Nutritional and Functional Properties of Unripe Plantain, White Yam and Sweet Potato Amala

Sunmonu[1], B.A., Abdulsalam[1] F., Adeyanju[2], E.B., Akinsola[3], O.O., Salimon[3], R.Y., & Akinsola[4], A.O.

[1]Department of Food Technology, Federal Polytechnic Offa, Kwara state, Nigeria
[2]Department of Home Economics, Federal University of Education, Ondo, Ondo State, Nigeria
[3]Department of Home Economics, Federal College of Education, Abeokuta, Ogun State, Nigeria
[4]Department of Home Economics, Federal College of Education (Special), Oyo, Oyo State, Nigeria.
Corresponding author: akinsola.akinjide1333@fcesoyo.edu.ng

Abstract: Nutritional and functional properties of unripe plantain, white yam and sweet potato *amala* were investigated. The samples were coded as sample FPP (unripe plantain flour), FYP (yam flour) and FSP (Sweet potato flour) and analyzed for nutritional and functional properties. Selected mineral content showed that calcium content ranged from 14.48 - 5.26 mg/100g; magnesium 29.83 - 92.66 mg/100g; sodium 7.18 - 86.27 mg/100g; potassium 214.85 - 413.43 mg/100g and iron content from 2.15 - 56.19 mg/100g. Total starch ranged from 56.98 - 69.71 % and total carbohydrate from 67.76 - 75.08 %. Functional properties showed that bulk density ranged from 0.66 - 0.78 g/100g; water absorption capacity 2.63 - 4.92 g/g; oil absorption capacity 1.80 - 4.64 g/g; emulsion capacity 3.69 - 4.58 %; emulsion stability 2.90 - 6.38 %; foam capacity 3.98 - 5.16 %; foaming stability 0.33 - 6.38 %; swelling capacity 4.23 - 8.29 %; swelling index 1.00 - 1.94 %; dispersibility 58.50 - 68.50 % and gelatinization temperature from 60.23 - 62.31 ^oC. Pasting properties showed that peak viscosity ranged from 142.22 - 368.63 RVU; trough 136.44 - 294.35 RVU; breakdown 21.67 - 26.77 RVU; final viscosity 182.36 - 463.24 RVU; setback 42.88 - 102.41 RVU; peak time 4.92 - 5.62 min and pasting temperature from 83.83 - 87.33 ^oC. The result revealed that flour produced from yam had high nutritional and chemical content over other flour samples produced.
[Sunmonu, B.A., Abdulsalam F., Adeyanju, E.B., Akinsola, O.O., Salimon, R.Y., & Akinsola, A.O. **Nutritional and Functional Properties of Unripe Plantain, White Yam and Sweet Potato Amala.** *Researcher* 2026;18(1):1-9]. ISSN 1553-9865 (print); ISSN 2163-8950 (online). http://www.sciencepub.net/researcher. 01. doi:10.7537/marsrsj180126.01

Keywords: *Amala*; gelatinization temperature; pasting properties; nutritional property; unripe plantain flour.

Introduction

Amala, a traditional Nigerian dish is a gelatinized local food/meal product usually produced from yam flour (CF) or other flours from fermented and sundried yam and other root tubers. It is widely consumed in the Western part of the country. *Amala* can be prepared from yam, cassava, plantain and cocoyam flour after reconstituting the flour in boiling water until a stiff smooth paste is formed. Roots and tubers plays a major role in the African diets, however, *amala* have large consumption due to its cultural inclination has necessitated the need to evaluate alternatives that can serve same purposes and have nutrients dense composition. Hence, the use of plantain, sweet potato and yam composite flour for fortification and diversification of gel-like *Amala* meals/products.

Plantain, *Musa paradisiaca* of the family *Musaceae* and locally called 'Ogede-agbagba' in Yoruba, 'Ayaba' in Hausa and 'Ogadejioke' in Igbo, is a major staple food crop and source of energy for millions of people in the tropical humid regions of Africa. Plantain (*Musa paradisiacal*) serves as a significant carbohydrate source in various regions of Africa, Asia, and South America [1]. Its consumption is primarily attributed to its rich vitamin and mineral contents. Plantain flour, whether used alone or in combination with yam flour, can yield quality stiff dough known as *amala* [2]. Unripe plantain dough *amala* is a popular and common solid food for Ife and Ijesha people in Osun State, Nigeria. However, a comparative assessment of its stiff dough has not been compared with other sources of flour samples used to produce *amala*.

Sweet potato is a food crop that is increasingly being recognized as having an important role to play in improving household and national food security, health and livelihoods of poor families in sub-Saharan Africa. Sweet potatoes play an immense role in the human diet and are considered the second staple food in developed and underdeveloped countries [3]. Sweet potatoes are vegetable crops which have been grossly underutilized in Nigeria, and therefore efforts at promoting their utilization are being continuously researched. Nutritional profiling of sweet potato showed that it is rich in vitamins B_6 and C, beta carotene and dietary fibre [4].

