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Enhancement of the functional, pasting and textural properties of *poundo* yam flour through cassava flour supplementation

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ABSTRACT

In this study, poundo yam flour was supplemented with cassava flour (5, 15, 30 and 50%) and the functionality of the flour and quality of the cooked dough were determined. The composite flours and yam flour (approx. 56%) were more dispersible than the cassava flour (approx. 50%). Cassava flour addition significantly ($p \leq 0.05$) increased the lightness of *poundo* yam flour (75.65–84.67) and the ability of the flours to absorb water, but the lightness values (61.60–64.79) of the cooked dough did not change significantly ($p > 0.05$). Samples with cassava flour were firmer (7.56–22.87 N), stickier (2.51–5.92 Ns) and gummier (2.57–5.48 N) than the control dough. Sensory ratings were similar across the cooked poundo yam samples. This study demonstrated that cassava flour can be used to supplement yam flour for *poundo* yam flour production.

1. Introduction

Pounded yam is a staple food that is widely consumed in the Western parts of Africa, especially Nigeria (Ayodeji & Abioye, 2011). Its preparation involves crushing boiled yam using mortars and pestles (Ayodeji et al., 2012). The processing steps involved in transforming boiled yam into a dough (pounded yam) with a smooth consistency is very tedious and time-consuming (Ayodeji et al., 2012; Oluwamukomi & Adeyemi, 2005). Because of these shortcomings, instant *poundo* yam flour has been developed to simplify the tedious traditional process (Adebowale et al., 2008; Oluwamukomi & Adeyemi, 2005). *Poundo* yam flour is made by dehydrating pre-cooked yam chips in an oven, followed by pulverizing the dehydrated chips into flour. The resulting flour can be reconstituted to produce a creamy to white smooth dough that is similar to pounded yam made through the traditional process (Adebowale et al., 2008).

Ayodeji and Abioye (2011) reported that the consumption of *poundo* yam in the Western part of Africa has become more popular and increased in recent times. This may be due to the increased convenience provided with the flour which eliminates the laborious nature of pounding boiled yam in the traditional process. Although *poundo* yam flour is a commercial product that is widely available in the market, the associated cost has further discouraged people from buying this product. Previous research effort has focused on the fabrication of *poundo* yam processing facilities (Ayodeji et al., 2012) and enhancing the nutritional profile of *poundo* yam flour (Adebowale et al., 2008; Oluwamukomi & Adeyemi, 2005). For example, Oluwamukomi and Adeyemi (2005) reported higher (5 times) protein for *poundo* yam flour enriched with defatted soybean flour (10–30%) compared to 100% *poundo* yam flour. The protein content of *poundo* yam flour substituted with varying amounts (20–50%) of breadfruit flour also increased by approximately 10% (Adebowale et al., 2008).

Besides the nutritional value, the textural and sensory properties are important quality attributes that define a good pounded yam or cooked *poundo* yam flour dough. Babajide et al. (2010) studied the effect of storage on microbial and sensory characteristics of packaged yam-cassava *poundo* flour. The authors reported that a blend of 20% cassava flour and 80% yam flour packaged in high-density polyethyene was most preferred in terms of aroma, colour, texture, and overall

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acceptability after storage for 24 weeks (Babajide et al., 2010). Cassava flour was used because it is a cheaper source of carbohydrates and a very good source of starch compared to yam. The use of high-quality cassava flour in various food applications provides an opportunity to enhance the traditional utilization of cassava, especially in economically developing nations. Besides enhancing the utilization of cassava, it is also possible to enhance the functionality of poundo yam flour. For example, Karam et al. (2005) studied the gel textural characteristics of corn, cassava and yam starch blends using a mixture surface response methodology approach and found that blending starchy crops such as cassava and yam starch with corn starch reduced exudate in yam and corn starch gels and may improve their possible applications in foods. More recently, Oni et al. (2021) reported the nutritional assessment of instant poundo yam from yellow yam (*Dioscorea cayenensis*) supplemented with yellow cassava (*Manihot esculenta*) flour. The authors reported a significant reduction in water absorption capacity and oil absorption capacity of poundo yam flour but an increase in the pasting properties. To fully explore cassava flour in *poundo* yam supplementation, it is important to determine the influence of cassava flour addition on flour functionality, nutritional value, and textural properties of the supplemented flour. Hence, this study aimed to determine the chemical, functional, pasting, physical, and textural characteristics of *poundo* yam flour supplemented with cassava flour and the sensory properties of its cooked dough. For clarity, 100% cassava flour was not used in the preparation of the cooked dough, therefore, this sample was only analysed for proximate and mineral composition. The novelty of this work stems from the use of white-fleshed cassava and white yam in the production of *poundo* yam flour blends as well as reporting the pasting, functionality, and textural qualities of the cooked dough for the very first time. We hypothesise that the added cassava flour will improve the textural properties of the *poundo* yam dough, creating the possibility to reduce the cost associated with using yam while further enhancing the utilisation of cassava beyond the current level of usage.

2. Materials and methods

2.1. Raw materials

Yam tubers (*Dioscorea rotundata*) were obtained from Oja Oba market in Ilorin, Nigeria. A sweet, white-fleshed with poundable quality cassava variety (*Manihot utilisima* Pohl) was purchased from the Agricultural Farm at the University of Ilorin, Nigeria. Samples used were those harvested on the same day (within 24 h of harvest), including those purchased from the market. The yam tubers and cassava samples were conveyed in jute bags to a food processing facility.

