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Nutritional, functional, and sensory properties of poundo yam flour enriched with Irish potato flour

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ABSTRACT

This study was conducted to determine the influence of inclusions of Irish potato flour (IPF) into instant poundo yam flour (PYF) on their nutritional composition, functional properties, and sensory evaluation. The four treatments were 1) PYF produced from 100% yam flour (PYF), 2) 90% PYF yam flour + 10% IPF (10IPF), 3) 80% PYF + 20% IPF (20IPF), 4) and 70% PYF + 30% IPF (30IPF). Increasing the concentration of IPF flour increased the concentration of calcium, magnesium, potassium, and iron ($P<0.05$). However, zinc contents were similar ($P>0.05$). For pasting property, 20IPF showed higher peak, trough, breakdown, and final viscosities than 10IPF or 30IPF, but lower than PYF except for trough and final viscosities ($P<0.05$). In contrast, 10IPF showed higher setback viscosity and pasting temperature ($P<0.05$). However, all peak times were similar ($P>0.05$). For functional properties, pH values tended to decrease as the percentage of IPF increased ($P<0.05$); however, loose bulk density, packed bulk density, water holding capacity, swelling capacity, and solubility showed significant increases in response to increases in IPF, except solubility for 10IPF ($P<0.05$). Amylose and carbohydrate values were similar ($P>0.05$). Adding IPF affected amylose content, carbohydrate content, and color properties ($P<0.05$). The finding indicated that enrichment of PYF with IPF benefited mineral contents; 10 to 20 % of IPF might be optimal to include in PYF to maximize overall properties.

Keywords: poundo yam, pasting properties, Irish potato flour, functional properties, sensory evaluation.

INTRODUCTION

Tubers and roots are important carbohydrates as energy sources and are used as staple foods in tropical and sub-tropical countries (Liu et al., 2006). Using tubers as a source of carbohydrate instead of gluten-containing carbohydrates may aid in a reduction in the incidence of celiac disease (CD) or other allergic reactions (Rekha and Padmaja, 2002). Irish potato is an edible tuber from the *Solanum tuberosum* plant, which is actually native to South America, not Ireland. Irish potatoes are named after Ireland because they are closely associated with the Irish potato famine, a historical famine caused by a mold infestation of the Irish potato crop (Mondal et al., 2004; Robert and Cartwright, 2006). Potato production has been considered the first priority compared to other food crops because of its contribution to food security, income generation and double cropping advantages, and its utilization in different forms (Lung'aho et al., 2007; Muthoni and Nyamongo, 2009). It is the fourth most important crop in the world after wheat, maize, and rice, with an annual production of 314.1 million tons cultivated on about 18.1 million hectares of land (Adane et al., 2010).

Yam, a member of the genus *Dioscorea* is the most important staple food in West Africa after cereals (Ekwu et al., 2005). It is a major staple food for an estimated 60 million people in the region stretching from Ivory Coast to Cameroon, an area commonly referred to as the "Yam Zone" of West Africa (Akissoe et al., 2003). Yams are characterized by high moisture content, which renders the tubers more susceptible to microbial attacks and brings about high perishability the tubers. With an annual production of above 28 million metric tonnes (FOS, 2011), Nigeria is the world's largest producer of edible yams, with D. *rotundata* and D. *alata* as the two most cultivated yam species in the country. Yam belongs to the semi-perishable class of food due to its relatively high moisture content and vulnerability to gradual physiological deterioration after harvesting. However, yams can be processed into less perishable products, such as yam flour, through a drying process (Jimoh and Olatidoye, 2009). The traditional process of preparing pounded yam is a tedious process, which involves pounding cooked slices of yam in a mortar using a pestle to create a smooth dough consistency. However, instant poundo yam flour is a modern invention to simplify the tedious traditional process

(Oluwamukomi and Adeyemi, 2015). Instant poundo yam flour requires a short processing time and less energy which benefits preserving yam and reduces human drudgery associated with pounded yam production (Komolafe and Akinoso, 2005). The technology includes peeling, washing, slicing/dicing, cooking, drying, milling and packaging.

There is a need to overcome the challenges of under-nutrition and micronutrient deficiencies through intensive formulation and utilization of locally available food crops (such as yam and Irish potato) as a source of energy, protein, vitamin, and minerals, which will help to fight the problem thus preventing high postharvest losses (Ernest et al., 2017). According to Oluwamukomi and Adeyemi (2015), instant pounded yam flour is a modern invention aimed at simplifying the tedious traditional process of pounding cooked slices of yam in a mortar using a pestle to a smooth dough consistency. As reported by Umadevi et al. (2013), the Irish potato contains pro-vitamin A, vitamin K, sulfur, and a major contributor of vitamin C, thus making it a root crop necessary for consumption. A study conducted by Olumurewa et al. (2019) on production of poundo flour from yam and plantain revealed that the flour performed excellently with satisfactory nutritional and sensory acceptability; thus, a clear indication that poundo yam can also be fortified with other crops. However, there is a paucity of information regarding the fortification of poundo yam with Irish potato flour despite its numerous nutritional benefits; hence, the necessity for this research.