Yam belongs to the family *Dioscorea* spp. It is a semi-perishable class of food due to its relatively high moisture content [5]. It is a tuber crop that is grown widely in many part of the world. It is majorly grown in sub-saharan Africa, with the production of more than 95 % of the global yam cultivation and second most important root/tuber crop in Africa after cassava [6]. Yam is a source of carbohydrate and has a lower glycemic index which makes it a sustainable source of energy and gives better protection against obesity and diabetes [7]. Traditionally to the Nigerian southwestern culture, *amala* is exclusively obtained from yam or cassava flours [8]. Hence, there is a need to explore other food materials such as unripe plantain and sweet potato and compare with the commonly used yam tuber. This could help in enhancing the availability of the product and make different varieties available to consumers. The present study endeavours to produce yam, plantain, and sweet potato flours with a focus on conducting mineral analysis, evaluating functional and pasting properties and ultimately preparing *amala* from these flours to assess their sensory attributes.

Materials and Methods

Raw material and source of procurement

Freshly harvested samples of yam, sweet potato and unripe plantain fruits were sourced from Owode market in Offa town, Kwara State, Nigeria. Subsequent processing of the samples was carried out at the Food Technology Wet Processing Laboratory, Federal Polytechnic, Offa, Kwara State, Nigeria.

Samples preparation

Production of yam flour

Preparation of yam flour was done according to the method described by [9] with little modification. Yam tuber was washed, peeled, sliced and washed in potable water. The sliced yam was conditioned using 4 liter container. The parboiled yam slices was steeped in cleaned water for 24 hrs, drained, sundried for 4 days. The dried chips were milled into flour. The flour samples were passed through a sieve of 200 µm mesh size to obtain fine consistency. Finally, the flour was carefully packed into airtight plastic packages and stored at ambient temperature for further use.

Preparation of sweet potato flour

Preparation of sweet potato flour was done according to the method described by [10] with little modification. Fresh roots of flesh sweet potato free from any signs of infection or infestation were thoroughly washed under running tap water to eliminate any adhering soil, dirt, or dust. Subsequently, the roots were peeled, washed, sliced into water and washed. Following this, the slices were sun-dried for 4 days. The dried chips were milled into flour, flour samples were passed through a sieve of 200 µm mesh size to obtain fine consistency. Finally, the flour was carefully packed into airtight plastic packages and stored at ambient temperature for further use.

Preparation of unripe plantain flour

Preparation of unripe plantain flour was done according to the method described by [10]. The plantain fruits were carefully separated from its bunch, thoroughly washed with clean water, and then peeled using a sharp knife. The peeled plantain fruits were sliced manually with a sharp knife to an average thickness of 1cm, and the slices were laid out on stainless trays for sun drying. Dried chips were milled using a locally fabricated hammer mill and then sieved through a mesh (200 µm mesh size) to achieve a fine particle size flour texture. The resulting flour was meticulously packed into air-tight plastic containers, labeled, and stored at ambient conditions for future use.

Method of analysis

Minerals analysis

The digested Roasted fishes were analysed for Mg, Ca, Mn, K, Zn and Fe concentration using Atomic Absorption Spectrophotometer. All determinations were carried out in triplicate and reported as mean mineral content in mg/100g [11].

Determination of chemical composition of the *amala* flour samples

The standard method described by Association of Official Analytical Chemists [11] was used for chemical analysis such as total starch, amylose content and beta-carotene of the samples while carbohydrate content was determined by difference.

Determination of functional properties of the *amala* flour samples

The functional properties (bulk density, water and oil absorption capacity, emulsion activity and stability) of the maize varieties flours samples were determined as described by [12]. Foaming capacity was evaluated using the method of [13] while swelling power and solubility capacity were analyzed by the methods of [14]. Dispersibility was determined by the methods described by [15] while gelatinization temperature was determined by the method described by [16].

Determination of sensory evaluation of the *amala* cooked dough samples

Sensory attributes of the maize varieties flour samples were determined using preference test as described by [17]. Twenty semi-trained panelists that were familiar with *moin-moin* and *ekuru* puddy, a similar steaming product to the study samples were drawn from the Polytechnic community. The panelists were asked to indicate their preference for the samples in term of colour, appearance, mouldability, flavour, taste and overall acceptability on 9-point Hedonic scale where 9 =like extremely and 1=disliked extremely. Each panelist sat in an enclosed cubicle designed for sensory evaluation and water was provided to rinse mouths before and after tasting each of the samples.