2.2. Production of yam and cassava flour

Instant *poundo* yam flour was produced as earlier reported with slight modifications (Adebowale et al., 2008). Briefly, the yam tubers were peeled and washed in potable water to remove all foreign materials. The peeled yam was sliced and cut into chips with a stainless-steel knife to a thickness of about 0.2–0.3 cm. Sliced samples were immediately immersed in a 0.5% solution of potassium metabisulphite for 30 min, drained and parboiled by steaming for 15 min to allow partial gelatinization to occur. After the parboiling process, the chips were dried on a stainless-steel perforated tray in an oven dryer (D-37,520, Thermo Fischer Scientific, Pretoria, South Africa) at 60 °C for 12 h. The chips were crushed into flour using a warring blender (Model: 8010S, Torrington, USA) and packed in Ziploc bags.

Cassava flour was also processed the same way the yam was processed. The resulting chips were oven-dried (D-37,520, Thermo Fischer Scientific, Pretoria, South Africa) at 60 °C for 12 h. The dried chips were milled into flour using a warring blender (Model: 8010S, Torrington, USA) and mixed in different proportions (5, 15, 30, and 50%) with *poundo* yam flour, prepared as described above. The mixture was sieved using a 350 μm sieve and packaged in Ziploc bags. Samples were immediately used for analysis. Residual samples were kept at room temperature (25 ± 2 °C) until needed.

2.3. Colour of flour and cooked dough

The colours of the flour and cooked dough from the composite flours were assessed using a bench-top colorimeter (A60–1014–593, Hunter Associates, Reston, USA) (Oyeyinka et al., 2015). The parameters assessed include the L* (lightness) using the axis ranging between 0 for black and 100 for white, red (+*a**) and green (-a*) axis as well as the yellow (+*b**)-blue (-b*) axis. The total colour change (ΔE) was also calculated using the equation given below (Falade & Oyeyinka, 2015).

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

2.4. Functional properties of the flour

The bulk densities, dispersibility, water absorption capacity and swelling power of the flours were assessed according to established methods. Briefly, for bulk densities, a measuring cylinder (100 mL) was filled with the flour samples, and the content was weighed. Loose bulk density was determined as the ratio of the sample weight (g) to the volume (100 mL) occupied by the sample. Packed bulk density was determined using the same procedure, but with additional tapping for 50 times before weighing (Oyeyinka et al., 2015).

Dispersibility was measured by weighing 10 g of each sample in 200 mL measuring cylinder (100 mL) and distilled water was added to reach the 100 mL mark. The set-up was vortexed and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility (Kulkarni et al., 1991).

To determine water absorption capacity, a flour sample (1 g) was mixed with 10 mL distilled water. The mixture was allowed to stand at 30 ± 2 °C for 30 min and then centrifuged (Model K241R, Centurion Scientific, Chichester, UK) at 2000 × *g* for 30 min. Water absorption capacity was expressed as gram of water per gram flour (Falade & Nwajei, 2015). Swelling power was determined by preparing a solution of flour samples (10%) in distilled water. The sample was stirred and placed in a water bath for 30 min at temperatures ranging from 50 to 90 °C with constant stirring. The suspension was centrifuged (Centrifuge Model: Ependorf 5810R, Germany) at 3400 × g for 20 min and the supernatant was discarded. Swelling power was obtained by weighing the swollen starch residue after centrifugation and dividing it by the original weight of starch on a dry weight basis (Oyeyinka et al., 2015).

2.5. Pasting properties of the flour

A rapid visco-analyser (RVA super 3, Newport Scientific Pty. Ltd, Australia) was used to determine the pasting properties of the flour samples following the method of Wireko-Manu et al. (2014) with slight modifications. Flour (3 g) was mixed with about 25 mL of water in a canister, after accounting for the differences in the sample's moisture content. Samples were heated from 50 to 95 °C, held for 2 min, followed by cooling to 50 °C within 4 min. The heating and cooling were done at a constant rate of 11.25 °C/min with a constant shear of 160 rpm. The pasting temperature, peak, breakdown, setback, and final viscosities of the samples were reported.

2.6. Chemical composition

The analysis of moisture, ash, crude fat crude fibre and crude protein contents was determined using AOAC (2000) methods. The carbohydrate content of the samples was calculated by difference [100- (ash + fat + fibre + moisture + protein)]. The mineral content of flour samples was determined using Inductively Coupled Plasma (ICP) spectroscopy. Samples were acid-digested by the addition of 1 ml of 55% (v/v) HNO_3. Briefly, each sample (1 g) was weighed into digestion vessels and mixed with the acid. The mixture was then heated in a fume cupboard. The digested sample was cooled, filtered (0.45 μm), and transferred into a 100 mL volumetric flask, and then diluted to the mark with deionized water before analysis.

2.7. *Preparation of cooked poundo yam dough*

Cooked *poundo* yam dough was prepared as previously reported (Babajide et al., 2010). Each flour (100 g) sample was dispersed in boiling water (500 ml) to form a paste and the resulting paste was stirred for 10 min in the cooking pot till a dough with smooth consistency was obtained. The samples were wrapped in polythene films and immediately used for sensory evaluation.

2.8. *Texture profile of cooked dough*

A texture analyser (Testometric, M500–100AT, Lincoln, England) was used to assess the firmness of the dough using a previous method with slight modifications (Otegbayo et al., 2007). Texture profile parameters including gumminess, adhesiveness, springiness, cohesiveness, and hardness were obtained from the texture analyser. The *poundo* yam samples were placed on a flat surface and compressed to 50% of their original height using a cylindrical plunger probe of 100 mm diameter and a preload test speed set at 60 mm/min.

