COMPARATIVE STUDY OF NUTRITIONAL COMPOSITION, FUNCTIONAL, PASTRY AND ORGANOLEPTIC EVALUATION OF AMALA (FLOUR MEAL) FROM PLAINTAIN, COCOYAM, IRISH AND SWEET POTATO.

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Abstract

Instant flour from the different proportions of cocoyam, irish potato, sweet potato, and plantain was produced. Comparative studies were conducted on nutritional composition, functional, pastry properties and organoleptic evaluation of amala using standard analytical methods. From the results, moisture content ranged from 4.87 - 7.09%, ash (0.90–0.94%), fat (0.69–4.86%), protein (1.82–4.80%), fibre (0.12–0.95%), carbohydrates (55.59–84.86%).The bulk density ranges from (0.61–0.86g/cm3), Water absorption capacity ranged from 1.05 -1.93%,Oil absorption capacity (AOC) (1.11 - 1.31g/ml) & swelling power (1.14 - 1.7g/g).Peak viscosity value obtained ranges from (536.00 - 3866.00 RVU), Trough (532.00 - 3274.00RVU), Breakdown (4.00 - 592.00RVU), Setback (157.00 - 789.50RVU), Final viscosity (689.00–3904.00 RVU), Peak time (5.97 - 6.60mins) and Pasting temperature (73.93-86.30°C). Sensory attributes were carried out on general acceptability of the flour sample to determine the optimum quality of the results. Cocoyam and plantain flours emerged as promising choices, having higher functional and nutritional benefits that can prove advantageous for both household and industrial production activities.

Keywords: *Amala, viscosity, functional, pastry, sensory.*

Introduction

In Nigeria, amala stands as a substantial paste crafted from sun-dried and fermented sweet potatoes, cassava, or yam flour. The description offered by Abiodun and Akinoso (2014) characterizes amala as a dense gel or rigid dough, typically hailing from yam (Dioscorea spp) flour. The process involves reconstituting yam flour in hot water until it transforms into a smooth, dark-hued paste. As noted by Karim et al. (2013), a similar paste with a paler complexion can be produced using fermented cassava flour. Predominantly savored in Nigeria's southwestern regions and certain parts of Ghana, amala is recognized as Kokonte in these areas (Abiodun & Akinoso, 2014; Jimoh & Olatidoye, 2009).

Over 95% of the global sweet potato production transpires within developing nations (Fatuga et al., 2013). In this context, Nigeria takes the lead as Africa's primary and the world's second-largest sweet potato producer (Lebot, 2009), emphasizing its focus on bolstering food security (Minde et al., 1999). The insufficiency of essential micronutrients is emerging as a pressing public health concern across developing countries, with a particular impact on women and young children (UN SCN, 2004). Addressing this challenge, the orange-fleshed sweet potato emerges as a promising solution due to its elevated levels of β-carotene and ascorbic acid, particularly crucial for combating deficiencies. Recognized as a nutrient-rich crop, the orange-fleshed sweet potato harbors a variety of natural compounds that promote health (Bovell-Benjamin, 2007). However, it's essential to note that processing procedures can lead to nutrient depletion. Previous research highlights that modifications to processing techniques can result in mitigated nutrient loss, reinforcing the need for strategic approaches.

Plantain (Musa paradisiacae), a foundational source of carbohydrates, holds sway as a dietary cornerstone in numerous regions across Africa, Asia, and South America (Falade & Olugbuyi, 2010). Esteemed for its rich vitamin and mineral content, plantain flour can stand alone or meld harmoniously with yam flour, culminating in the creation of a resilient dough colloquially known as amala (Abulude & Ojediran, 2006). Meanwhile, potatoes (Solanum tuberosum L.) have been progressively assuming a more substantial role in bolstering food supplies within economically challenged nations (Okello et al., 2016). The potent combination of high potato productivity and cost-effectiveness positions it as an ideal counterpart to maize, which often shoulders the burden of being the primary staple crop. Beyond their pivotal role in ensuring food security, potatoes also radiate potential for profitable commercial applications. From consuming raw tubers to processing them into culinary delights like French fries, potatoes offer a versatile palette. The art of processing bestows added value upon potatoes, prolongs their shelf life, introduces convenience, mitigates post-harvest losses and waste, and births an array of diverse products tailored to multifarious needs (Gikundi et al., 2021).

