STUDY OF QUALITY ASSESSMENT OF FLOUR AND AMALA PRODUCED FROM WHITE YAM (*DIOSCOREA ROTUNDATA*), UNRIPE PLANTAIN (*MUSA PARADISIACA*) AND SWEET POTATO (*IPOMOEA BATATAS*)

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ABSTRACT
Traditionally to the Nigerian southwestern culture, amala is exclusively obtained from yam or cassava flours. Enhancing the availability of amala and making different varieties available to consumers, will require the comparison of amala produced from other sources. Therefore, yam, unripe plantain and sweet potato flours were produced using standard methods, and subjected to analysis for their proximate composition, functional properties, and pasting characteristics. Amala produced from the flours using the standard method was sensorially evaluated by 30 member panellists using a 9-point hedonic scale. The proximate values of flour samples were moisture content (7.26-8.38%), protein (4.33-5.13%), fat (2.56-4.10%), fibre (2.56-4.10), ash (1.36-3.04%), and carbohydrate (73.75-81.36), with energy ranging from 302.10 to 311.40kcals, respectively. Functional analysis revealed varying bulk density, swelling capacity, and water absorption index, ranging from 0.45 to 0.59 g/cm^3, 1.35 to 1.71 g/cm^3, and 2.34 to 6.93 g/cm^3, respectively. The peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature ranged from 4315.50 to 6613.00 cP, 2786.00 to 4385.00 cP, 45.00 to3827.00 cP, 3926.50 to 6474.5 cP, and 4.13 to 6.93 minutes, respectively. All amala samples produced received high likeness ratings in all sensory attributes while the overall likeness was for unripe plantain amala. Considering, the comparative nutritional and sensory properties of all flour samples studied, the utilisation of yam, unripe plantain and orange-fleshed sweet potato flours for amala preparation would provide variety and enhance food security.

Keywords: Amala, sweet potato, plantain, pasting, sensory

1.0 INTRODUCTION

Amala, a traditional Nigerian dish, is a gelatinised product usually produced from yam flour (CF) or other flours from fermented and sundried yam tubers; and is widely consumed in the Western part of Nigeria. Amala preparation from yam or cassava flour involves reconstituting the flour in boiling water until a stiff smooth paste is formed(Oluwamukomi & Lawal, 2020). A wide variety of roots and tubers plays a major role in the human diet (Chandrasekara, 2018), however, amala's large consumer base due to their cultural attachment has necessitated the need to evaluate alternatives that can serve food security purposes and nutritionally adequate composition.

Sweet potato remains an underutilized crop because its cultivation to harvest is a short period of about four months and the dry matter yield is high(Osunrinade et al., 2023). As such, 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(Alam, 2021). Sweet potatoes are vegetable crops which have been grossly underutilised in Nigeria, and therefore efforts at promoting their utilisation are being continuously researched. Nutritional profiling of sweet potato showed that it is rich in vitamins B6 and C, beta carotene and dietary fibre (Jenfa et al., 2024).

Plantain (*Musa paradisiacae*) serves as a significant carbohydrate source in various regions of Africa, Asia, and South America (Oyeyinka & Afolayan, 2019). 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 a quality stiff dough known as amala (Adenekan et al., 2021). Unripe plantain has been reported to be used for amala preparation, especially for diabetic patients(Ajiboye & Shodehinde, 2022). However, a comparative assessment of its stiff dough has not been compared with other sources of flour samples used to produce amala.

Traditionally to the Nigerian southwestern culture, amala is exclusively obtained from yam or cassava flours(Oluwamukomi & Lawal, 2020), there is a need to explore other sources such as unripe plantain and sweet potato to compare with the commonly used raw materials (yam). 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 proximate analysis, evaluating functional properties, and ultimately preparing amala from these flours to assess their sensory attributes.

2.0 Materials and Methods

2.1 Raw material and source of procurement.

Freshly harvested samples of sweet potato and unripe plantain fruits were sourced from the Oke-Ogun Polytechnic farm community in Saki, Oyo State, Nigeria. Botanical identification was conducted at the International Institute of Tropical Agriculture (IITA) in Ibadan, Oyo State, Nigeria. Subsequent processing of the samples was carried out at the Food Science Technology laboratory of The Oke-Ogun Polytechnic, Saki (TOPS).