MATERIALS AND METHODS

Source of materials

Yam (*Discorea spp.*) and Irish potatoes (*Solanum tuberosum*) were procured from Owode Market in Offa Local Government Area, Kwara State, Nigeria. Also, Sodium metabisulphite was obtained from the Food processing laboratory of Food Technology Department, Federal Polytechnic Offa Kwara State.

Sample preparation

Preparation of Irish potato flour

The method of Ernest et al. (2017) was used. The Irish potatoes were thoroughly washed, peeled, cut into suitable sizes, and dried in a hot air oven at a temperature of 60oC for 12 hours until a constant weight was obtained. The dried Irish potato samples were subsequently milled into fine particle sizes using an attrition mill and sieved with a sieve with a mesh size of 600 µm to obtain the Irish potato flour (Figure 1).

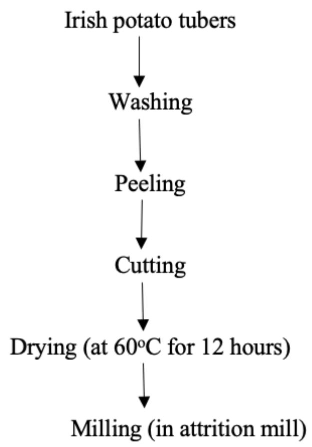

Figure 1. Flow chart for the preparation of Irish potato flour.
Source: Ernest et al., (2017)

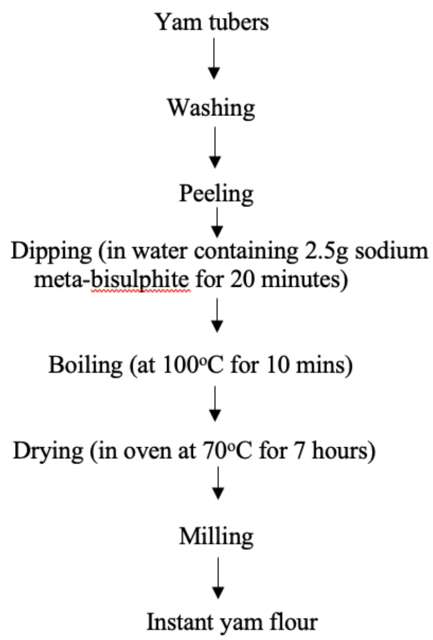

Figure 2. Flow chart for the preparation of instant yam flour.
Source: Oluwamukomi and Adeyemi (2015)

Preparation of instant yam flour

Yam flour was produced according to the modified method of Oluwamukomi and Adeyemi (2015). Briefly, the yam tubers were washed to remove sand, dirt, and other adhering materials. The yam tubers were peeled and sliced to about 0.02 mm thickness, after which they were dipped in water containing 2.5g sodium meta-bisulphite in about 500 ml of water for 20 minutes so as to arrest the browning reaction and placed in a sieve to remove excess water after which they were cooked by boiling for 10 minutes at 100°C. The cooked (boiled) yams were dried in a hot air oven at 70°C for 7 hours, after which milling using an attrition mill was done (Figure 2).

Treatments

There were four treatments including 1) instant poundo yam flours produced from 100% yam flour (PYF), 2) 90% PYF + 10% Irish potato flour (10IPF), 3) 80% PYF + 20% Irish potato flour (20IPF), 4) and 70% PYF + 30% Irish potato flour (30IPF).

Method of analysis

Mineral determination

1 g of sample was weighed into a digestion tube or a conical flask. 10 ml of H_2SO_4 and 30 ml of nitric acid were added. This was placed on a hot plate in a fume cupboard and digested until the digest became clear. The digest was diluted to 100 ml and taken to Atomic Absorption Spectrophotometer (Buck Scientific Model, 2010, UK), a corresponding lamp for a corresponding mineral was placed in the AAS, and the wavelength specific to a particular mineral to be determined was set. The AAS siphoning hose was dipped into the digested sample after running the standards for the mineral of interest. The concentration of the mineral in the solution was displayed on the screen of the AAS machine (AOAC, 2006).

Determination of pasting properties

A Rapid Visco Analyser, RVA (Model RVA-SUPER3, USA), was used to determine the viscosity of the composite flours according to Hahn and Hozio (1987) method. About 3 g of sample were weighed into a dried empty canister, and then 25 mL of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed so that no lumps were obtained, and the canister was fitted into the Rapid Visco-Analyzer. A paddle was then placed into the canister. The measurement cycle was initiated by depressing the motor tower of the instrument. Samples were pasted according to a programmed heating and cooling cycle. The dispersions were heated from 50 to 95oC with constant stirring at 2.67 Hz, and were held at 95oC for 2.5 min (breakdown). Then, the blocking temperature was cooled to 50oC and held for 2 min. The total cycle was 13 min. Parameters estimated were peak viscosity, setback viscosity, final viscosity, trough, breakdown viscosity, pasting temperature, and time to reach peak viscosity (Hahn and Hozio, 1987.