Hence, endeavors are actively underway to enhance the nutritional profile of such staple foods through the incorporation of legumes and other plant-based sources rich in protein. Awoyale et al. (2010) highlight that introducing 35% distillers waste grain into yam flour yielded a remarkable protein content increase of over 100%. Correspondingly, Jimoh and Olatidoye (2009) revealed that augmenting yam flour with 30% soybean flour elevated protein levels from 3.16% to an impressive 18.21%. The burgeoning awareness among consumers regarding the intricate interplay between food, health, and nutrition has sparked a surge in the pursuit of edibles featuring functional constituents, particularly those sourced from plants. Nevertheless, it is imperative to recognize that the incorporation of fortifying agents into foods has the potential to reshape the composition and utility of the end product. Consequently, this study delves into an exploration of the nutritional content, functional attributes, pasting characteristics, and sensory attributes of amala derived from yam, plantain, and cocoyam flour.

Materials & methods

Raw material and source of procurement

Fresh samples of sweet potato, cocoyam, and unripe plantain were gathered from the agricultural community of The Oke Ogun Polytechnic farm in Saki, Oyo State, Nigeria. Irish potato was procured from the local commercial market. Precise botanical verification was performed at the International Institute of Tropical Agriculture (IITA) located in Ibadan, Oyo State, Nigeria. Subsequent processing of these samples took place within the Food Science and Technology Laboratory of The Oke-Ogun Polytechnic, Saki (TOPS).

Samples preparation

Preparation of irish potato, sweet potato and cocoyam flour

The process employed to produce flour from Irish potato, sweet potato, and cocoyam is illustrated in Figure 1.0. Starting with fresh sweet potato and cocoyam free from any signs of infection or infestation, a thorough wash was carried out under running tap water to eliminate adhering soil, dirt, and dust. Following this, the tubers underwent peeling, washing, and subsequent slicing into pieces that were immersed in water containing sodium metabisulphite, with an immersion period of approximately 10 minutes, followed by sun-drying. After a week of drying, the resulting dried chips of Irish potato, sweet potato, and cocoyam were each individually subjected to milling, producing flour. This flour was subsequently sieved to achieve a fine consistency before being packaged in distinct air-tight plastic containers.

Preparation of unripe plantain flour

The production of unripe plantain flour followed the process depicted in Figure 2.0. Commencing with the plantain fruit, it was extracted from its clusters, subjected to a thorough cleansing with clean water, and subsequently peeled using a sharp knife. The peeled plantain was then sliced to an average thickness of around 1cm. These slices were arranged on a tray and left to sun-dry. Upon completion of the drying process, the dried plantain was subjected to milling via a hammer mill, and the resultant product was passed through a mesh to attain a fine consistency. The fine flour was then meticulously packaged within an air-tight plastic container, appropriately labeled, and stowed for storage.

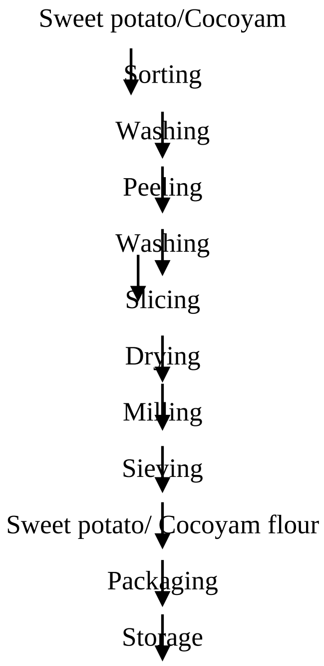

Figure 1.0 Flowchart for sweet potato/ cocoyam flour preparation

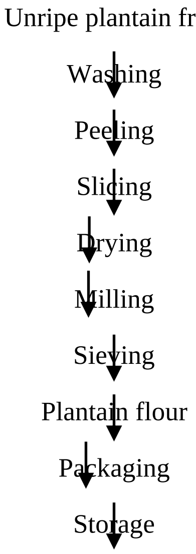

Figure 2.0: Flowchart for Plantain flour preparation

Analytical method of flour samples

Determination of the proximate composition of flour samples

The levels of Ash, Crude fat, crude fiber, moisture, and protein in the flours were ascertained utilizing the methods outlined in the AOAC (2005) guidelines established by the Association of Analytical Chemists. Carbohydrate content was deduced through the method of difference, involving subtracting the summation of ash, fat, protein, crude fiber, and moisture contents from 100. The Energy value, expressed in kilocalories (kcals), was computed using multiplication factors of 2.44, 8.37, and 3.47, applied to the percentages of crude protein, crude lipid, and carbohydrate, respectively. These factors, conforming to vegetable analysis conventions, were detailed in previous work by Ijarotimi et al. (2013).

Determination of functional properties of flour samples

Bulk density was evaluated following the procedure outlined by Mbofung et al. (2006). Water absorption capacity was determined utilizing the method established by Sosulski et al. (1976), and for oil absorption properties, the method introduced by Sathe et al. (1981) was adopted. Additionally, the swelling index of the flour samples was assessed following the methodology elucidated by Tharise et al. (2014).