2.2 Samples preparation

2.2.1 Preparation of sweet potato and yam flour.

Fresh roots of flesh sweet potato and yam, 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, and sliced into water containing 0.01% sodium metabisulphite, where they were left to soak for approximately 10 minutes. Following this, the slices were sun-dried for a week. The dried chips were milled into flour. The flour samples were passed through a sieve of 200 µm mesh size to obtain fine consistency (Osunrinade et al., 2023**)**. Finally, the flour was carefully packed into airtight plastic packages and stored at ambient temperature for further analysis and preparation of amala for sensory evaluation.

2.2.2 Preparation of unripe plantain flour.

The plantain fruits were carefully separated from their bunches, 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, labelled, and stored at ambient conditions for future use.

2.3 Analytical method.

2.3.1 Determination of proximate composition of flour
The ash, crude fat, crude fibre, moisture, and protein contents were analysed using the standard methods outlined in AOAC (2005)by the Association of Analytical Chemists. Carbohydrate content was determined by the difference method, wherein the sum of ash, fat, protein, crude fibre, and moisture contents was subtracted from 100. Additionally, the energy value (in kcals) was calculated using factors of 2.44, 8.37, and 3.47 to multiply the percentages of crude protein, crude lipid, and carbohydrate, respectively, following the methodology specified for vegetable analysis (Ijarotimi et al., 2013).

2.3.2 Determination of functional properties of flour

Bulk density was determined following the procedure outlined by Agume Ntso et al.(2017), while water absorption capacity was assessed using the method detailed by Chandra et al. **(**2015**)**. For the determination of oil absorption properties, the method described by Joshi et al. (2015) was employed. Additionally, the swelling index of flour samples was determined according to the method outlined by (Tharise et al., 2014)

2.3.3Flour pasting property determination

Pasting properties were determined using a rapid visco-analyser (RVA). Initially, 2.5g of the flour was precisely weighed into a dried empty canister. Subsequently, 25 ml of distilled water was dispensed into the sample canister, and the suspension was thoroughly mixed. The canister was then fitted into the rapid visco-analyser. Each suspension underwent a temperature regime starting at 50°C for 1 minute, followed by heating up to 95°C at a rate of 12.2°C per minute, and held at 95°C for 2.5 minutes. Subsequently, it was cooled to 50°C at a rate of 11.8°C per minute and maintained at 50°C for 2 minutes.

2.3.4 Sensory Evaluation.

The sensory characteristics of the amala samples produced from flour samples were assessed by a panel of thirty semi-trained panellists. Before the evaluation process, all panellists received a briefing outlining the sensory attributes to be evaluated, including appearance, taste, texture, flavour, and overall acceptability. A nine-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) was used for rating. It's worth noting that all panellists were regular consumers of amala and water was provided to rinse the mouth between evaluations.

3.0 RESULTS AND DISCUSSION

3.1 Proximate analysis of potato flour, plantain flour and yam flour.

The moisture content of each sample ranged from 7.26 to 8.38%, with significant differences observed among them at *p*<0.05. This falls within the maximum level of 10% recommended for flour and flakes indicating favourable storage conditions (Sujitha et al., 2018). Regarding protein content, results ranged from 3.13 to 4.83%, showing significant differences among the samples (Table 1). Sample 532 exhibited a significantly higher value than the average content of 2% for plantain flour, while sample 352's value surpassed the typical 1.5%. The crude fibre composition varied from 2.43 to 4.10% and showed significant differences among the samples. Dietary fibre is known to reduce the risk of cardiovascular diseases, with increased consumption contributing to a decline in the incidence of conditions such as diabetes, coronary heart disease, colon cancer, and various digestive disorders (Reynolds et al., 2022)

Ash content ranged from 3.02 to 3.78%, with all three samples significantly differing at p<0.05. This indicates that the samples could serve as good sources of nutritionally essential minerals and trace elements. All samples exhibited high carbohydrate content values ranging from 73.27 to 75.50%. This is typical of root and tuber crops, which are naturally rich in carbohydrates compared to other crops. Sample 352 had the lowest energy value at 302.10 kcal, while samples 532 and 523 had 306.48 and 311.40 kcal, respectively.