Pasting Properties

Pasting properties was determined with a Rapid Visco Analyzer (RVA). Five grams (5 g) of each sample was weighed into a dried empty canister, and then 5 ml of distilled water was dispensed into the canister containing the sample. The slurry was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 - 95 °C with a holding time of 2 min followed by cooling to 50 °C with 2 min holding time. The rate of heating and cooling was at 22.5 °C per min. Peak viscosity, trough viscosity, breakdown viscosity; final viscosity, setback viscosity, pasting temperature and peak time were read from the pasting profile with the aid of a thermocline for windows software connected to a computer [18].

Statistical Analysis

All analyses were conducted in duplicates. Data were subjected to analysis of variance, Duncan's multiple range tests was used to separate the means while SPSS software version 2020 was used for all statistical analyses.

Results and Discussion

Table 1: Selected mineral content of *amala* flour samples

Sample (mg/100g)	FPP	FYP	FSP
Calcium	14.48 ± 0.01^{a}	75.26 ± 0.01^{c}	45.57 ± 0.01^{b}
Magnesium	29.83 ± 0.01^{a}	45.63 ± 0.01^{b}	92.66 ± 0.01^{c}
Sodium	7.82 ± 0.01^{b}	86.27 ± 0.01^{c}	7.18 ± 0.01^{a}
Potassium	413.43 ± 0.01^{c}	214.85 ± 0.01^{a}	397.15 ± 0.01^{b}
Iron	2.15 ± 0.01^{a}	56.19 ± 0.01^{c}	4.25 ± 0.01^{b}

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at p<0.05. Sample FPP - plantain *amala* flour, Sample FYP - yam *amala* flour, Sample FSP - sweetpotato *amala* flour.

Mineral content of *amala* flour samples

The result of the mineral analysis of amala flour is shown in Table 1. The Calcium content of the sample ranged from 14.48 - 75.26 mg/100g with sample FPP (plantain flour) having the least value (14.48 mg/100g and sample FYP (yam flour) had the highest (75.26 mg/100g), there are significant difference (p<0.05) between the samples. Calcium is the most abundant mineral in the body and it function include regulating muscular contractions including heartbeat, blood clotting and formation of strong bones and teeth [19; 20]. Magnesium content ranges from 29.83 - 92.66 mg/100g with sample FSP (sweet potato flour) having the highest value (92.66 mg/100) while sample FPP (plantain flour) had the least value (29.83 mg/100g). The result showed significant difference between the samples (p<0.05).

The sodium content of the samples ranged from 7.18 - 86.27 mg/100g for sample FSP (sweetpotato flour) and sample FYP (yam flour) respectively, there is significant difference (p<0.05) between samples. The amount of sodium content obtained for sample FYP is higher than the RDA requirement and could be recommended for hypertensive patients. Sodium is essential for the control of blood pressure. It is an electrolyte that controls the extracellular amount of fluid in the body and is needed for hydration. In addition, sodium stimulates the muscles and nerves. The sodium content of most plantain flour and sweet potato flour can be considered relatively low compared with the RDA of 1.5 g/day. Excessive sodium intake has been associated with high blood pressure and stiffening of arterial walls and therefore a risk factor for CVD [21].

The result further shows the value for potassium ranges from 214.85 - 413.43 mg/100g for FYP and FPP, respectively. There are significant differences (P≤0.05) among the samples. Low potassium is associated with a risk of high blood pressure, heart disease, stroke, arthritis, cancer digestive disorders, and infertility. For people with low potassium, improved diets (or potassium supplements) to prevent or treat some of these conditions may be recommended. Potassium was below the recommended levels in the analyzed food samples. There is abundant evidence that a reduction in dietary sodium and increase in potassium intake decreases BP, incidence of hypertension, and morbidity and mortality from CVD [22].

The result for Iron ranges from 2.15 - 56.19 mg/100g for FPP and FYP, respectively. There are significant differences (P≤0.05) among the samples. Iron is the most common micronutrient deficiency in the world. Women of childbearing age are the highest risk group because of menstrual blood losses, pregnancy, and lactation. Iron conveys the capacity to participate in redox reactions to a number of metalloproteins such as haemoglobin, myoglobin, cytochrome enzymes, and many oxidases and oxygenases. It is required for many proteins and enzymes, notably haemoglobin to prevent anaemia. Anaemia has been shown to be linked maternal mortality and premature child birth [23]. Thus, yam flour analyzed contains adequate proportion of iron when compared with RDA of 18 mg. Thus, dietary iron is best supplied by consumption of foods like amala made from yam flour in this research work.