Determination of Pasting properties of flour samples

The pasting characteristics were assessed using a rapid visco analyser. To initiate the process, 2.5g of the flour was meticulously weighed and deposited within a pre-dried empty canister. Subsequently, 25 ml of distilled water was introduced into the canister containing the flour sample. Following a thorough blending of the suspension, the canister was positioned within the rapid visco analyser. The suspension was subjected to an initial maintenance at 50°C for a duration of 1 minute, subsequently undergoing heating at a rate of 12.2°C per minute until reaching 95°C. Upon attaining 95°C, the system was maintained at this temperature for 2.5 minutes. The next step encompassed a cooling phase, wherein the suspension was brought down to 50°C at a cooling rate of 11.8°C per minute and held at 50°C for a period of 2 minutes.

Sensory Evaluation of stiff porridge (Amala) from flour Samples

Fifteen semi-trained panelists participated in the sensory evaluation of the flour transformed into firm porridge (amala). Each panelist assessed various sensory attributes. Prior to the evaluation, all panelists received a briefing to ensure consistent understanding. The evaluated sensory criteria included appearance, taste, texture, crispiness, flavor, and overall acceptability. Ratings were provided on a hedonic scale spanning nine points, ranging from 9 (very liked) to 1 (strongly disliked), as described by Ihekoronye & Ngody (1985). All panelists were regular consumers of amala, and between assessments, they were provided with water to cleanse their palates.

Results and Discussion

Proximate composition of flour samples

The moisture content of the flour samples exhibited a range from 4.87% to 7.09%, displaying statistically significant differences ($p<0.05$). Sample CCY (comprising 100% cocoyam flour) showcased the highest moisture content at 7.09%, while the SWIR sample (consisting of equal parts Irish potato and sweet potato) displayed the lowest value. Notably, both sample PL (100% plantain flour) and sample IR (100% Irish potato flour) yielded an identical moisture content of 6.54%. This measurement for cocoyam surpassed the value reported by Ajewole (2004) for the Zanthosoma variety, potentially attributed to variations in chemical composition across different varieties and drying methods. Significantly, all flour samples exhibited moisture content below 10%, a guideline deemed safe for the storage of flour samples. This signifies a favorable shelf life for the flour samples. The moisture content of a food item significantly impacts factors such as shelf life, packaging, and overall consumer acceptance (Okaka & Okaka, 2001; Obiegbuna et al., 2014).

Fat contributes both flavor and a supple texture to food. However, elevated fat content can lead to undesired outcomes, such as rancidity. Among the samples, the highest fat content was observed in IR (100% Irish potato flour) at 4.86%, followed by cocoyam flour at 3.85%. Sweet potato flour and its substituted variants displayed lower fat content. Sample PL (100% plantain flour) exhibited the lowest fat content. Notably, sweet potato flour's fat content of 2.29% significantly contrasts with the 4.34% reported by Makanjuola et al. (2017). Falling within the range of 0.69% to 4.86%, the crude fat content observed in these instant flours aligns favorably with product preferences, as fat constitutes a substantial portion of the body's required caloric intake (Smith and Ojofeitimi, 1995).

Crude fibers, classified as non-starchy polysaccharides, elude digestion and absorption in the stomach. Instead, they play a pivotal role in promoting regular bowel movements, mitigating constipation, and contributing to blood pressure regulation, as reported by SFGATE (2017a). Examining the flour samples, the highest crude fiber content (0.95%) was observed in cocoyam flour and the sweet potato-cocoyam flour composite. Following closely, irish potato flour registered a crude fiber content of 0.93%. In stark contrast, the irish-sweet potato flour composite displayed the lowest value at 0.12%. Remarkably, the fiber content of these flour samples remained within the recommended threshold of not surpassing 5 g dietary fiber per 100g of dry matter, in accordance with FAO guidelines (2004). Noteworthy health benefits accompany the consumption of fiber-rich foods, including a diminished risk of diabetes, cardiovascular ailments, constipation, appendicitis, hemorrhoids, and colon cancer, as highlighted by Ekwe et al. (2009) and Chugh et al. (2013).

Ash content serves as a reflection of mineral content, although it's important to note that contamination can also influence readings by artificially elevating concentrations in a sample. Across the flour samples, the ash content spanned from 0.90% to 0.94%. Notably, the lowest value emerged in both plantain flour and sweet potato-cocoyam flour at 0.90%, while cocoyam flour exhibited the highest ash content. Sweet potato and irish potato shared an identical ash percentage of 0.91%. Worth mentioning, the ash content for plantain flour deviated from the 1.93% reported by Abioye et al. (2011).