2.9. *Sensory properties of cooked dough*

The sensory properties of freshly prepared cooked *poundo* yam dough from 100% yam flour and the composite flours were assessed using consumers ($n = 55$) who eat the product regularly. The appearance, taste, aroma, mouldability and overall acceptability were determined using a 9-point hedonic scale with 9 representing 'like extremely' and 1 'dislike extremely'. Samples were given to the panellist in a randomized order, which was done using a table of permutation and panel members were informed of the need to rinse their mouths with water before and in-between sample testing. The study proposal was presented to the Departmental Research and Ethical Committee and was approved by the Ethical Committee of the Department of Home Economics and Food Science, University of Ilorin, Nigeria. All participants used in the study were duly trained and informed of the implication of participating in the investigation and gave their consent.

2.10. *Statistical analysis*

Samples were prepared in duplicate while the analyses were done in triplicate. Data were analysed using a one-way analysis of variance (ANOVA). Results were presented as mean ± standard deviation and the means separated using the Fisher Least Significant Difference (LSD) test ($p \leq 0.05$), using the Statistical Package for the Social Sciences (SPSS) Version 16.0 for Windows (SPSS Inc., Chicago, USA).

3. Results and discussion

3.1. *Proximate composition of flours*

Proximate composition data expressed on a dry weight basis showed that yam flour had significantly ($p \leq 0.05$) different compositions from the cassava flour (Table 1). The dry matter composition of 100% yam, 100% cassava and the composite flours were generally high (90.17–91.82%). Both yam and cassava flour samples, as well as their composites, had carbohydrates as their main components, but the carbohydrate content of the 100% cassava flour (approx. 90%) was significantly ($p < 0.05$) higher than the 100% yam flour (approx. 88%).

Table 1
Proximate and mineral composition of *poundo yam* flour supplemented with cassava flour .

Sample	Dry matter	Fats	Protein	Ash	Fibre	*CHO	Sodium	Potassium	Magnesium	Calcium	Copper
A	90.86^{bc}±0.02	0.53^{c}±0.01	9.84^{a}±0.09	1.12^{e}±0.00	2.39^{f}±0.01	87.87^{b}±0.01	230^{b}±7.10	528^{ab}±7.78	211^{a}±7.07	485^{a}±4.14	0.90^{a}±0.02
B	90.70^{c}±0.69	0.43^{d}±0.01	8.08^{b}±0.14	1.19^{d}±0.00	2.69^{d}±0.04	90.20^{a}±0.68	251^{a}±7.70	529^{ab}±4.00	189^{b}±7.07	377^{b}±1.92	0.80^{ab}±0.12
C	91.52^{ab}±0.03	0.53^{c}±0.01	7.57^{bc}±0.00	1.36^{c}±0.00	2.88^{c}±0.01	87.68^{b}±0.01	253^{a}±2.23	534^{a}±3.40	183^{b}±7.07	273^{d}±8.28	0.85^{b}±0.02
D	90.23^{c}±0.02	0.57^{b}±0.00	7.29^{c}±0.01	1.37^{c}±0.01	2.58^{e}±0.01	88.19^{b}±0.01	237^{b}±8.28	531^{a}±4.49	186^{b}±0.00	383^{b}±8.28	0.30^{c}±0.02
E	90.17^{c}±0.01	0.57^{b}±0.01	5.47^{d}±0.73	1.46^{a}±0.00	3.46^{a}±0.02	84.68^{c}±0.07	228^{b}±5.36	528^{b}±0.00	189^{b}±0.00	378^{b}±4.50	0.30^{c}±0.10
F	91.82^{a}±0.01	0.66^{a}±0.00	5.11^{d}±0.00	1.41^{b}±0.00	3.29^{b}±0.01	89.53^{a}±0.01	230^{b}±4.00	539^{a}±7.07	201^{a}±7.07	362^{c}±3.36	0.90^{a}±0.15

Mean ± Standard deviation. Mean values with different superscripts within a column are significantly different ($p \leq 0.05$); *CHO: Carbohydrate; A: 100% yam flour + 0% Cassava flour; B: 95% yam flour + 5% Cassava flour; C: 85% yam flour + 15% Cassava flour; D: 70% yam flour + 30% Cassava flour; E: 50% yam flour + 50% Cassava flour; F: 0% yam flour + 100% Cassava flour. **Proximate composition data is expressed as g/100 g, while minerals are expressed in mg/100 g.

All other components such as ash (1.12–1.46%), fats (0.43–0.66%), fibre (2.39–3.46%), and protein (5.11–9.84%) were generally low compared to the carbohydrate content (84.68–90.20%). The proximate composition of the flours agrees with earlier reports on cassava flours (Alamu et al., 2017; Kasaye et al., 2018) and yam (Harijono et al., 2013; Kasaye et al., 2018).

3.2. *Functional properties of flour*

The functional properties of 100% yam flour, 100% cassava flour and their composites that were determined include bulk density (Fig. 1A), dispersibility (Fig. 1B), water absorption capacity (Fig. 2A) and swelling power (Fig. 2B). The flours showed higher packed bulk density (PBD) than their loose bulk density (LBD). Except for sample C (85% yam flour + 15% Cassava flour), all the composite flours displayed significantly ($p \leq 0.05$) higher PBD and LBD than the 100% yam flour and 100% cassava flour. Higher bulk densities indicate greater compactness of the particles and are important for ease of dispersibility in water (Amandikwaa et al., 2015).