Table 2: Physicochemical properties of *amala* flour samples

Parameter	FPP	FYP	FSP
Total starch	63.23±0.01^{b}	56.98±0.01^{a}	69.71±0.01^{c}
Total carbohydrate	67.76±0.01^{a}	73.34±0.01^{b}	75.08±0.01^{c}

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at p<0.05. Sample FPP - plantain *amala* flour, Sample FYP - yam *amala* flour, Sample FSP - sweetpotato *amala* flour

Physicochemical properties of *amala* flour samples

The starch content of amala flour ranged 56.98 % for sample FYP (yam flour) to 69.71 % for sample FSP (sweet potato flour). All the results were significantly different at alpha 0.05. The differences in the starch content obtained may be due to the variation in botanical source. The result obtained is lower to the result 70.99 - 79.81 % reported by [24] for sweet potato-cassava flour. There are two types of molecules in the starches in crops - amylose and amylopectin, and the proportions and the structures of the two molecules in starch may be the main factors that affect the cooking quality of the amala from tuber flours. Study by [25] has shown that amylose has a huge impact in the cooking quality of food products, however it cannot be used alone as predictor of quality of the food product. The amylose content and amylose characteristics of starch dictate most of its uses and in most instances determine the properties of starch

All samples exhibited high carbohydrate content values ranging from 67.76 - 75.08 % with sample FSP (sweetpotato flour) having the highest value and sample FPP (unripe plantain flour) had the least. The results are significantly different from each other (p<0.05). This is typical of root and tuber crops, which are naturally rich in carbohydrates compared to other crops. The result obtained in this research work is in agreement with the findings of [9] who also reported high carbohydrate content of orange fleshed sweet potato flour (77.36 %) and low carbohydrate content in unripe plantain flour (73.75 %). High carbohydrate content 84.51 - 89.62 % reported by [26] for plantain flour blanched at various temperatures.

Table 3: Functional properties of *amala* flour samples

Parameter	FPP	FYP	FSP
BD (g/100g)	0.74±0.01^{b}	0.66±0.01^{a}	0.78±0.01^{b}
WAC (g/g)	2.63±0.01^{a}	3.33±0.01^{b}	4.92±0.01^{c}
Swelling capacity (g/g)	5.28±0.01^{b}	4.23±0.01^{a}	8.29±0.01^{c}
Swelling index (g/g)	1.94±0.01^{b}	1.76±0.01^{b}	1.00±0.01^{a}
Dispersibility	65.50±0.01^{b}	58.50±0.01^{a}	68.50±0.01^{c}
Gelatinization (°C)	60.23±0.01^{a}	60.81±0.01^{b}	62.31±0.01^{c}

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at p<0.05. Sample FPP - plantain *amala* flour, Sample FYP - yam *amala* flour, Sample FSP - sweetpotato *amala* flour

Functional properties of *amala* flour samples

The functional properties of yam, plantain and sweet potato flour for *amala* production are presented in Table 3. The bulk density (g/100g) of the yam flour, potato flour, and plantain flour exhibited significant variation (p<0.05). Ranging from 0.66 - 0.78 for sample FYP and FSP, respectively. The result obtained in this research work is similar 0.194 - 0.420 g/ml reported by [26] for plantain flour blanched at various temperature. Bulk density of 0.45 g/cm^3 reported by [27] was in line with the value obtained in this study. It was also observed that the value obtained from this study is similar to the one obtained by [28] on effect of processing on cocoyam which ranged from 0.588 -

0.714 g/ml. The bulk density of the flour samples plays a crucial role in determining packaging requirements, material handling and transportation in food industry.

Water absorption capacity (WAC), which measures the flour's ability to retain water, significantly differed among the produced flours. The WAC ranged from 2.63 - 4.92 g/g with sample FSP having the highest value (4.92 g/g) and sample FPP had the least value (2.63 g/g). The result shows significant difference between the samples ($p<0.05$). Vikuson [26] reported 118.50 - 124.50 % which is found to be very high to the values obtained in this present work. The result of the 100 % plantain flour in this study is lower than the one reported by [29] who obtained 131.75 % WAC for 100 % plantain flour. The value 216.00 % obtained by [27] for 100 % plantain flour is higher than the value obtained (2.26 g/g) for plantain flour in this research work. WAC influences the flour's ability to form a paste and impacts physicochemical properties in various food products such as soup, dough, and baked goods [30]. Low water absorption capacity suggests a compact molecular structure, while a high value indicates a loose structure of starch polymers, making it suitable for composite flour in bread making [31].

The result of swelling capacity in this study shows significant variation among the samples ($p<0.05$). The swelling capacity obtained in this research work ranged from 4.23 - 8.29 g/g for sample FYP and FSP, respectively. Vikuson [26] reported 38.47 - 48.09 % for plantain flour which is higher than the values obtained in this study. The swelling power obtained for plantain flour 6.48 g/g reported by [27] and the values (8.22 g/100 g) reported by [32] for plantain flour are higher than the value (5.28 g/g) obtained for plantain flour in this study and this may be attributed to the variety of plantain used for the study.