The protein content found within the instant flour samples encompassed a range extending from 1.82% to 4.80%. Notably, sweet potato-cocoyam flour exhibited the highest protein content at 4.80%, which surpassed the protein content of plain sweet potato flour. This elevation could be attributed to the incorporation of cocoyam flour. In contrast, sweet potato flour exhibited the lowest protein content (1.82%), followed by irish-sweet potato flour (1.87%). The protein content for plantain flour (2.00%) aligned with the value (2.54%) reported by Abioye et al. (2011). Additionally, the protein content observed for cocoyam flour (2.77%) exceeded the value (2.50%) documented by Oluwamukomi et al. (2015).

Table 1.0 : Proximate composition of Sweet potato, cocoyam, plantain, irish potato flour

Sample	Moisture	Fat	Protein	Fibre	Ash	CHO	Energy value
SWP	5.64 ± 0.65^{ab}	2.29 ± 0.44^{d}	1.82 ± 0.09^{c}	0.53 ± 0.03^{c}	0.91 ± 0.01^{a}	78.82 ± 0.26^{b}	297.13±0.01
PLT	6.54 ± 0.45^{a}	0.69 ± 0.05^{e}	2.00 ± 1.26^{b}	0.85 ± 0.01^{b}	0.90 ± 0.03^{a}	70.03 ± 1.70^{c}	253.59±0.01
SWIR	4.87 ± 1.07^{b}	2.65 ± 0.81^{b}	1.87 ± 0.50^{bc}	0.12 ± 0.03^{d}	0.92 ± 0.02^{a}	55.59 ± 2.40^{e}	156.60±0.01
IRP	6.53 ± 0.42^{a}	4.86 ± 0.35^{c}	1.93 ± 0.25^{bc}	0.93 ± 0.04^{a}	0.91 ± 0.02^{a}	79.42 ± 1.03^{b}	321.48±0.01
CCY	7.09 ± 0.16^{a}	3.85 ± 0.40^{a}	2.77 ± 0.19^{b}	0.95 ± 0.02^{a}	0.94 ± 0.02^{a}	84.86 ± 0.71^{a}	333.47±0.01
SWGY	6.75 ± 0.51^{a}	2.78 ± 0.78^{a}	4.80 ± 0.59^{a}	0.95 ± 0.02^{a}	0.90 ± 0.01^{a}	66.83 ± 0.73^{d}	266.80±0.01

Values are mean, standard deviations (SD) if triplicate samples. Means with different superscripts in the same roll were significantly different ($p>0.05$). Sample SWP; 100% Sweet potato flour, PL; 100% plantain, SWIR; 50% Sweet potato flour and 50% Irish potato flour, IRP; 100% Irish potato flour, CCY; 100% Cocoyam flour, SWCY; 50% Sweet potato flour and 50% Cocoyam flour.

The carbohydrate content exhibited a diverse range among the flour samples, varying from 55.59% to 84.86%. This variance was statistically significant ($p<0.05$) among the flour samples. Cocoyam flour stood out with the highest carbohydrate content at 84.89%, whereas plantain flour held the lowest value at 55.59%. Conversely, there was no significant difference ($p<0.05$) in the carbohydrate content between sweet potato flour and Irish potato flour. The carbohydrate content determined for cocoyam closely mirrored the value (83.33%) reported by Makanjuola et al. (2017). The substantial carbohydrate content underscores cocoyam's role as a potent source of energy.

The energy content within the flour samples displayed a notable range, spanning from 156.60 kcal to 333.46 kcal. Leading in this aspect, sample CCY (comprising 100% cocoyam flour) commanded the highest energy value at 333.46 kcal, while SWIR (a mixture of 50% sweet potato and 50% Irish potato) demonstrated the lowest value at 156.60 kcal. This disparity underscores cocoyam's role as a robust source of carbohydrates, particularly starch, which serves as a substantial energy-yielding food source. The energy derived from cocoyam primarily stems from intricate carbohydrates referred to as amylose and amylopectin, as noted by FAO (2004). Notably, significant differences ($p \leq 0.05$) in energy value were detected across the various samples.

Functional properties of Flour samples

The interplay between particle size and true density significantly influences the bulk density of flour. In this study, the bulk density of the flour samples exhibited a range from 0.61 to 0.86 g/cm³. Among these, flours derived from Irish potatoes registered the highest bulk density at 0.86 g/cm³, followed by sweet potato flours at 0.83 g/cm³. The bulk density for both sweet potato-Irish potato composite and cocoyam flours were identical at 0.72 g/cm³. Notably, this value surpassed the bulk densities of flours from sweet potatoes-cocoyam and plantain, which stood at 0.61 and 0.66 g/cm³ respectively. This observation suggests that the particle size of sweet potato-cocoyam and plantain flours is smaller than that of cocoyam and Irish-sweet potato flours, which possess larger particle sizes. Bulk density holds significance in determining packaging requisites, materials handling, and applications within wet processing in the food industry, as emphasized by Kulkarni et al. (1991).