Determination of pH

A pH meter model (Model PHS-25CW Microprocessor pH/mv meter) was used to determine the pH. 100 ml sterile distilled water was added to ten grams of the flour samples weighed and dissolved in a beaker containing 25ml distilled water to form slurry. It was allowed to stand for 10 min with constant stirring. The pH was then directly determined with the aid of pH meter (Jones et al., 2000).

Water holding capacity (WAC)

1 g of powdered sample was weighed into a previously weighed centrifuge tube. 10 ml of distilled water was added and shaken severally to make sure water circulates throughout the entire powdered sample. The tube and content were centrifuged at 3000 rpm for 30 min, after which the supernatant was decanted. The tube and its content (residue) were weighed. The amount of water absorbed was obtained by subtracting the weight of the tube and sample from the weight of the tube and residue (Onwuka, 2005; Noor Aziah and Komathi, 2009).

Determination of solubility and swelling index/ power

1 g of sample was weighed into a previously weighed empty centrifuge tube. 10 ml of distilled water was added and mixed severally. The tube was placed in a boiling water bath for 30min. After 30 min, the tube was allowed to cool and then centrifuged at 2200 rpm for 15 minutes. The supernatant was decanted into a previously weighed petri dish, and the petri dish was dried in the oven. The tube and its content (gel) were also weighed. The swelling power was calculated by subtracting the weight of the tube from the weight of the tube and gel, while the solubility index was calculated by subtracting the weight of the empty crucible from the weight of the dried crucible and content (residue) (Onwuka, 2005; Noor Aziah and Komathi, 2009; Masur Shakuntala et al., 2009; Kaushal et al., 2012; Jitngarmkusol et al., 2008).

Wettability

The method of AOAC (2006) was used. Into a 25 ml graduated cylinder with a diameter of 1 cm, 1 g of sample was added. A finger was placed over the open end of the cylinder which was invested and clamped at a height of 10cm from the surface of a

600 ml beaker containing 500 ml of distilled water. The finger was removed and the rest material allowed to be dumped. The wettability is the time required for the sample to become completely wet.

Bulk density

This was determined using the method described by AOAC (2006). About 2.5 g of sample was filled in a 10 ml graduated cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample. The volume was recorded.

$$\text{Bulk density} = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (ml)} \qquad \text{equation (1)}$$

Swelling capacity

Swelling capacity was determined according to the method given by Onwuka (2005). About 100 mg of the sample was mixed with 10 ml of distilled water in a calibrated cylinder at room temperature. After equilibration for 18 hours, the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gram of original sample dry weight.

equation (2)

$$\text{Swelling capacity mL/g} = \frac{Change\ in\ volume\ of\ sample}{Original\ weight\ of\ sample}$$

Determination of colors

This was determined according to Noor Aziah and Komathi (2009) method. 1.00 g of sample was weighed into a beaker and 25 ml ethanol was added. It was stirred for 30 min and allowed to stand for 10 minutes. The supernatant was filtered using filter paper into clean tubes and labeled accordingly. The absorbances of the supernatant were determined using UV visible spectrophotometer at the wavelengths of 615nm, 650nm and 585nm for lightness (l), redness (a) and yellowness (b) respectively. The equivalent values for each colour is obtained (Makanjuola and Coker, 2019; FAO, 2009).

Chemical analysis

Amylose

It was determined by the method of Masur Shakuntala et al. (2009). Iodine reagent was prepared by dissolving 1 g and 10 g potassium iodide in water and making it up to 500 ml mark. 0.1 g of sample was weighed into a flask and 1 ml of distilled ethanol was added followed by addition of 10 ml 1 N NaOH. This was heated for 10 minutes or left over night before continuation. The content was made up to 100ml using distilled water. 2.5ml was taken into a 10ml volumetric flask and 20 ml distill water, followed by addition of 3 drops of phenolphthalein indicator. Few drops of 0.1 N HCl was introduced until the pink colour disappeared. 1 ml of iodine reagent was added and made up to 50 ml with distilled water. The absorbance was read at 590 nm using a spectrum lab23A UV visible spectrophotometer. The concentration was obtained from a standard amylase graph (Bolade et al., 2009; McCready et al., 1950; Juliano, 1971).