The swelling index of the flours shown significant relationship between sample FPP and FYP ($p<0.05$) with results ranged from 1.00 - 1.94 g/g. Sample FSP exhibited the lowest swelling index (1.00 g/g) while the highest was recorded for sample FYP (1.94 g/g). This aligns with the finding of [9] who reported 1.35 - 1.71 g/cm^3 for amala flour from yam, sweetpotato and unripe plantain. The values obtained in this research work is slightly lower than 1.26 - 2.00 g/ml findings reported by [28] on the effect of processing on cocoyam flour. The swelling index reflects the extent of associative forces within the granules which indicate the presence of amylase influencing the quantity of amylase and amylopectin present in the flour [30].

Dispersibility index of the amala flours is as reported in Table 3. Dispersibility is a useful functional parameter which measures the reconstitution of flour in water to have a fine and consistency paste, and it gives an indication on water-absorption capacity [15]. Dispersibility index of the flours significantly different; ranged from 58.50 - 68.50 % between the samples. An earlier study by [33] on dispersibility of yam flours had reported a value of 51.17, 52.83 and 62.83 %, respectively for *D. dumetorum*, *D. cayenensis* and *D. alata* flours which are within the range obtained in this research work. According to [34], these higher values of dispersibility observed for flours samples in this research work indicate that they will easily reconstitute to give a fine consistency of dough during mixing.

Gelatinization temperature of all the flour samples investigated fell within the ranged from 60.23 - 62.31^oC. The result shows that sample FPP had the lowest value (60.23 ^oC) while sample FSP had the highest value (62.31 ^oC). There was significant variation between the samples at alpha 0.05. Gelatinization temperature is the temperature at which starch molecules in a food substance lose their structure and leach out from the granules as swollen amylose and it affects the time required for the cooking of food substances [35].

Table 4: Pasting properties of *amala* flour samples

Parameter	FPP	FYP	FSP
Peak	368.63±0.01^b	142.22±0.01^a	333.72±0.01^b
Trough	210.66±0.01^b	136.44±0.01^a	294.35±0.01^c
Breakdown	96.34±0.01^b	21.67±0.01^a	26.77±0.01^c
Final	284.23±0.01^b	182.36±0.01^a	463.24±0.01^c
Setback	102.41±0.01^c	42.88±0.01^a	82.69±0.01^b
Time (min)	4.92±0.01^a	5.62±0.01^c	5.42±0.01^b
Temperature (0C)	83.83±0.01^a	87.33±0.01^c	86.35±0.01^b

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$. Sample FPP - plantain *amala* flour, Sample FYP - yam *amala* flour, Sample FSP - sweetpotato *amala* flour

Pasting properties of *amala* flour samples

The pasting properties of the amala flours are as shown in Table 4. Peak viscosity, which is the maximum viscosity, developed during or soon after the heating portion of the pasting test [36] ranged from 142.22 - 368.63 RVU. Sample FSP had the highest value (333.72 RVU) while sample FYP had the least value (142.22 RVU). The result showed that statistical variation among the samples at alpha 0.05. The variation might be as a result of the method of processing or equipment used for analysis. Peak viscosity is often correlated with the final product quality. It also provides an indication of the viscous load likely to be encountered during mixing [37]. The result obtained in this research work is lower than 414.08 - 511.92 RVU reported by [26]. [8] reported 1783.00 - 3682.00 cP for yam flour which was found to be higher than the value obtained in this research work. The result obtained is similar to the one reported by [38] on chemical and sensory properties of water yam – cassava flour and paste which ranged from 212.00 - 362.07 cP. The result obtained in this research work is in line with the findings of [39] who says higher swelling capacity is indicative of higher peak viscosity while higher solubility, as a result of starch degradation results in paste viscosity reduction [39].

Trough is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand breakdown during cooling [36]. Trough value exist between samples FYP (yam flour) (136.44 RVU) and sample FSP (294.35 RVU). The results are significantly different from each other ($p<0.05$). The different might be as a result of the sample used in this study or the processing method. The result obtained in this study similar to the one recorded by [40] on effect of processing methods on pasting and functional properties of aerial yam (Dioscorea bulbifera) flour which ranged from 16.67cP - 239.17 cP, lower than 276.92 - 325.75 RVU reported by [26]. Trough is period is often associated with a breakdown in viscosity [41] and an indication of breakdown or de-stability of the starch gel during cooking [42]; the lower the value obtained, the more stable the starch gel.

Breakdown viscosity content ranged from 21.67 - 26.77 RVU with sample FSP having the highest value (26.77 RVU) and sample FYP had he least value (21.67 RVU). Results obtained shown that all the samples are significantly different ($p<0.05$). The value obtained in this present work is within the ranged value of breakdown viscosity 5.00 - 30.25 RVU reported by [5] for yam flour. The breakdown viscosity, also referred to as shear thinning is an indication of the ease with which the swollen granules can be disintegrated [43]. The ability of the mixture to withstand heating and the shear stress that is usually encountered during processing is an important factor for many processes, especially those requiring stable paste and low retrogradation or syneresis [44].