Water absorption capacity (WAC) elucidates the starch particles' capability to interact with or absorb limited amounts of water (Omueti et al., 2009). Notably, Irish potato flour exhibited the highest water absorption capacity at 1.93%. This value considerably surpasses the 1.91% reported by Abioye et al. (2013) for Irish potatoes. Conversely, the lowest water absorption capacity was observed in the flours derived from Irish-sweet potatoes at 1.05%. The elevated water binding capacity inherent in Irish potato flour is likely attributable to its augmented content of undamaged starch granules, as posited by Mayaki et al. (2003). However, no significant differences ($p<0.05$) were discerned in the water binding capacity of sweet potato and potato-cocoyam composite flours.

The oil absorption capacity spanned a range from 1.11 to 1.31 g/ml, with no significant differences ($p > 0.05$) noted among the flour samples. Among these samples, both sweet potato and Irish-sweet potato flours exhibited the highest value (1.31 g/ml), closely followed by sweet potato-cocoyam flour at 1.27 g/ml. In contrast, cocoyam and Irish potato flours displayed the lowest values, 1.13 and 1.11 g/ml respectively. Worth highlighting, the values obtained for cocoyam were lower than those reported by Oloye et al. (2020).

The swelling capacity doesn't exhibit a congruent pattern with the starch content of the flours; rather, it mirrors the trend of bulk densities. This observation implies that both the particle size of the starch granules and the extent of starch damage due to the milling process significantly influence the flour's swelling capacity. Leading in swelling capacity, IRP (100% Irish potato flour) attained the highest value at 1.78 g/g, closely followed by SWIR (a blend of 50% Irish potato and 50% sweet potato flour) at 1.71 g/g. In contrast, PL (100% plantain flour) yielded the lowest value at 1.14 g/g. Notably, there were no significant differences in the swelling capacity between cocoyam flour and sweet potato-cocoyam flour. The swelling capacity values for both plantain flour (1.14 g/g) and cocoyam flour deviated considerably from those reported by Oladeji et al. (2013).

Table 2.0: Result for functional properties of cocoyam, plantain, sweet potato,irish potato flours

Sample	Water absorption (%)	Oil absorption (g/ml)	Bulk density (g/cm3)	swelling power g/g)
SWP	$1.39±0.07^{ab}$	$1.31±0.13^{a}$	$0.83±0.01^{a}$	$1.61±0.01^{b}$
PLT	$1.17±0.01^{b}$	$1.19±0.01^{abc}$	$0.61±0.01^{d}$	$1.14±0.03^{c}$
SWIR	$1.05±0.32^{b}$	$1.31±0.02^{a}$	$0.72±0.01^{b}$	$1.71±0.02^{ab}$

IRP	1.93±0.31^{a}	1.13±0.04^{bc}	0.86±0.01^{a}	1.78±0.16^{a}
CCY	1.16±0.04^{b}	1.11±0.06^{c}	0.72±0.01^{b}	1.20±0.02^{c}
SWCY	1.40±0.35^{ab}	1.27±0.01^{ab}	0.66±0.01^{c}	1.21±0.01^{c}

* Value are mean standard deviations (SD) if triplicate samples. Means with different superscript in the same roll were significantly different ($p>0.05$). SWP; 100% Sweet potato flour, PL; 100% plantain, SWIR; 50% Sweet potato flour and 50% Irish potato flour, IRP; 100% Irish potato flour, CCY; 100% Cocoyam flour, SWCY; 50% Sweet potato flour and 50% Cocoyam flour.

Pasting properties of flour samples

The outcomes of the pasting properties evaluation for cocoyam flour, plantain flour, sweet potato flour, Irish potato flour, and their composite flours are succinctly presented in Table 3. Peak viscosity signifies the utmost viscosity attained during the cooking process, offering insights into the viscosity load encountered during mixing (Maziya-Dixon et al., 2004). The peak viscosity values spanned from 536.00 to 3866.00 RVU (Rapid Visco Units). Plantain flour secured the highest peak viscosity value, with cocoyam flour following closely at 2960.59 RVU. Conversely, sweet potato flour posted the lowest peak viscosity value at 536.09 RVU. The lowest peak viscosity observed in sweet potato flour might be attributed to its elevated fat content, potentially engendering a dampening impact on starch gelling properties (Oluwamukomi et al., 2005). It's noteworthy that the peak viscosity value for cocoyam flour (2960.59 RVU) exceeded the range (1370 RVU) reported by Sefa-Dedeh and Sackey (2002) for the red variety of cocoyam starch.