Total carbohydrate

Anthrone reagent was prepared by dissolving 0.2g of anthrone powder in 100 ml of 95 % sulphuric acid. 0.1 g of sample was weighed into a centrifuge tube. This was hydrolyzed by adding 5ml of 2.5 N HCl and placing it in a boiling water bath for 3 hours. After 3 hours, it was neutralized by adding solid sodium carbonate until effervescence ceased. The content was transferred into a 100 ml standard flask and made up to mark using distilled water. This was centrifuge,ed and 0.5 ml aliquot was taken for total carbohydrate determination. 4 ml of the prepared anthrone was added and heated in a boiling water bath for 8 minutes. This was co,oled and absorbance read at 630 nm ua sing spectrum 23A UV visible spectrophotometer. The total carbohydrate content was estimated by extrapolating the absorbances from a glucose standard graph (Kaushal et al., 2012).

Statistical analysis

The results obtained from proximate, functional, and pasting analysis were subjected to an independent sample T-test using IBM SPSS (version 20). Significant differences between samples were tested at $P \leq 0.05$ using the Tukey test.

RESULTS AND DISCUSSION

Mineral content evaluation

The mineral component of poundo yam-Irish potato flour produced (Table 1) indicated that calcium content ranged from 18.16 to 35.44 mg/100g. The result showed that 30IPF had the highest value (35.44 mg/100g) while PYF (100% yam flour) had the least value (18.16 mg/100g). The result showed a significant difference between treatments ($P<0.05$). It was observed that the higher the percentage of Irish potato supplementation, the higher the value obtained. The values obtained in all the samples supplemented with Irish potato were significantly higher than PYF. The calcium content obtained in this research was higher than the value (0.47 mg/100g) obtained for 100% yam flour by Thayumanavan and Sadasivam (1984) in effect of water yam and soybean composite flours on the quality of wheat based bread. The variation in the result obtained could be a result of different proportions of IPF used.

Table 1. Mineral contents (mg/100g).

Items	PYF	10IPF	20IPF	30IPF
Calcium	18.16±0.14[a]	23.30±0.76[b]	30.40±0.78[c]	35.44±0.12[d]
Magnesium	51.34±0.11[a]	57.24±0.42[b]	60.91±0.27[c]	65.49±0.18[d]
Potassium	310.35±0.55[a]	352.91±0.31[b]	396.34±0.15[c]	423.92±0.36[d]
Iron	6.23±0.04[a]	6.38±0.09[b]	7.00±0.06[c]	7.59 ±0.16[d]
Zinc	1.10±0.00	1.10±0.00	1.11±0.00	1.13±0.04

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate determination ± standard deviation. Mean values within the same row having different superscripts are significantly different (P<0.05)

Magnesium content ranged from 51.34 to 65.49 mg/100g. The 30IPF had the highest value, while PYF had the least (51.34 mg/100g). The result showed a significant difference between the treatments (P<0.05). The treatment with the highest value would provide the body with the magnesium needed if consumed adequately. This magnesium has been reported to serve as a co-factor in more than 300 enzymes systems that regulate diverse bronchial reactions in the body, including protein synthesis, muscle and heme function, blood glucose control, blood pressure regulation, structural development of bone, nerve impulse conduction, muscle contraction and normal heart rhythm (Sadasivam and Manickman, 2004). Potassium content ranged from 310.35 to 423.92 mg/100g, where PYF had the least (310.35 mg/100g); 30IPF had the highest (423.92 mg/100g) (P<0.05). The results obtained in this work were lower than the result obtained (773.48 mg/100g) for PYF by Thayumanavan and Sadasivam (1984). Potassium influences the contraction of smooth, skeletal, and cardiac muscles and profoundly affects the excitability of nerve tissue. It is also essential in maintaining electrolyte and pH balance (Thayumanavan and Sadasivam, 1984); therefore, consumption of poundo meal supplemented with 30IPF would be of great benefit for people with potassium deficiency. The same trend observed in the aforementioned mineral elements also occurred in iron content of this research work; 30IPF had the highest value of iron (7.59g/100g) while PYF had the least (1.10 mg/100g); however, it was observed that PYF and 10IPF had the same (P>0.05). The increase in supplemented IPF led to the increased value obtained, which could be due to the fact that Irish potato is richer in mineral content than the yam tuber. The result obtained was higher in iron than that reported by Thayumanavan and Sadasivam (1984) obtained (1.84g/100g) for PYF. This will be of nutritional importance, especially to infants and growing children, and pregnant mothers. Sufficient consumption of Iron will help prevent impaired intellectual development in children, lead poisoning in children, anemia in adults and children, and help in the metabolism of almost living organisms and humans. It is an essential component of hundreds of proteins and enzymes (Sadasivam and Manickman, 2004). The result for zinc content showed that 30IPF had the highest value (1.13 mg/100g) while PYF had the lowest (1.10 mg/100g). The result obtained was higher than that obtained (0.70 mg/100g) for PYF by Thayumanavan and Sadasivam (1984). Minerals are important in diets as they play essential roles in body metabolism. For example, calcium helps regulate muscle contractions and transmission of nerve impulses as well as bone and teeth development. Phosphorus has also been reported to be required for bone growth, kidney function, cell growth, and maintaining the body's pH balance (Ochelle et al., 2019). Furthermore, potassium is essential for its vital role is the synthesis of amino acids and proteins. Moreover, magnesium helps in the relaxation of the muscle and the formation of strong bones and teeth. It also plays a fundamental role in most reactions involving phosphate transfer, believed to be essential in the structural stability of nucleic acid and intestinal absorption. At the same time, its deficiency can cause severe diarrhea, hypertension, and stroke.

