nutrient, antinutrient, mineral molar ratios, and aflatoxin content. *Food Chemistry*, *286*, 651-658.