Trough viscosities were observed to span a range of 532.00 to 3274.00 RVU (Rapid Visco Units). The sample of plantain flour exhibited the highest trough viscosity, reaching 3274.50 RVU, followed closely by cocoyam flour at 2792.00 RVU. On the other hand, sweet potato flour displayed the lowest trough viscosity value of 532.00 RVU. Remarkably, the trough viscosity values for plantain flour (3274.00 RVU) substantially exceeded the range (243.00 RVU) reported by Abioye et al. (2011). These trough viscosity values exhibited significant variation ($p<0.05$) across all flour samples. Trough viscosity, also known as hot paste stability, indicates the lowest viscosity value and assesses the capacity of the paste to withstand degradation during the cooling process (Newport Scientific, 1998). It highlights the susceptibility of the cooked starch to disintegration, with lower values signifying greater stability of the starch gel. The notably low trough viscosity value observed for sweet potato flour (532.00 RVU) implies robust hot paste stability, rendering it suitable for utilization in the filler meat canning industry.

Significant differences ($p<0.05$) emerged in the breakdown viscosities across the scrutinized flour samples. Plantain flour secured the highest breakdown viscosity value at 582.00 RVU, significantly surpassing ($p<0.05$) both cocoyam flour (168.00 RVU) and the remaining samples. Notably, augmented peak viscosities correlate with escalated breakdown viscosities, which can be linked to the degree of starch granule swelling during the heating process (Ribotta et al., 2007). A diminished breakdown value signifies starch stability in elevated temperature conditions. This indicates that a higher breakdown viscosity is inversely related to a sample's capability to endure the combination of heating and shear stress during cooking (Adebowale et al., 2005). Consequently, the sweet potato samples, with their lower breakdown viscosities (4.00 RVU), are more likely to withstand the effects of heating and shear stress.

The final viscosities exhibited a broad spectrum ranging from 689 to 3904.50 RVU, with the sweet potato sample registering the lowest values, and the plantain sample attaining the highest values in final viscosities. Notably, significant distinctions ($p<0.05$) were discerned in the final viscosities of the various flour samples. Of paramount importance, final viscosity stands as a quintessential parameter for determining the quality of starch-based samples. This parameter underscores a starch-based food sample's capacity to transform into a viscous paste or gel subsequent to cooking and subsequent cooling (Shimelis et al., 2006). Consequently, the sweet potato flour samples, characterized by their lower final viscosity values, are anticipated to exhibit enhanced stability following the cooling process compared to the other samples.

Setback viscosity plays a pivotal role in the occurrence of starch molecule retrogradation or re-ordering (Sanni et al., 2006). The setback values of the flour samples encompassed a range from 157.00 to 789.50 RVU. Cocoyam flour commanded the highest setback value at 789.50 RVU, while Irish sweet potato flour exhibited the lowest value at 157.00 RVU. Notably, significant differences ($p<0.05$) were evident in the setback viscosities among the flour samples. The setback viscosity values obtained for plantain flour (630.50 RVU) far exceeded the range (156.33 RVU) documented by Abioye et al. (2014). This observation underscores the considerable variation in setback viscosities across different samples.

The peak time spanned from 5.93 to 6.55 minutes, with sweet potato and Irish potato varieties recording values of 6.60 and 6.55 minutes, respectively. Remarkably, cocoyam and sweet potato-cocoyam flour shared the same value at 5.97 minutes. However, there was a significant difference ($p<0.05$) between the values recorded for sweet potato and plantain flour. Peak time holds significance as a measure of cooking time (Adebowale et al., 2005). The outcomes revealed that cocoyam flour (5.93 minutes) exhibited a swifter cooking time compared to the other samples, while Irish-sweet potato flour samples necessitated the longest time for cooking (6.60 minutes). This observation aligns with the findings of Oluwalana et al. (2011), who reported a reduction in the peak time of plantain flour with an increase in pre-cooking.

Pasting temperature denotes the juncture at which starch granules initiate swelling upon heating, culminating in the creation of a viscous paste (Afoakwa, Adjonu, & Asomaning, 2010). For the principal flours - cocoyam, plantain, sweet potato, and Irish potato - no significant differences ($p>0.05$) were discerned in their respective pasting temperatures: 86.30°C, 84.70°C, 84.70°C, and 82.53°C. Nonetheless, some distinctions in pasting temperature manifested within the composite flours.

Table 3.0 Result of pasting properties of cocoyam, plantain, irish potato, sweet potato and their composite flour.