Generally, the 100% yam flour and the composite flours were more dispersible than 100% cassava flour (Fig. 1A). Cassava flour addition did not significantly ($p > 0.05$) change the dispersibility of the yam flour samples, though a slight increase was observed at 5 and 50% levels of inclusion. Dispersibility represents the tendency of flour to move apart from water molecules and shows its hydrophobic interaction (Baranwal & Sankhla, 2019). The slight but insignificant differences in dispersibility may be due to variation in particle size distribution and degree of compactness of the composite flours as shown by their bulk density values (Fig. 1A). Previous studies indicated that higher flour densities is an important attribute that influences the mixing quality of

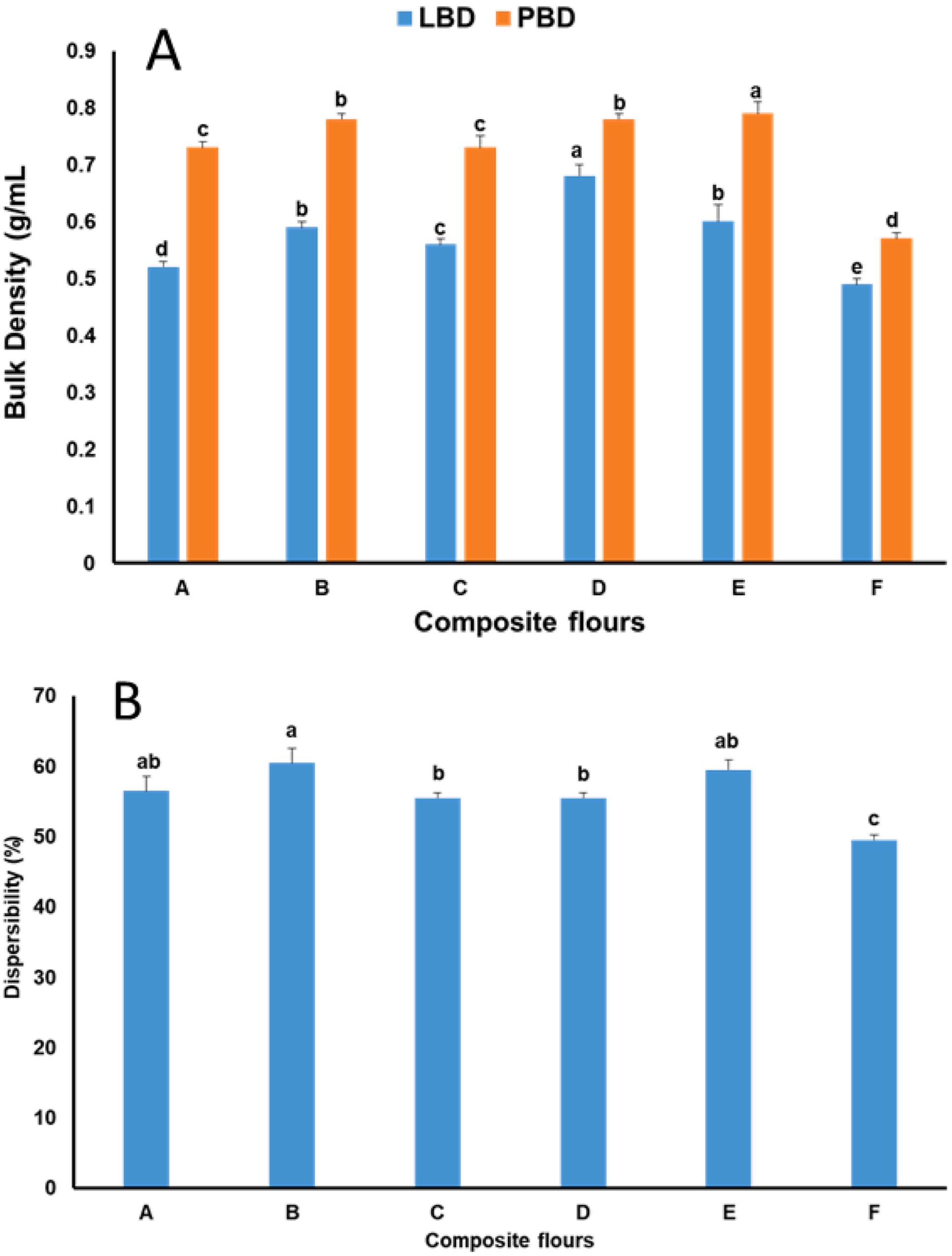

Fig. 1. Bulk densities and dispersibility of *poundo* yam flour supplemented with cassava flour. A: 100% yam flour + 0% Cassava flour; B: 95% yam flour + 5% Cassava flour. C: 85% yam flour + 15% Cassava flour; D: 70% yam flour + 30% Cassava flour. E: 50% yam flour + 50% Cassava flour F: 0% yam flour + 100% Cassava flour. Error bars indicate standard deviation ($N = 4$). LBD = Loose bulk density; PBD = Packed bulk density.