The final viscosity of the amala flour ranged from 182.36 - 463.24 RVU for FYP and FSP sample, respectively. FYP sample had the lowest final viscosity (182.36 RVU) while FSP had the highest peak viscosity (463.24 RVU). The result varied significantly at alpha 0.05. The result obtained is not similar to the result recorded by [45] on effect of yam varieties on pasting properties of traditional dry yam which ranged from 55.5 - 378.0 cP and lower to the findings 2464.00 – 4332.50 cP of [8] for yam flour. The difference might be as a result of the processing method or equipment used for the analysis. The peak and final viscosities are considered to be the most important paste viscosity especially with regard to product properties [46]. [47] reported the use of starches with high viscosity value in pharmaceutical companies especially as tablet binders.

The values obtained for setback varied significantly at $P<0.05$. FYP had the lowest setback value (42.88 RVU) while FPP had the highest setback value (102.41 RVU). The values obtained from this study differs from the result recorded by [38] which ranged from 118.75 - 168.96 cP and the value 340.50 - 799.00 cP recorded by [8]. Higher setback value means reduced dough digestibility [39] while lower setback during cooling of paste indicates lower tendency for retrogradation [41].

The peak time is a measure of the cooking time [48]. The peak time of the yam flour varied significantly. The peak time value ranged from 4.92 - 5.62 min. FPP had the lowest peak time (4.92 mins) while FYP had the highest peak time (5.62 mins). The values obtained are similar to the values obtained by [40] on aerial yam flour poundo-yam which ranged from 4.07 - 5.66 mins but lower to 5.10 - 7.03 mins by [8] for yam flour and 7.0 min by [49] on pasting properties of the poundo-yam flour.

The pasting temperature of the flour ranged from 83.83 - 87.33 ^oC. The lowest value (83.33 ^oC) was recorded for FPP while the highest value (87.33 ^oC) was recorded for FYP. The result showed significant difference between the samples ($p<0.05$). The result obtained is similar to that recorded by [40] on aerial yam flour which ranged from 82.45 - 88.25 ^oC and the value 81.35 - 89.10 ^oC reported by [8] for yam flour. The pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured and is an index characterized by the initial change due to the swelling.

Conclusion

Nutritional and functional properties of unripe plantain, white yam and sweet potato flour showed that sample FPP (plantain flour) had the highest value in potassium; sample FYP had the highest value in calcium, sodium, iron while FSP had the highest score in magnesium. Sample produced from sweetpotato had the highest value in total starch and carbohydrate content. The results revealed that all the samples were high in functional and pasting properties when compared with previous research work. This study recommends further investigation on proximate and sensory properties on the variables used in this work. In addition, different pretreatment on the tubers used could be investigated on the use of yam, sweet potato and unripe plantain flour in preparation of *amala* meals/products.

Funding and conflict of interest

There was no direct funding for the research, and authors declare no conflict of interest. The project was self-funded by the authors.

Correspondence address
Akinsola, Akinjide O. PhD
Department of Home Economics
Federal College of Education (Special)
P.M.B. 1089, Oyo, Oyo State, Nigeria.
email: Akinsola.akinjide1333@fcesoyo.edu.ng

References

[1] Oyeyinka, B.O., & Afolayan, A.J. (2019). Comparative evaluation of the nutritive, mineral, and antinutritive composition of Musa sinensis L.(Banana) and Musa paradisiaca L.(Plantain) fruit compartments. *Plants, 8(12)*, P. 598.

[2] Adenekan, M.K., Odunmbaku, L. A., & Lawal, O.A. (2021). Effect of Pre-Treatment Conditions on the Anti-Nutrients of Dried Unripe Plantain (Musa Parasidiaca) and the Application in Dough Making. *International Journal of Advances in Engineering and Management, 3(8)*, 1268–1274.

[3] Alam, M.K. (2021). A comprehensive review of sweet potato (Ipomoea batatas Lam): Revisiting the associated health benefits. *Trends in Food Science and Technology, 115*, 512–529.

[4] Akinsola, A.O., Idowu, O.A., Laniran, A.M., Ojubanire, B.A., & Oke, E.K. (2017). Development, evaluation and sensory quality of orange fleshed sweet potato (*ipomoea batatas* lam) extruded pasta products. *Croatian Journal of Food Technology, Biotechnology and Nutrition, 12*(1-2), 83-89.

[5] Jimoh, K.O., & Olatidoye, O.P. (2009). Evaluation of physic-chemical and Rheological characteristics of soya beans fortified with yam flour. *Journal of Applied Boscience,* 13, 703-706.

[6] Makanjuola, O.M., & Coker, O.J. (2019). Assessment of sensory, functional and pasting properties of different yam cultivar flours subjected to the same processing condition. *GSJ, 7(10)*, 26-32.