Value are mean standard deviations (SD) if triplicate samples. Means with different superscript in the same roll were

Sample	PEAK	TROUGH (RVU)	BREAKDOWN (RVU)	FINAL VISOSITY (RVU)	SETBACK (RVU)	PEAKTIME (mins)	PASTING TEMPERATURE(°C)
SWP	536.00±42.43^{d}	532.00±42.3^{d}	4.00±0.00^{c}	689.00±49.50^{d}	157.00±7.0^{c}	6.03±0.04^{ab}	84.20±0.0^{c}
PL	3866.00±186.68^{a}	3274.00±135.76^{a}	592.00±50.9^{a}	3904.50±212.84^{a}	630.50±77.^{ab}	6.04±0.05^{b}	84.70±0.07^{b}
SWIR	1151.50±40.31^{cd}	1138.00±35.36^{cd}	13.50±4.95^{c}	1308.00±38.18^{cd}	170.00±2.8c	6.60±0.10^{a}	73.93±0.53^{d}
IRP	1596.50±749.0^{cd}	1516.50±963.79^{d}	85.00±103.24^{bc}	1874.50±1327.24^{cd}	358.00±363.45^{bc}	6.55±0.35^{a}	82.53±1.59^{d}
CCY	2960.50±0.71^{ab}	2792.50±13.44^{ab}	168.00±14.14^{b}	3582.00±28.28^{ab}	789.50±14.85^{a}	5.97±0.00^{b}	86.30±0.92^{ab}
SWGY	1985.00±90.5^{bc}	1903.00±80.61^{bc}	82.00±9.90^{bc}	2263.00±111.72^{bc}	360.00±31.11^{bc}	5.97±0.14^{b}	76.98±0.11^{a}

significantly different ($p>0.05$). SWP; 100% Sweet potato flour, PL; 100% plantain, SWIR; 50% Sweet potato flour and 50% Irish potato flour, IRP; 100% Irish potato flour, CCY; 100% Cocoyam flour, SWCY; 50% Sweet potato flour and 50% Cocoyam flour.

Sensory acceptability of thick porridge from flour samples

The outcomes of the sensory assessment of thick porridge formulated from the flour samples are succinctly displayed in Table 4. The textural attributes of the samples resided within a range spanning 5.10 to 6.50%. Notably, the samples' acceptability with respect to texture exhibited slight disparities ($p<0.05$). In specific terms, sample PL (100% Cocoyam flour) garnered the highest value at 6.50, indicating a slight preference for its texture. Conversely, CCY (100% cocoyam flour) posted the lowest value at 5.10, signifying a neutral stance towards its texture. The suboptimal texture of SWCY might be attributed to the absence of gluten in cocoyam (Emmanuel-Ikpeme et al., 2007). According to Okaka (2005), gluten, composed of glaidin and glutenin proteins, bestows flour with the elasticity that becomes apparent upon the introduction of hot water during cooking. Gluten is most notably abundant in wheat, a grain distinct in its gluten content.

The sensory evaluation outcomes concerning the aroma of the thick porridge extended across a spectrum ranging from 5.33 to 7.03%. Notably, sample PL (100% Plantain flour) registered the highest value at 7.03, indicating a moderate preference for its aroma. In sequence, SWP (100% sweet potato flour) achieved a value of 6.13, signifying a mild likeness for its aroma. Conversely, IRP (100% Irish potato flour) recorded the lowest value at 5.33, implying a neutral stance towards its aroma. Within the context of the samples, significant distinctions ($P<0.05$) emerged in terms of aroma.

Taste serves as an indicator of how well the taste buds on the tongue perceive flavors (Iwe, 2007). Consequently, heightened flavor equates to higher scores and acceptability. The taste attributes of the thick porridge derived from flour samples spanned a range from 5.47 to 6.33%. Remarkably, plantain flour secured the highest taste value at 6.33, signifying a mild preference for its taste. In contrast, sweet potato-cocoyam flour garnered the lowest value at 5.47, implying a neutral stance towards its taste. The taste values exhibited significant distinctions ($P<0.05$) among the samples. The findings indicate that the thick porridge (amala) sample crafted from plantain flour emerged as the preferred choice in terms of taste among the panelists.

Color, as described by Wrolstad & Smith (2010), is a pivotal factor influencing consumer perceptions of food. Within the context of flour, color holds particular significance, exerting an impact on both marketing and product acceptability (Van Hal, 2000). The color variations in the samples spanned from 5.00 to 6.47. Evidently, sample PL (100% Plantain flour) took the lead in color values, with CCY (100% cocoyam flour) following closely at 6.47, signifying a slight preference for their respective colors. On the contrary, SWIR (50% sweet potato and 50% cocoyam flour) presented the lowest color value at 5.00, indicating a neutral standpoint regarding its color. It's worth noting that color serves as an indispensable sensory attribute in the realm of food, as it markedly influences the overall acceptability of a product.