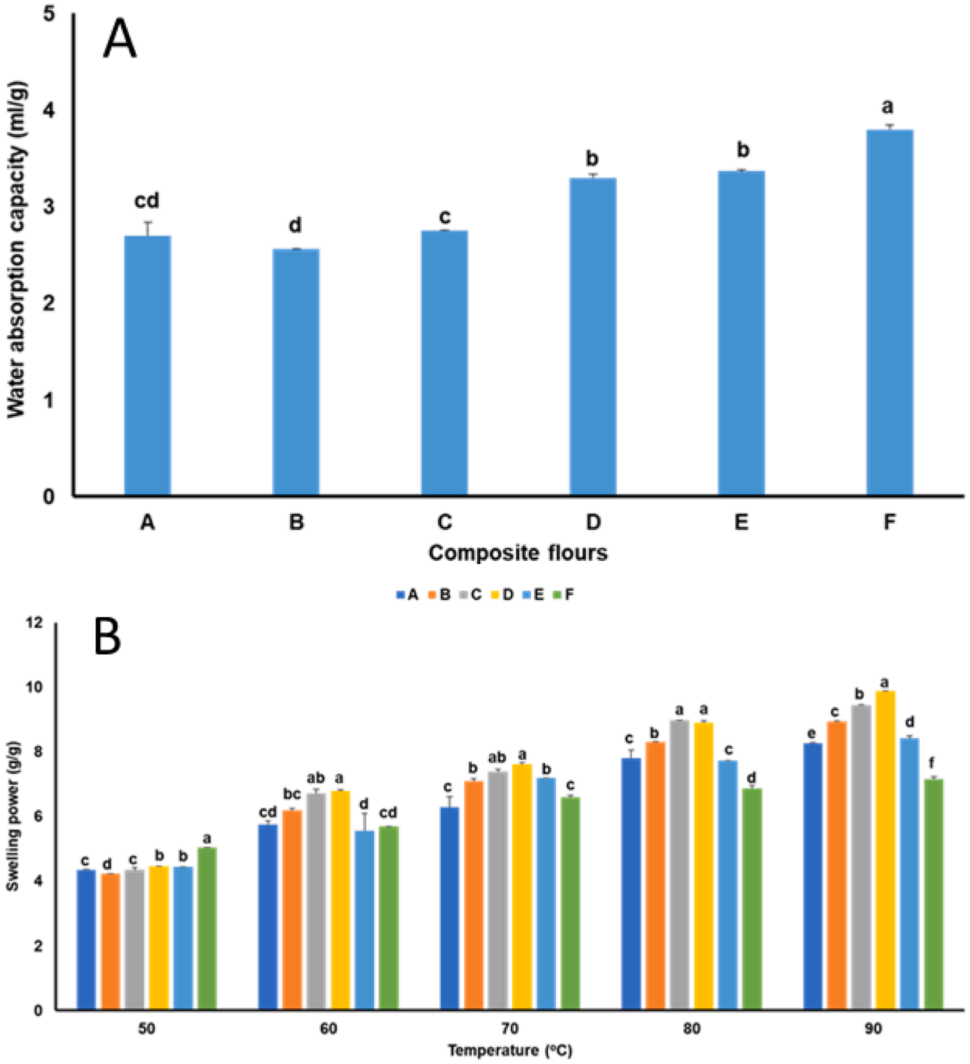

Fig. 2. Water absorption capacity and swelling power of *poundo* yam flour supplemented with cassava flour. A: 100% yam flour + 0% Cassava flour; B: 95% yam flour + 5% Cassava flour. C: 85% yam flour + 15% Cassava flour; D: 70% yam flour + 30% Cassava flour. E: 50% yam flour + 50% Cassava flour F: 0% yam flour + 100% Cassava flour. Error bars indicate standard deviation ($N = 4$).

food materials (Baranwal & Sankhla, 2019).

Cassava flour showed a greater ability to absorb water than 100% yam flour and the composite flour samples (Fig. 2A). The addition of cassava flour did not significantly ($p > 0.05$) change the water absorption capacity (WAC) of the yam flour when 5 and 15% level of cassava was used. However, a significant ($p \leq 0.05$) increase in the WAC was observed beyond 15%. The increase in WAC may be linked to higher fibre and carbohydrate contents of the cassava flour (Table 1). High amounts of fibre in composite flours reportedly displayed high WAC (Oyeyinka et al., 2020). Other factors that may influence the WAC of flours are the amylose content (Oyeyinka et al., 2015), starch granule structure and starch content (Falade & Oyeyinka, 2015). Oni et al. (2021) reported that the addition of yellow-fleshed flour resulted in a reduction in the WAC of *poundo* yam flour, which contradicts the findings in this study. Differences in flour composition used in the respective studies may have influenced the ability of the flours to imbibe water. For example, Oni et al. (2021) used yellow-fleshed cassava which has a relatively higher lipid content (0.68–0.87%) (Abiodun et al., 2020) than white-fleshed cassava. Although these values are low, lipids which are hydrophobic may create a barrier to water absorption on or within the flour.

The swelling power of the flour samples (yam, cassava, and composite flours) increased progressively with an increase in temperature from 50 to 90 °C (Fig. 2B). The swelling behaviour of the flour samples was very similar at low temperatures (50, 60 and 70 °C) but showed significant ($p \leq 0.05$) differences at higher temperatures (80 and 90 °C). The increase in swelling power at higher temperatures may be attributed to the gelatinization of the starch present in the flours. Furthermore, the composite flours and 100% yam flour showed significantly ($p \leq 0.05$) higher swelling power than the 100% cassava flour. The swelling ability of starchy flours depends on several factors including particle size distribution and starch content. Cassava has a higher starch (66.16–77.4%) level than yam (57.08–70.20%) as reported earlier (Aprianita et al., 2014; Eke-Ejiofor, 2015) and this as well as the ratio of amylose to amylopectin may explain the variation in the swelling behaviour of the flour samples. The significantly higher fat content in the 100% cassava flour compared to the 100% yam flour and the composite flours may also explain the lower swelling power of the cassava flour. This seems plausible since fat can create hydrophobicity, restricting the ingress of water into the starch granules.

3.3. Mineral composition of flours

The mineral composition of yam and cassava flours and their composites are presented in Table 1. Among the minerals determined, copper (0.30–0.90 mg/100 g) was the lowest in the flour samples while potassium (528–539 mg/100 g), calcium (273–485 mg/100 g), sodium (228–253 mg/100 g) and magnesium (182–210 mg/100 g) were present in sufficient quantities. Except for calcium, the mineral compositions of the 100% yam and 100% cassava were very similar. Potassium was the major mineral element in all the flours. Previous studies also found high levels of potassium in fresh yam flour (Abiodun & Akinoso, 2014; Asiyanbi-Hammed & Simsek, 2018) and cassava flour (Maduka et al., 2019).