[7] Brand-miller, J., Burani, J., & Foster-Powell, K. (2003). The New Glucose Revolution Pocket Guide to the Top 100GI Foods. ISBN 1-56924-500-2.

[8] Oluwamukomi, M.O., & Lawal, O.S. (2020). Textural characteristics of Nigerian foods. *Textural Characteristics of World Foods*, 361–383.

[9] Babalola, J.O., Olakunle, E.J., Elutilo, O.O., Adeoti. O.M., & Adesina, D.A. (2021). Effect of processing methods on functional, pasting properties of flours and sensory evaluation of "*Amala*" made from different yam cultivars. *GSC Advanced Research and Reviews*, 07(1), 123–132. DOI: https://doi.org/10.30574/gscarr.2021.7.1.0006

[10] Babalola, J., Osunrinade, O., Adesina, D., & Oyeniran, D. (2024). Study of quality assessment of flour and *amala* produced from white yam (dioscorea rotundata), unripe plantain (*Musa paradisiacal*) and sweet potato (*Ipomoea batatas*). FEPI-JOPAS 2024:6(1): 23-26 Babalola et.el https://fepi-jopas.federalpolyilaro.edu.ng

[11] Association of Analytical Chemists, AOAC (2010). Official Methods of Analysis of Association of Official Analytical Chemists (18th ed.) Washington DC.

[12] Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T., & Ishii, K. (1972). Whipping and emulsifying properties of soybean products. *Agricultural and Biological Chemistry, 36*, 719-727.

[13] Narayana, K., & Narasinga-Rao, M. (1982)." "Functional properties of raw and heat processed winged bean (Psophocarpus tetragonolobus) flour". *Journal of Food Science, 47*, 1534-1538.

[14] Ukpabi, U., & Ndimele, C. (1990). "Evaluation of the quality of gari produced in Imo State," *Nigerian Food Journal, 8,* 105-110.

[15] Kulkarni, K.D., Kulkarni, D., & Ingle, U. (1991)."Sorghum malt-based weaning food formulations: Preparation, functional properties, and nutritive value". *Food and Nutrition Bulletin, 13*, pp. 17.

[16] Shinde, B.G. (2001). "Isolation and characterization of starch horse grain."

Rahuri (India)," Unpublished M.Sc Thesis, Mahatma Phule Krishi Vidyapeeth.

[17] Akinsola, A., Segilola, V., Oloso, S. & Durojaiye, O. (2018). Quality evaluation of plantain-African yam bean flour blends and sensory properties of its cooked (amala) paste. *Research Journal Food Science and Nutrition*, *3*, 31-40.

[18] American Association of Cereal Chemists, AACC (2000). Approved Methods of the American Association of Cereal Chemists. Official Methods of Analysis. 10th Edition, AACC International, USA, St. Paul, MN, 54-21 (1).

[19] World Health Organization, Food and Agriculture Organization of the United Nations. (2004). Vitamin and mineral requirements in human nutrition. 2nd ed. Report of a joint FAO/WHO expert consultation. Bangkok: FAO/WHO.

[20] World Health Organization (2004). Global strategy on diet, physical activity and health. Obesity and overweight. 57th Health Assembly. Provisional Agenda, Item 12.6. A57/9.

[21] Ha, S.K. (2014) Dietary salt intake and hypertension. *Electrolyte Blood Pressure, 12*, 7-18.

[22] Whelton, P.K., He, J. (2014). Health effects of sodium and potassium in humans. *Current Opinion in Lipidology 25*, 7579.

[23] Carriaga, T.M., Skikne, B.S., Finley, B., Cutler, B., & Cook, J. (1991). Serum transferring receptor for the detection of iron deficiency in pregnancy. *American Journal of Clinical Nutrition*, *54*, 1077- 1081.

[24] Idowu, O.A., Olaoye, O.A. Sogotemi, C.M., & Ajayi, B. (2013). Quality assessment of flours and *amala* produced from three varieties of sweet potato (*Ipomea batatas)*. *International Journal of Food and Nutritional Sciences, 2(4)*, 23 – 34.

[25] Cuevas, R.K., & Fitzgerald, M. (2007). Linking starch structure to rice cooking quality. *IREC Farmer's Newsletter*, *177*, 1-8.

[26] Vikuson, O.E. (2017). Effects of varying temperature on physicochemical, pasting and sensory properties of plantain flour. *Global Journal of Food Science and Technology*, *5(2)*, 237-242.

[27] Ilelaboye, N.O., & Ogunsina, T.I. (2018). Proximate Composition, Functional Properties and Sensory Evaluation of Stiff Dough (*Amala*) Prepared from Okara Fortified Plantain-Sorghum Flours. *Asian Food Science Journal*, *5(1)*, 1-10.

[28] Ukom, A.N., Richard, C.P., & Abasiekong, S.K. (2018). Effect of processing on the proximate, functional and anti-nutritional properties of cocoyam (Xanthosoma Maffa) flour. *Nigerian Food Journal*, *35(2)*, 9–17.