Appearance holds a substantial and influential role within sensory evaluation, as it serves as the initial point of interaction that influences acceptability. Prior to making choices about consumption, consumers often engage visually with food offerings (Oluwole, 2009). In the context of the samples, their appearance ranged from 5.17 to 7.93%. Notably, sample CCY (100% cocoyam flour) emerged with a significantly higher appearance score (7.93%; moderate liking) in comparison to all other samples. Subsequently, PL (100% Plantain flour) secured a score of 7.17, indicative of a moderate liking for its appearance. In contrast, the composite flours registered lower values of 5.33 and 5.17 respectively. The enhanced appearance scores for cocoyam and plantain could potentially be attributed to their fine particle sizes, bolstering their visual appeal.

The overall acceptability ratings of the samples encompassed a spectrum from 4.97 to 6.97. Evidently, sample PL (100% Plantain flour) clinched the highest value at 6.97, indicating a mild preference for its overall acceptability. This was succeeded by SWP and IRP, showcasing higher values. On the other end of the spectrum, SWCY (50%

cocoyam flour and 50% sweet potato flour) secured the lowest value at 4.97, signifying a slight disfavor in terms of its overall acceptability. While there was no marked disparity ($p<0.05$) in the overall acceptability of the primary flour samples, distinctions did emerge within the composite flours. Specifically, sample PL (100% plantain flour) commanded the highest scores in appearance, color, taste, and aroma. This collective preference propelled plantain flour to be the favored choice among the panelists.

Table 4: **Result of sensory properties of cocoyam, plantain, irish Potato, sweet potato and their composite flour.**

SAMPLE	AROMA	TEXTURE	TASTE	COLOUR	APPEARANCE	OVERALL ACCEPTABILITY
SWP	6.13 ± 0.78^{b}	5.77 ± 0.97^{b}	6.23 ± 0.73^{ab}	5.27 ± 0.87^{a}	6.00 ± 0.98^{ab}	6.53 ± 0.82^{a}
IRP	5.33 ± 1.32^{c}	5.70 ± 0.92^{b}	6.13 ± 1.17^{ab}	5.57 ± 1.25^{a}	6.43 ± 1.07^{bc}	6.47 ± 1.04^{a}
CCY	5.79 ± 0.94^{bc}	5.10 ± 1.25^{b}	5.73 ± 0.94^{abc}	6.27 ± 0.98^{a}	7.93 ± 1.14^{ab}	5.63 ± 1.22^{b}
PLT	7.03 ± 1.22^{a}	6.50 ± 0.97^{a}	6.33 ± 1.21^{a}	6.43 ± 1.22^{a}	7.17 ± 0.83^{a}	6.97 ± 1.19^{a}
SWIR	5.77 ± 1.22^{bc}	5.97 ± 1.01^{b}	5.67 ± 1.06^{bc}	5.00 ± 1.08^{a}	5.33 ± 1.18^{c}	5.13 ± 1.81^{b}
SWCY	5.76 ± 1.02^{bc}	5.20 ± 0.96^{c}	5.47 ± 1.61^{c}	5.33 ± 1.15^{a}	5.17 ± 1.32^{c}	4.97 ± 1.77^{b}

Value are mean standard deviations (SD) if triplicate samples. Means with differerent superscript in the same roll were significantly different ($p>0.05$). Sample SWP; 100% Sweet potato flour, PL; 100% plantain, SWIR; 50% Sweet potato flour and 50% Irish potato flour, IRP; 100% Irish potato flour, CCY; 100% Cocoyam flour, SWCY; 50% Sweet potato flour and 50% Cocoyam flour.

Conclusion

In conclusion, flour could be used to produce acceptable starch staples Food is reconstituted by boiling. Cocoyam and plantain flours show better pastry performance than others. Pastry properties of sweet potato, irish potato, Irish-sweet potato, and cocoyam-sweet potato compared favorably with cocoyam and plantain. Apart from the nutritional advantages of cocoyam and plantain flours. Since they are underutilized crops and weather are favourable for their growth in developing countries, combining these flours will reduce production cost and improve nutritional quality for product development.

Recommendation

Cocoyam, plantain, irish, and sweet potato flours are sources of dietary fiber and potassium and are useful as oil absorption capacity imparts desirable sensory properties to foods. As a result of the high gelatinization temperature exhibited, flours are recommended for incorporation with other materials for product development. However, research on the microbiology, mineral, phytochemicals and anti- nutrients of those flours could be carried out. Farmers of cocoyam, plantain irish potato, and sweet potato should be encouraged by giving them loans, incentives, and post-harvest losses should be worked on as they will be making more sales since more new products will be developed.

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