Pasting properties evaluation

Pasting properties are essential functional characteristics of starches. When an aqueous suspension of starch is heated above a critical temperature, granules swell irreversibly, and amylose leaches out into the aqueous phase, resulting in increased viscosity (pasting). Peak viscosity is a measure of the ability of the starch to form a paste. Starch also can swell freely before its physical breakdown (Fallon and Enig, 2001). Peak viscosity has been reported to be closely associated with the degree of starch damage. According to Fallon and Enig (2001), high starch damage results in increased viscosity. The result obtained in this research work (Table 2) showed that PYF had the highest value (1728.50 RVU) while 10IPF had the least (1377.40 RVU) (P<0.05). The peak viscosity obtained for this research work was higher than the result obtained by Sanni et al. (2001), who reported peak viscosity ranging from 325-398 RVU for starch extracted from sorghum; however, it was low when compared with the result obtained by Aviara et al. (2010), who recorded peak viscosity of 639-726 RVU for yam starches. The higher peak viscosity observed in 100% yam flour may be suitable for products requiring high gel strength, thick paste, and elasticity.

Table 2. Pasting properties.

Items	PYF	10IPF	20IPF	30IPF
Peak (RVU)	1728.50±0.71^{d}	1377.10±1.98^{a}	1627.51±3.52^{c}	1483.50±3.54^{b}
Trough (RVU)	922.04±1.47^{c}	812.51±2.14^{a}	928.00±2.83^{c}	821.00±4.24^{b}
Breakdown (RVU)	808.01±1.42^{d}	567.50±3.54^{b}	697.50±3.54^{c}	654.50±3.54^{b}
Final viscosity (RVU)	1744.55±5.02^{a}	1790.02±0.28^{b}	1852.51±7.77^{d}	1811.50 ±3.54^{c}
Setback (RVU)	821.00±1.41^{a}	980.50±2.12^{c}	929.00±1.41^{b}	965.00±35.34^{bc}
Peak time (min)	5.70±0.14	5.35±0.64	5.85±0.28	5.71±0.35
Pasting temp (^{0}C)	80.87±0.05^{a}	89.45±0.21^{c}	82.13±0.18^{a}	85.75±2.12^{b}

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate determination ± standard deviation. Mean values within the same row having different superscripts are significantly different (P<0.05).

The trough (Table 2) ranged 812.51 to 928.00 RVU; 20IPF had the highest value (928.00 RVU) while 10IPF had the least (812.51 RVU) (P<0.05), but there was no significant difference between PYF and 20IPF (P>0.05). These results were lower than the result reported (1688 RVU) by Olumurewa et al. (2019), but higher than those (38.040 to 262.830 RVU) reported by Amoo et al. (2014). The holding period (Trough) sometimes referred to as shear thinning, holding strength, or hot-paste viscosity is a period when the samples were subjected to a period of constant temperature and mechanical shear stress. Breakdown results ranged from 567.50 to 808.01 RVU (P<0.05); PYF had the highest value (808.01 RVU) while 10 IPF was the least (567.50 RVU). Breakdown measures the ability of starch to withstand collapse during cooling or the degree of disintegration of granules or paste stability (Oduro et al., 2001). Adebowale et al. (2005) reported that the higher the breakdown viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. The breakdown viscosity of this research work was higher than the range obtained by Sanni et al. (2001) (145 to 216 RVU) for sorghum and (15 to 385 RVU) for yam starches (Aviara et al., 2010). The result showed that sample 10IPF would withstand heating and shear stress during cooking more than other treatments. Setback value ranged from 821.00 to 980.50 RVU. Setback measures the re-association of starch (Jimoh et al., 2009). High setback value is associated with cohesive paste. The result obtained from this work (821 to 980 RVU) was higher than the values obtained by Sanni et al. (2001) and also higher than the value obtained by Aviara et al. (2010) for yam (79 to 339 RVU). Low setback values are useful for products like weaning foods which require low viscosity and paste stability at low temperature (Adebowale et al., 2005). Hence, the Irish potato may be useful for such products. Conversely, starch from Irish potato may be useful for products such as pounded yam that require high cohesive pastes. The final viscosity ranged from 1744.55 RVU for PYF to 1852.51 RVU for 20IPF where the highest value was 20IPF and the least value was PYF. The final viscosity of 20IPF (1852.51 RVU) indicated the ability to form a firm, viscoelastic paste or gel after cooking and cooling owing to the re-association of starch molecules. This work was not aligned with the finding of Amoo et al. (2014) who reported high values ranged value of (84.04 to 356.79 RVU) for the various yam starches produced. The result obtained was within the range (1409 to 2430 RVU) and in agreement with reported by Olumurewa et al. (2019) in the evaluation of functional and pasting properties of instant pounded yam/plantain flour. The pasting time of this research work ranged from 5.35 to 5.85 minutes (P>0.05). The pasting time of the composite flour used in this research work is low compared with the pasting time recorded by Aviara et al. (2010), who observed pasting time of 17.40 to 17.55 minutes for yam varieties. The slight difference in the pasting time may be attributed to a difference in formulation. The starches with a shorter pasting time such as that of 10IPF may be appropriate for the production of foods that require shorter processing time. It can be observed from the results (Table 2) that the higher the pasting temperature, the shorter the pasting time. The pasting temperature provides an indication of the minimum temperature required for sample cooking, energy cost involved and other component stability (Jimoh et al., 2009). It also gives an indication of the gelatinization time during processing (Ikegwu et al., 2009). The associative bonding of the amylose fraction is responsible for the structure and pasting property of the starch granule. The pasting temperature in this research work ranged between (80.87^{0}C - 89.45^{0}C). The result showed no significant difference between PYF and 20IPF (P>0.05). The pasting temperature of the yam-Irish potato flour used in this work is greater than the results obtained by Aviara et al. (2010), who recorded pasting temperatures for starches obtained from 4 local yam varieties, which ranged from 75.1 to 77.3°C.