3.4. Pasting properties of flour

The pasting properties of different samples of *poundo* yam flour supplemented with cassava flour as well as the 100% yam flour are shown in Table 2. Except for the pasting temperatures, the flours supplemented with cassava flour generally showed higher pasting properties compared with the 100% yam flour. The peak and final viscosities of yam flour increased by approximately 79% and 56%, respectively when 50% cassava flour was added. During pasting, starch granules are disrupted due to excessive water absorption and heating, resulting in starch gelatinization and subsequent increase in viscosity (Wireko-Manu et al., 2014). The increase in final and peak viscosities could be attributed to the higher carbohydrate in the cassava flour (Table 1) and possibly higher starch content in cassava flour than yam flour. Cassava reportedly contains higher total starch (66.16–77.4%) than yam (57.08–70.20%) (Aprianita et al., 2014; Eke-Ejiofor, 2015). Previous studies also found a significant increase in the swelling peak of yam flour supplemented with cassava starch (Abiodun et al., 2010; Anuonye & Saad, 2012). Furthermore, high peak viscosity is known to result from a high starch content and relates to the ability of starches to bind to water (Anuonye & Saad, 2012). The peak viscosity values in this study agree with the literature for different yam products (Adebowale et al., 2008; Olagunju-Yusuf et al., 2019; Oluwamukomi & Adeyemi, 2005). The breakdown viscosity, which represents the disintegration and stability of starch under heating, varied between 19 and 35 RVU (Table 2). Yam flour supplemented with cassava flour showed significantly ($p \leq 0.05$) higher breakdown viscosity than the 100% yam flour, suggesting that the supplemented flour has less resistance to hydrothermal disruption during gelatinization. High breakdown viscosity has been correlated and linked with the superior texture of *poundo* yam dough (Otegbayo et al., 2005). The setback viscosities (312–395 RVU) of the supplemented flour samples were also higher than the control 100% yam flour (275 RVU). High setback values indicate a greater tendency towards retrogradation and synaeresis in foods. However, it has been reported that a high setback viscosity in instant *poundo* yam dough or pounded yam is advantageous for good textural quality, as it confers better mouldability (Olagunju-Yusuf et al., 2019; Otegbayo et al., 2006). During retrogradation of starch, there is the possibility of reassociation of amylose-amylose chains and amylopectin chains to form junction zones. These junction zones are formed predominantly by amylose chains and the linear portion of amylopectin through hydrogen bridges and cross-links that enhance and strengthen gel structure (Wang et al., 2015). The setback viscosity is used to mimic what happens during the storage of starchy foods. Thus, the higher setback viscosity observed for the composite flours than for 100% yam flour may explain the increased hardness of the cooked dough as revealed by the textural properties (Table 2).

The pasting temperatures (71–73 °C) were slightly affected by cassava flour addition (Table 2), with a significant effect only observed at higher levels of cassava flour (30 and 50%). These values are within the range (72.3–95.8 °C) reported in the literature for *poundo* yam flour (Adebowale et al., 2008; Olagunju-Yusuf et al., 2019; Oluwamukomi & Adeyemi, 2005). The slight variation in the pasting temperatures suggests that the energy required for the preparation of the cooked dough will not vary greatly, despite the supplementation with cassava flour.

3.5. Textural properties of dough

The texture of food products especially cooked dough is important as it greatly influences consumers' perception and acceptability of such products. There were significant differences ($p < 0.05$) in the texture profile data obtained for cooked *poundo* yam flour supplemented with cassava flour (Table 2). The hardness, adhesiveness and gumminess increased with increasing levels of cassava flour, while the springiness and cohesiveness decreased. Cooked dough from 100% yam flour had the lowest hardness value of 5.11 N, while dough from flour supplemented with 50% cassava flour had the highest (22.87 N), indicating that the doughs with supplemented cassava flour were firmer. The hardness values in this study is within the range (5.6–26.9 N) reported for pounded yam prepared from freshly harvested and stored *Dioscorea rotundata* and *Dioscorea alata* by Otegbayo et al. (2007). The observed variation in the hardness values in the current study may be due to the variation in the levels of carbohydrates in the flour samples (Table 1). The firmness of starchy foods relates well with variations in starch content, starch composition (i.e., amylose content) and differences in starch granule shape and gelatinization properties. Earlier researchers found that starches with low amylose content showed lower firmness (hardness) than starches with high amylose (Oyeyinka et al., 2017). An earlier study also reported that amylose aggregation has a strong impact on the texture of yam pastes, and changes in textural attributes of yam pastes are very pronounced in the first hours after preparation (Brunnschweiler et al., 2006). The changes in the textural attributes of the *poundo yam* dough may not be as pronounced as what is experienced when pounding fresh yam tubers. This seems plausible as the traditional way of producing pounded yam involves mechanical disintegration of cooked yam cells which, in turn, contributes to the release of swollen starch granules and the formation of a continuous starch phase that governs the cohesion of the paste (Brunnschweiler et al., 2006). Good quality pounded yam must have high cohesiveness to allow for mouldability during consumption, and a less cohesive dough will be difficult to mould. The texture results with a decrease in cohesiveness is an indication that the addition of cassava flour beyond 5% would negatively affect the mouldability of the dough and may affect the acceptability by potential consumers.

As stated above, cassava flour addition increased the adhesiveness of the *poundo* yam dough samples, indicating that they became stickier. According to Otegbayo et al. (2007), a desirable degree of adhesiveness (stickiness) is an important quality for pounded yam. Except for *poundo* yam made from 100% yam flour and 5% cassava level of

Table 2
Pasting and texture profile result of *poundo* yam flour supplemented with cassava flour.