Table 1: Result for the proximate analysis of potato flour, plantain flour and yam flour

Sample code	Moisture Content(%)	Crude protein(%)	Crude fat(%)	Crude fiber(%)	Total ash(%)	Carbohydrate (%)	Energy value (kcal)
352	$7.26^{c}\pm 0.07$	$5.13^{a}\pm 0.06$	$3.77^{b}\pm0.31$	$3.13^{b}\pm0.24$	$1.36^{c}\pm0.08$	$81.36^{a}\pm0.49$	302.10 ± 0.15
532	$8.38^{a}\pm 0.10$	$4.83^{b}\pm 0.06$	$2.56^{c}\pm0.04$	$2.43^{c}\pm0.13$	$3.04^{a}\pm0.12$	$73.75^{b}\pm0.10$	306.48 ± 0.03
523	$7.74^{b}\pm 0.30$	$4.33^{c}\pm 0.21$	$3.87^{a}\pm0.25$	$4.10^{a}\pm0.18$	$2.61^{b}\pm0.02$	$77.36^{c}\pm0.81$	311.40 ± 0.01

*Values are Means±StandardDeviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different (p< 0.05).
Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

3.2 Functional properties of flours of yam, plantain and orange-fleshed sweet potato

The functional properties of yam, plantain and orange-fleshed sweet potatoflour derived from various cultivars are presented in Table 2.The bulk density (g/cm^3) of the yam flour, potato flour, and plantain flour exhibited significant variation (p<0.05). Ranging from 0.45 to 0.59 g/cm^3, the bulk density of the flour samples plays a crucial role in determining packaging requirements, material handling, and application in the wet-processing food industry (Km & Veteran, 2021). Flour with lower bulk density offers advantages in bulk storage and transportation.

Water absorption capacity (WAC), which measures the flour's ability to retain water, significantly differed among the produced flours. The WAC ranged from 2.34 to 6.93 g/cm^3, this property influences the flour's ability to form a paste and impacts physicochemical properties in various food products such as soup, dough, and baked goods (Awuchi et al., 2019). 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 (Cornejo-Ramírez et al., 2018)

The swelling index of the flours varied significantly (p<0.05), with results ranging from 1.35 to 1.71 g/cm^3. Sample 523 exhibited the lowest swelling index (1.35 g/cm^3), while the highest was recorded for sample 532. This aligns with findings reported by Ukom et al.(2018), on the effect of processing on cocoyam flour which ranged from 1.26 to 2.00 g/ml. 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 (Awuchi et al., 2019). Therefore, higher swelling power implies higher associative forces.

Table 2: Result for the Functional Properties of the flour

Sample code	Bulk density(g/cm^3)	Swelling capacity(g/cm^3)	Water absorption index (g/cm^3)
352	$0.59^a \pm 0.01$s	$1.47^b \pm 0.01$	$2.34^c \pm 0.01$
532	$0.45^c \pm 0.01$	$1.71^a \pm 0.01$	$6.93^a \pm 0.15$
523	$0.50^b \pm 0.01$	$1.35^c \pm 0.01$	$4.89^b \pm 0.01$

*Values are Means ± standard deviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different (p< 0.05).Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

3.3Sensory Evaluation

The sensory evaluation results are summarized in Table 4. sample 532 (plantain flour) received the highest ratings across all parameters, indicating superior sensory characteristics. Notably, sample 532 was particularly favoured for its colour, with significantly higher ratings compared to the other samples. Conversely, sample 523 received the lowest rating for colour, likely due to the darkness of the 'amala' attributed to the yam variety used.

Regarding taste, panellists showed a preference for sample 532 (plantain flour 'amala') over the other samples, with significant differences observed only for this sample. The processing method and cultivar type likely influenced these variations.Texture ratings for the 'amala' ranged from 8.20 to 7.40, while sample 532 consistently received the highest ratings. While no significant difference was observed between samples 352 and 523, sample 532 stood out for its superior texture.