Functional properties evaluation

Functional properties of flour products are among the most important parameters used to ascertain the suitability of flour and starch for certain end uses. Afoakwa et al. (2021) stated that functional properties aid in the choice of a variety for use in the industry as a thickener, binder, or any other food and industrial use. According to Afoakwa et al. (2021), functional properties are the properties of a food product that provide information on how food ingredients behave in a food system during processing. These properties include water absorption capacity, solubility, swelling power/index, wettability, bulk density, swelling capacity/volume, and gelation properties. These properties regulate the sensory characteristics and stability of processed starch products. Many factors have been stated to impact the degree and type of functional properties of foods. These factors, according to Mégnanou et al. (2009), including the starch composition and concentration, the ratio of amylose to amylopectin, characteristics of each fraction in terms of molecular weight/distribution, degree/length of branching, and conformation of starch.

The pH of poundo yam-Irish potato flour supplementation (Table 3) is important because it affects most of the functional properties of the flour (Odedeji and Adeleke, 2010). The pH values ranged from 5.43 to 5.71 (P<0.05). A decrease in pH was observed along with increasing in IPF percentage (P<0.05); however, the pH values of 10IPF and 20IPF were similar (P>0.05). PYF had the highest pH (5.71) while 30IPF had the least value (5.43). Low pH values have been reported to be caused by high amylase activity which increases the level of acidity. The pH will affect palatability and discourage the growth of pathogenic bacteria and subsequent spoilage of the yam flour (Eleazu and Ironua, 2013). pH is also a critical factor that influences the reconstitution characteristics of food products. Loose bulk density (Table 3) ranged from 0.48 to 0.52g/mL. PYF had the lowest value (0.48g/mL) while sample 30IPF had the highest value (0.52g/mL). There was no significant difference between 10IPF and 20IPF (P>0.05). Packed bulk density ranged from 0.73 to 0.80g/mL (P<0.05); 30IPF was the highest in packed bulk density (0.80g/mL) while PYF was the lowest (0.73g/mL). It was observed that the packed bulk density increased in response to increasing IPF supplementation. The result obtained for both bulk density in this research work was slightly lower than the result (0.84g/mL) recorded by Eleazu and Ironua, et al. (2013) for yam flour in rheological and functional properties of soy-poundo yam flour. The bulk density is influenced by particle size and the density of the flour and is important in determining the packaging requirement and material handling. Bulk density is influenced by the structure of the starch polymers, and the loose structure of the starch polymers could result in low bulk density. The high loose and packed bulk density indicated its heaviness, this means that 30% Irish potato supplemented might be useful in food preparations to reduce paste thickness in food products, as well as in the pharmaceutical industry as a drug binder and disintegrant (Solakunmi et al., 2013; Chandra et al., 2015). The results of bulk density revealed that it depended on the particle size and initial moisture content of flours (Zaku et al., 2009). The increase observed in this study in bulk density was not desirable in packaging because higher density often results in reduced ability to compress the flour. This is unlikely to result in cost savings since more packaging materials would be required.

Table 3. Functional properties.