[29] 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)*, 28-39.

[30] 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.

[31] Cornejo-Ramírez, Y.I., Martínez-Cruz, O., Del-ToroSánchez, C.L., Wong-Corral, F.J., BorboaFlores, J., & Cinco-Moroyoqui, F.J. (2018). The structural characteristics of starches and their functional properties. *CyTA-Journal of Food*, *16(1)*, 1003–1017.

[32] Abioye, V.F., Olodude, O.A., & Akinwande B.A. (2022). Chemical Composition, Nutritional, Functional and Pasting Properties of Yellow Root Cassava Grits and African Yam Bean Flour Blends. *International Journal of Food Studies, 11*, 71–84.

[33] Wahab, B.A., Adebowale, A.A., Sanni, S.A., Sobukola, O.P., Obadina, A.O., Kajihausa, O.E., Adegunwa, M.O., Sanni L.O., & Tomlins, K. (2016). Effect of species, pretreatments, and drying methods on the functional and pasting properties of highquality yam flour. *Food Sci. Nutr. 4(1*, 50-58.

[34] Adebowale, A.A., Sanni, L.O., & Onitilo, M.O. (2008). Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. *Afr. J. Food Sci.*, *2*, 77-82.

[35] Eleazu, O.C., Eleazu, K.C., Kolawole, S. (2014). Use of indigenous technology for the production of high quality cassava flour with similar food qualities as wheat flour. *Acta Sci Pol Technol Aliment, 13*, 249-256.

[36] Newport Scientific (1998). Applications manual for the Rapid visco analyzer using thermocline for windows. Newport Scientific Pty Ltd., 1/2 Apollo Street, Warriewood NSW 2102, Australia, 2-26.

[37] Maziya-Dixon, B., Dixon, A.G.O., & Adebowale, A.A. (2004, October 31-November 5). Targeting different end uses of cassava: genotypic variations for cyanogenic potentials and pasting properties. A paper presented at ISTRC-AB Symposium, Whitesands Hotel, Mombassa, Kenya.

[38] Babajide, J.M., & Olowe, S. (2013). Chemical functional and sensory properties of water yam-cassava flour and its paste. *International Food Research Journal, 20(2),* 902-909.

[39] Shittu, T.A., Lasekan, O.O., Sanni, L.O., & Oladosu, M.O. (2001). The effect of drying methods on the functional and sensory characteristics of pukurua fermented cassava product. *ASSET-An Int. J. A., 1(2),* 9-16.

[40] Princewill-Ogbonna, I.L., & Ezembaukwu, N.C. (2015). Effect of various processing methods on the pasting and functional properties of Aerial yam (Dioscorea bulbifera) flour. *British Journal of Applied Science and Tech., 9(5),* 517-526.

[41] Ragaee, S., & Abdel-Aal, E.M. (2016). Pasting properties of starch and protein in selected cereals and quality of their food products. *J. Food Chem.*, 9-18.

[42] Zaidhul, I.S.M., Hiroaki, Y., Sunju, K., Naoto, H., Takahiro, N. (2006). RVA study of mixture of wheat flour and potato starches with different phosphorus contents. *Food Chemistry*, 6, Pp. 56.

[43] Yadav, D.N., Anand, T., Kaur, J., & Singh, K. (2012). Improved storage stability of pearl millet through microwave treatment. *Agricultural Research, 1(4),* 399-404.

[44] Sanni, L.O., Adebowale, A.A., Awoyale, W., & Fetuga, G.O. (2008). Quality of garri (roasted cassava mash) in Lagos State, Nigeria. *Nigerian Food J., 26(1),* 125-134.

[45] Babajide, J.M., Henshaw, F.O., & Oyewole, O.B. (2008). Effect of yam variety on the pasting properties and sensory attribute of traditional dry-yam and its product. *Journal of Food Quality*. 295-305.

[46] Akissoe, N.H., Hounhouigan, J.D., Mestres, C., Nago, M. (2003). How blanching and drying affects the colour and functional and functional characteristics of yam (D. cayenensis-rotundata) flours. *Food Chemistry, 82*, 257-264.

[47] Brooks, M.A., & Schitzsaci, U. (1999). Food Science and technology, *Abstracts Int'l. Food into serves (IFIS), 4(70),* 67.

[48] Adebowale, A.A., Sanni, L.O., & Awonorin, S.O. (2005). Effect of texture modifiers on the physiochemical and sensory properties of dried fufu. *Food Science and Technology International Journal, 11(5),* 373-382.

[49] Oluwamukomi, M.O., & Adeyemi, A.O. (2015). Physicochemical, Pasting and Sensory properties of "Poundo-yam" enriched with defatted soy flour. *J. Applied Tropical Agriculture, 20(1),* 89-95.