In terms of overall acceptability, sample 532 (plantain flour) emerged as the preferred choice, receiving the highest rating. Samples 352 and 523 were not significantly different from each other, both receiving favourable ratings.

Table3: Sensory EvaluationAmala Samples

Sample code	Appearance	Colour	Taste	Texture	Overall
352	$7.70^a \pm 1.26$	$7.20^b \pm 1.24$	$7.75^a \pm 1.02$	$7.40^a \pm 1.19$	$7.60^a \pm 1.35$
532	$7.90^a \pm 1.07$	$8.05^a \pm 0.89$	$7.95^a \pm 1.36$	$8.20^a \pm 0.95$	$8.35^a \pm 0.88$
523	$7.15^a \pm 1.53$	$6.80^b \pm 1.58$	$7.55^a \pm 1.61$	$7.50^a \pm 1.47$	$7.70^a \pm 1.17$

Values are mean ± standard deviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different (p< 0.05).Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

4.0 Conclusion

Since 'Amala' from yam were the commonly accepted one, the research work 'Amala' made from plantain and sweet potato has no significant difference in the nutritional compositions, functional properties and sensory evaluation. Plantain and sweet potato were generally underutilized in this part of the world but were beneficial for individuals with diabetes, offering comparable functionality to yam flour ('amala'), a commonly consumed staple. Notably, the presence of fibres in sweet potatoes offers various health benefits, including a reduced risk of diabetes and improved gut health. Therefore, incorporating these flours into diets can contribute to overall health and well-being, especially for individuals managing diabetes or seeking to enhance their dietary fibre intake.

REFERENCES

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 (IJAEM), 3*(8), 1268–1274.

Agume Ntso, A. S., Njintang, Y. N., & Mbofung, C. M. F. (2017). Physicochemical and pasting properties of maize flour as a function of the interactive effect of natural-fermentation and roasting.

Journal of Food Measurement and Characterization, *11*, 451–459.

Ajiboye, A. O., & Shodehinde, S. A. (2022). Diet supplemented with boiled unripe plantain (Musa paradisiaca) exhibited antidiabetic potentials in streptozotocin-induced Wistar rats. *Journal of Food Biochemistry*, *46*(12), e14431.

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

AOAC. (2005). *Official method of Analysis*. (18th ed.). Association of Official Analytical Chemists, Washington DC.

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.

Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*, *52*, 3681–3688.

Chandrasekara, A. (2018). Roots and tubers as functional foods. *Bioactive Molecules in Food. Reference Series in Phytochemistry. Springer, Cham. 10*, 978–3.

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

Jenfa, M. D., Adelusi, O. A., Aderinoye, A., Coker, O. J., Martins, I. E., & Obadina, O. A. (2024). Physicochemical compositions, nutritional and functional properties, and color qualities of sorghum–orange-fleshed sweet potato composite flour. *Food Science & Nutrition*, *12*(4), 2364–2378.

Joshi, A. U., Liu, C., & Sathe, S. K. (2015). Functional properties of select seed flours. *LWT-Food Science and Technology*, *60*(1), 325–331.

Km, R. K., & Veteran, J. (2021). The physicochemical properties of white sorghum (Sorghum bicolor L.) flour in various particle sizes by soaking the seeds before and after dehulling. *Food Research*, *5*(3), 129–143.

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

Osunrinade, O., Phillips, A., & Alabi, A. (2023). Physical properties, proximate composition and sensory acceptability of gluten-free cookies from sweet potato using shea butter as shortening. *Acta Periodica Technologica*, *54*, 165–175. https://doi.org/10.2298/APT2354165O

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), 598.

Reynolds, A. N., Akerman, A., Kumar, S., Diep Pham, H. T., Coffey, S., & Mann, J. (2022). Dietary fibre in hypertension and cardiovascular disease management: Systematic review and meta-analyses. *BMC Medicine*, *20*(1), 139.

Sujitha, J., Muneer, M. R., Mahendran, T., & Kiruthiga, B. (2018). *Influence of storage temperature on the quality parameters of wheat flour during short-term storage*.

Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *International Food Research Journal*, *21*(4).

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 (Scoth)) flour. *Nigerian Food Journal*, *35*(2), 9–17.