Items	PYF	10IPF	20IPF	30IPF
pH	5.71±0.01^{c}	5.58±0.00^{b}	5.53±0.03^{b}	5.43±0.04^{a}
Loose bulk density (g/mL)	0.48±0.01^{a}	0.49±0.00^{b}	0.50±0.00^{b}	0.52±0.01^{c}
Packed bulk density (g/mL)	0.73±0.00^{a}	0.74±0.00^{b}	0.79±0.00^{c}	0.80±0.00^{d}
Water holding capacity (%)	342.30±0.65^{a}	359.14±0.23^{b}	374.41±0.18^{c}	386.03 ±0.34^{d}
Swelling capacity (ml/g)	620.65±0.50^{a}	634.01±0.23^{b}	683.64±0.19^{c}	687.90±0.34^{d}
Solubility (%)	5.07±0.05^{b}	3.79±0.02^{a}	7.37±0.13^{c}	9.16±0.08^{d}

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate determination ± standard deviation. Mean values within the same row having different superscripts are significantly different (P<0.05).

The water absorption/holding capacity (Table 3) of poundo yam flour ranged 342.30 to 386.03 %. The highest value was recorded for 30IPF (386.03 %) while PYF had the least value (342.30%) (P<0.05). The result obtained in this research work was high compared to the result reported (2.70 %) by Ezeama (2007) for flour in rheological and functional properties of soy-poundo yam flour. Water absorption capacity influenced product viscosity and the properties of starch system (Chandra and Singh, 2013). High water holding capacity may assure product moisture stability (Richana and Sunarti, 2004). Water absorption capacity is useful in determining the capacity of flour to take up water and swelling to improve uniformity in food. It is also advantageous in food processing for improving yield, uniformity, and giving shape to food products (Adebowale et al., 2007); the higher value of water holding capacity may cause by a high polar amino acid residue of protein having an affinity for water molecule (Osundahunsi et al., 2003). Since they have hydrophilic parts such as polar or charged side chains, proteins and carbohydrates are the major chemical constituents that increase the water holding capacity of flours. The water holding capacity of the flours could also be influenced by an increase in the solubility, leaching out of amylose, and loss of molecular structure of the starch as well as the crystalline structure (Yusuf et al., 2008). It might also be influenced by the non-identical structure of flours. The high water holding capacity of the flours showed that they could be used in the formulation of various foods such as meat sausage, bakery products, dough, and processed cheese (Hashimoto and Grossman, 2003).

The swelling capacity ranged from 620.65 to 687.90 ml/g. The highest swelling capacity was recorded for 30IPF (687.90 ml/g) while PYF had the least value (620.65 ml/g). It was observed that the higher the Irish potato supplementation, the higher the value recorded ($P<0.05$). The result obtained in this research work was higher than the range value recorded (9.70 to10.20 ml/g) by Amoo et al. (2014) in the evaluation of starch from trifoliate yam (*Dioscorea dumetorum*) Landraces. The swelling power is an indication of the presence of amylase which influences the quantity of amylase and amylopectin present in the yam flour. The swelling power of flour granules is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch-based flour during heating. Therefore, the higher the swelling power, the higher the associate forces. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water (Malomo et al., 2012).

The solubility index ranged from 3.79 to 9.16 % ($P<0.05$). 10IPF had the lowest value (3.79%) while 30IPF had the highest value (9.16 %). The result obtained in this research work was lower than the result recorded (16.16 %) for yam flour by Udensi and Okaka (2000) in Rheological and Functional Properties of Soy-Poundo Yam Flour. The wettability capacity values ranged from 32.50 to 59.50 sec; wettability value was highest for 30IPF with a value of 59.50 sec while 10IPF had the least value at 32.00 sec. There was no significant difference between PYF, 10IPF, and 20IPF ($P>0.05$). These wettability capacity values were higher than the value of 42.5 sec reported for *D. rotundata* (Udensi and Okaka, 2000) and 27 to 35 sec for *D.alata* flours (Udensi et al., 2008) of similar products, but lower than 135 to 148 sec for soy-melon 'garri' (Oluwamukomi and Jolayemi, 2012). This means these flours were denser and would sink in water more than those reported. Wettability provides a useful indication of the degree to which dried flour is likely to possess instant characteristics which are aided by high porosity.

Amylose and carbohydrate evaluation

Amylose contents (Table 4) ranged from 13.00 to 19.47%. The results showed significant differences among treatments ($P<0.05$). PYF had the highest value (19.47%) while 30IPF had the least value (13.00%). It was observed that the higher the supplemented sample the lower the value obtained. The result obtained in this research work was lower to the result recorded (35.92%) for yam flour by Oluwamukomi and Akinsola (2015) in thermal and physicochemical properties of some starchy foods: yam (*Dioscorea rotundata*), cocoyam (*Xanthosoma sagittifolium*) and plantain (*Musa paradisiaca*). The amylose content is simply the linear molecular structure of starch. It is an important factor with regard to the end use properties of various products such as noodles and dough. It has a strong bond and therefore takes a lot of energy to breakdown during digestion due to its tightly packed structure. It is reported to be an effective prebiotic. Amylose positively influences the functioning of the digestive tract microbial flora, the blood cholesterol level and the glycemic index, and assists in the control of diabetes (Hu et al., 2012).