Yam (%)	Cassava (%)	Hardness (N)	Springiness	Adhesiveness (N.s)	Cohesiveness	Gumminess (N)	PV (RVU)	BV (RVU)	SV (RVU)	FV (RVU)	PT °C
100	0	$5.11^{c}\pm0.69$	$0.45^{a}\pm0.05$	$0.95^{e}\pm0.34$	$0.33^{a}\pm0.03$	$1.69^{d}\pm0.33$	$406^{d}\pm4.24$	$19^{c}\pm1.41$	$275^{d}\pm9.19$	$657^{e}\pm4.24$	$73^{a}\pm0.14$
95	5	$7.56^{c}\pm0.08$	$0.40^{a}\pm0.06$	$2.51^{d}\pm0.19$	$0.34^{a}\pm0.05$	$2.57^{c}\pm0.31$	$563^{c}\pm18.39$	$21^{c}\pm2.12$	$312^{c}\pm16.97$	$836^{d}\pm6.36$	$73^{a}\pm0.04$
85	15	$14.74^{b}\pm1.24$	$0.30^{b}\pm0.04$	$3.12^{c}\pm0.34$	$0.23^{b}\pm0.02$	$3.39^{b}\pm0.31$	$576^{c}\pm5.66$	$35^{a}\pm2.12$	$395^{a}\pm4.95$	$928^{c}\pm2.83$	$72^{a}\pm0.35$
70	30	$14.60^{b}\pm2.89$	$0.30^{b}\pm0.05$	$3.64^{bc}\pm1.50$	$0.23^{b}\pm0.12$	$3.36^{b}\pm0.34$	$659^{b}\pm2.12$	$32^{ab}\pm2.83$	$361^{b}\pm4.24$	$983^{b}\pm3.54$	$71^{b}\pm0.49$
50	50	$22.87^{a}\pm2.55$	$0.27^{b}\pm0.02$	$5.92^{a}\pm0.18$	$0.24^{b}\pm0.19$	$5.48^{a}\pm0.74$	$727^{a}\pm4.24$	$29^{b}\pm1.41$	$338^{b}\pm7.07$	$1026^{a}\pm4.95$	$71^{b}\pm0.35$

Mean ± Standard deviation. Mean values with different superscripts within a column are significantly different ($p \leq 0.05$).
PV: Peak viscosity; BV: Breakdown viscosity; SV: Setback viscosity; FV: Final viscosity; PT: Pasting temperature.

supplementation, the adhesiveness values recorded in the current study were higher than the range (1.24–2.62) reported for pounded yam from *Dioscorea rotundata* and *Dioscorea alata* (Otegbayo et al., 2007).

Another important textural attribute of pounded yam is gumminess. It is determined by multiplying the values of cohesiveness and hardness and indicates the energy needed to break up solid foods for swallowing. The addition of cassava flour to yam flour significantly ($p \leq 0.05$) increased the gumminess from 1.69 to 5.48 N (Table 2) and these values are similar to calculated values from a previous study on pounded yam from *Dioscorea rotundata* and *Dioscorea alata* (Otegbayo et al., 2007).

3.6. Colour of flour and dough

The addition of cassava flour to *poundo* yam flour did not substantially change the Hunter lab colour attributes of the flour samples and their corresponding dough (Table 3). *Poundo* yam flour prepared from 100% yam was lighter (L*= 75.65) compared to flours supplemented with cassava flour, which showed higher lightness values (80.34–84.67). The increase in lightness values may be attributed to the higher carbohydrate content of the cassava flour (Table 1), suggesting a higher starch content (Villarreal et al., 2013).

Earlier studies reported higher total starch content for cassava (66.16–77.4%) than yam (57.08–70.20%) (Aprianita et al., 2014; Eke-Ejiofor, 2015). Differences in the colour of the flour may also be due to variable amounts of polyphenols in the respective flours. Generally, there were no significant differences ($p > 0.05$) amongst the L* (61.60–64.79), a* (8.61–8.86) and b* (1.21–2.10) values of the cooked *poundo* samples (Table 3). However, the colour attributes for the dough were much lower than those of the flour samples. This may be due to the effect of heat and subsequent gelatinization of the flour samples resulting in lower lightness, redness and yellowness values. Collins and Falasinnu (1977) reported similar L* (65.00–69.60) values for dough prepared from yam enriched with soybean flour.

The calculated total colour change (ΔE) of the flour samples ranged between 5.04 and 9.27, while those of the dough ranged between 0.58 and 1.72 (Table 3). The ΔE values of the flour did not change significantly ($p > 0.05$) when cassava flour was added up to 30% level, but the values increased significantly ($p \leq 0.05$) at 50% level of cassava. Cooked dough samples, however, showed a slightly different trend with the ΔE values showing similar values up to 15% level of cassava addition and thereafter increasing significantly between 30 and 50% level of cassava addition. A higher level of cassava addition (30 and 50%) had a greater effect on the total colour of the cooked dough samples. The changes in the colour of the cooked dough relate well to the physical appearance of the samples (Fig. S1).

3.7. Sensory properties of the cooked dough

The sensory panel scores presented in Table 4, showed that the addition of cassava flour did not significantly ($p > 0.05$) affect the sensory attributes (appearance, taste, aroma, mouldability) of the dough, except the overall acceptability. The non-significant effect indicates that the presence of cassava flour did not produce changes to the extent that panellists preferred one sample over another. The mean score for each sample was greater than 6.0, placing them above the 'like slightly' category of the hedonic scale. The similarity in the ratings for the samples may be because *poundo yam* in the cooked form is very similar to other starchy doughs such as *fufu* made from cassava. The cohesiveness of the poundo sample (Table 2) did not agree with the mouldability result since the addition of cassava did not significantly change the mouldability of the samples. Consumers are the final judge for any product and hence, a wider consumer acceptability test may be further required to validate this before commercialisation.