The total carbohydrate ranged from 90.06 to 93.09%; PYF had the highest value (93.09%) while 30IPF had the least (90.06%) ($P<0.05$), but there was no significant difference between 10IPF and 20IPF ($P>0.05$). The high carbohydrate value in YPF could be attributed to the high content of starch in yam tuber.

Table 4. Amylose and carbohydrate contents (%).

Items	PYF	10IPF	20IPF	30IPF
Amylose	19.47 ± 0.72^{d}	17.61 ± 0.21^{c}	15.03 ± 0.11^{b}	13.00 ± 0.18^{a}
Carbohydrate	93.09 ± 0.48^{c}	$90.66\pm0.15a^{b}$	91.45 ± 0.28^{b}	90.06 ± 0.59^{a}

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate determination ± standard deviation. Mean values within the same row having different superscripts are significantly different ($P<0.05$).

Color property evaluation

The results of color measurement, as presented in Table 5, were significantly (P<0.05) different in lightness (L^*), redness (a^*), and yellowness (b^*) values for all the flour treatments. Lightness values ranged from 60.85 to 84.21; PYF had the highest value (84.21), while 30IPF had the least (60.85) (P<0.05). Yellowness result showed that 30IPF had the highest value (15.17) while YF sample had the lowest value (5.85) (P<0.05). High yellowness values in supplemented samples could be due to the higher amount of beta carotene in supplemented flour (Ahmed et al., 2005). Beta-carotene is a very sensitive nutrient that degrades during processing or storage and occurs via oxidation or isomeration (Van Hal, 2000). Irish potato flour could add natural color to food products. Results obtained for the measurement of redness represented by a^* values indicated that redness (a^*) was significant (P<0.05) and showed an increase in redness values which ranged from 1.02-2.47 as supplemented increased. A higher redness value of 2.47 was obtained in 30% Irish potato flour. The higher redness value could be due to the presence of the anthocyanin pigments in the Irish flour.

Table 5. Color properties.

Items	PYF	10IPF	20IPF	30IPF
Lightness (L^*)	84.21±0.16^d	79.55±0.18^c	67.07±0.13^b	60.85±0.49^a
Yellowness (b^*)	5.85±0.28^a	8.22±0.16^b	11.66±0.64^c	15.17±0.52^d
Redness (a^*)	1.02±0.85^a	1.77±0.02^b	2.10±0.07^c	2.47±0.50^d

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate determination ± standard deviation. Mean values within the same row having different superscripts are significantly different (P<0.05).

Sensory evaluation

Sensory evaluation of poundo-yam-Irish potato (Table 6) produced showed the preference of the panelists for the poundo yam produced. For color, PYF tended to obtain a higher value at 8.5 while 30IPF the lowest at 6.5. The preference for the color decreases as the substitution with IPF increases this may be due to the fact that consumers are already used to the off-white or creamy color of PYF. For aroma, PYF tended to have the highest value (8.2) while 30IPF had the least value (6.1%). For taste, 30IPF tended to have the least value (5.9) while PYF tended to obtain the highest value (8.5). For appearance, PYF tended to be the most preferred while 30IPF was the least preferred. For texture, PYF had the highest value (8.6) while 30IPF had the least value (5.8). For overall acceptability, sample PYF was most preferred by the panelist (8.7) while 30IPF was least preferred (6.4). All the samples were acceptable by the panelist meanwhile PYF was rated the highest. Consumers' preference for PYF could be attributed to their familiarity with the product more so, the pounded yam for which the poundo flour is an alternative is originally made from yam only.

Table 6. Sensory evaluation.

Items	PYF	10IPF	20IPF	30IPF
Color	8.5	7.5	7.5	6.5
Aroma	8.2	7.4	7.4	6.1
Taste	8.5	7.2	7.9	5.9
Appearance	8.5	7.4	7.9	5.7
Texture	8.6	7.7	7.4	5.8
Overall acceptability	8.7	7.6	7.1	6.4

IPF = Irish potato flour, PYF = instant poundo yam flour produced from 100% yam flour, 10IPF = 90% PYF + 10% IPF, 20IPF = 80% PYF + 20% IPF, 30IPF = 70% YPF + 30% IPF. Results are mean values of duplicate.

CONCLUSIONS

The research revealed the mineral content and pasting properties of PYF-IPF. For mineral content, there was an increase in values obtained as the percentage of supplemented IPF increased while PYF had the least value. Functional and pasting properties showed that all the treatments could be acceptable for industrial use. However, 10 to 20 % of Irish potato flour may be an optimal dose added into instant poundo yam flour to achieve optimal responses to overall property criteria. In sensory evaluation, the inclusion of IPF tended to decrease acceptability of consummers.

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