4. Conclusion

Yam flour showed different chemical composition from cassava flour, but both flours and their composites had carbohydrates as the major component. Yam flour and the composite flours showed better dispersibility and swelling than 100% cassava flour, indicating a synergistic effect on functionality. The addition of cassava flour increased the water absorption capacity and lightness values of *poundo* yam flour and the cooked dough, and increased the breakdown, final, peak and setback viscosities of the *poundo* yam flour, but resulted in a slight reduction in the pasting temperatures. Samples with cassava flour were firmer, stickier, and gummier than the control dough. Sensory ratings were similar across the *poundo* yam samples. This study demonstrated that cassava flour can be used to supplement yam flour for *poundo* yam flour production without substantial changes in acceptability and quality. A pilot-scale model to scale up the current findings, an economic analysis, and the digestibility of the product are also required.

CRediT authorship contribution statement

Samson A. Oyeyinka: Investigation, Conceptualization, Data curation, Formal analysis, Writing – original draft. **Oluwatosin E. Taiwo:** Data curation, Formal analysis. **Hamza Abdul:** Data curation, Formal analysis. **Ginalyn A. Rustria:** Writing – review & editing, Validation. **Ajibola B. Oyedeji:** Data curation, Formal analysis, Writing – review & editing. **Oluwafemi A. Adebo:** Writing – review & editing, Validation, Funding acquisition. **Abe S. Gerrano:** Writing – review & editing, Validation. **Stephen O. Amoo:** Writing – review & editing, Validation. **Patrick B. Njobeh:** Writing – review & editing, Validation, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 3

Colour of *poundo yam* flour supplemented with cassava flour and its cooked dough.

Yam (%)	Cassava (%)	Flour				dough			
		L*	a*	b*	ΔE	L*	a*	b*	ΔE
100	0	$75.65^{c}\pm2.01$	$10.13^{c}\pm0.27$	$7.90^{c}\pm0.57$	–	$61.76^{b}\pm1.01$	$8.75^{a}\pm0.86$	$1.73^{a}\pm0.25$	–
95	5	$80.34^{b}\pm1.34$	$10.31^{bc}\pm0.55$	$9.67^{a}\pm0.78$	$5.04^{b}\pm1.54$	$61.60^{b}\pm0.85$	$8.76^{a}\pm0.12$	$1.21^{a}\pm0.44$	$0.63^{b}\pm0.17$
85	15	$81.86^{b}\pm0.86$	$10.66^{ab}\pm0.23$	$9.04^{ab}\pm0.45$	$6.35^{b}\pm0.45$	$62.23^{b}\pm0.94$	$8.86^{a}\pm0.15$	$1.70^{a}\pm0.46$	$0.58^{b}\pm0.23$
70	30	$81.76^{b}\pm1.57$	$10.39^{bc}\pm0.19$	$8.32^{bc}\pm0.62$	$6.15^{b}\pm1.60$	$64.35^{ab}\pm1.57$	$8.61^{a}\pm0.24$	$2.17^{a}\pm1.09$	$1.72^{a}\pm0.42$
50	50	$84.67^{a}\pm1.39$	$11.08^{a}\pm0.11$	$9.77^{a}\pm0.32$	$9.27^{a}\pm1.42$	$64.79^{ab}\pm2.42$	$8.77^{a}\pm0.24$	$2.16^{a}\pm1.30$	$1.46^{a}\pm0.30$

Mean ± Standard deviation. Mean values with different superscripts within a column are significantly different ($p \leq 0.05$).

L* (lightness) axis – 0 is black, 100 is white, a* (red-green) axis-positive values are red, negative values are green and 0 is neutral; b* (yellow-blue) axis- positive values are yellow, negative values are blue and 0 is neutral; A: 100% yam flour + 0% Cassava flour; B: 95% yam flour + 5% Cassava flour; C: 85% yam flour + 15% Cassava flour; D: 70% yam flour + 30% Cassava flour; E: 50% yam flour + 50% Cassava flour; ΔE: Total colour difference.

Table 4
Mean sensory scores of cooked *poundo yam* flour supplemented with cassava flour.

Yam (%)	Cassava (%)	Appearance	Taste	Aroma	Mouldability	Overall acceptability	Total score*
100	0	6.91^{a}±1.65	6.43^{a}±2.04	6.91^{a}±1.51	6.48^{b}±1.31	6.65^{ab}±1.56	33.38
95	5	7.39^{a}±1.50	6.96 ^{a} ± 1.61	6.74^{a}±1.74	7.52^{a}±1.20	7.30^{a} ±1.26	35.91
85	15	6.78^{a}±1.45	6.57^{a}±1.20	6.35^{ab}±1.19	6.70^{ab}±1.10	6.78^{ab} ±0.90	33.18
70	30	6.75^{a}±1.59	6.38^{a}±1.78	6.08^{ab}±1.35	7.00^{ab}±1.18	6.67^{ab}±1.13	32.88
50	50	6.43^{ab}±1.83	6.22^{a}±1.83	6.00^{ab}±1.75	6.17^{b}±1.23	6.26^{bc}±1.29	31.08

Mean ±Standard deviation. Mean values with different superscripts within a column are significantly different ($p \leq 0.05$).

[*] Calculated as a total of all the sensory attributes after finding their average and mean values.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.focha.2023.100372.

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