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Research Article

Physicochemical Properties and Total Carotenoid Content of High-Quality Unripe Plantain Flour from Varieties of Hybrid Plantain Cultivars

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Unripe plantain has been considered as having commercial potential or used as an ingredient for other foods. Information on the physicochemical and carotenoid properties of flours from hybrid plantain cultivars in the literature is limited. This study was conducted to determine the physicochemical properties and carotenoid contents of unripe plantain flour from selected hybrid plantain cultivars using standard laboratory methods. The unripe plantain pulps of four varieties (PITA 26, PITA 27, Mbi Egome and Agbagba (control)) used in this study were cabinet dried at 65°C for 48 h and milled into flour. The result showed that moisture content ranged from 6.15 to 7.27%, Ash (2.01–3.69%), Fat (0.49–1.20%), Protein (2.47–2.99%), Fibre (0.73–0.97%), Sugar (6.29–9.33%), starch (84.34–104.96%), total carotenoid content (2.96–24.19 μg/g). Potassium ranged from 328.30–528.50 mg/kg, Calcium (9.46–11.98 mg/kg), Magnesium (24.73–29.11 mg/kg), Sodium (6.30–7.24 mg/kg), Zinc (0.12–0.29 mg/kg), and manganese (0.03–0.15 mg/kg). The L^* (Lightness) ranged from 62.88 to 67.00. Bulk density ranged from 0.72 to 0.77 g/ml, WAC (143.59–174.08), OAC (98.07–100.66%), swelling power capacity (10.63 to 11.82%), solubility (5.58–6.71%), and dispersibility (86.50–88.00%). Peak viscosity ranged from 568.17 to 761.64 RVU, final viscosity (378.53–496.58 RVU), and peak temperature (81.62–83.23°C). The results suggest that the hybrid plantain cultivars could be used to produce good quality plantain flours with improved physicochemical and pasting properties.

1. Introduction

Plantain (*Musa paradisiaca*) is an important starchy staple and commercial crop in the West and Central Africa where fifty per cent of the world's plantain crop is produced [1]. It constitutes a significant source of carbohydrate, low in protein and fat but rich in starch and mineral elements, especially potassium. It is widely cultivated in most of the eastern and southern parts of Nigeria. The largest plantain producing countries are mostly African countries where plantain is one of the staple foods in the region. According to FAO [2], over 2.11 million metric tonnes of plantains are produced in Nigeria annually and consumed as a staple food. Plantain flour is derived from mature but unripe plantain fingers by carefully peeling its greenish skin. The finger is then sliced into flat shapes (chips) and spread under sunlight to dry. Plantain finger may also be dried in the ovens or mechanical dryers. After the chips have been dried to a safe moisture content of about 13%, it will be pulverised into flour.

Postharvest loss is a significant problem affecting the production of plantain in Africa due to the unavailability of established storage facilities that can guarantee a long shelf life. Considerably high quantity of banana is wasted before it reaches the target market or consumers. A high postharvest loss caused by inadequate and insufficient postharvest handling is reported to be one of the major problems limiting the expansion of banana production. It increased the cost of bananas in the market, led to scarcity, and reduced the profits of farmers involved in banana production in Africa [3]. Similarly, lack of postharvest and marketing infrastructures such as packaging, cold storage, prepackage, and distribution, postharvest treatments and washing facilities together with production constraints are reported problems leading to considerable postharvest losses of bananas [4]. Projected postharvest losses of banana are high as 40% in some parts of West Africa or roughly 35% for emerging nations in general [4]. In Cameroon, studies confirmed that about 30% of postharvest losses of bananas are incurred during wholesale and about 70% during retailing [5]. Postharvest loss of banana associated with storage and marketing was reported to be prominent and reaches up to 80% in Rwanda [5]; on season and off-season market losses of 6.6% and 2.2% in Nigeria [6]; total value chain loss of 26.5% in Ethiopia [7]. A novel way of utilising green bananas is to process the fruit into flour. Banana flour, a major product of green banana of different cultivars, is one of the most common ways of preserving bananas as well as their masses. In flour form, the shelf life can be extended and provide secure storage. It has high starch content and is widely used in infant feeding as a source of energy and have excellent medicinal properties, especially for cases of gastrointestinal infection [8]. By-products from postharvest losses of plantains and bananas are presumed to serve as an undervalued commodity with limited commercial value. They could serve as new alternatives to avoid postharvest losses. Creating new products at the cost of recycling banana by-products from postharvest losses will add value to them. Banana by-products are readily available to be used as a source of raw material for industries. Starch, pectin, and cellulose from these by-products are used in the food industry as a gelling agent, thickening agents, and stabilisers. By-products of banana from postharvest losses can be utilised as a feed with high nutritive value to overcome the limited and expensive source of materials for animal feed production [9].

Unripe green plantains have been processed into flour, and such flour has been commercially useful on their own or as an ingredient for other foods such as weaning food. Plantain flour can be reconstituted in boiled water to form a gelatinised paste called *'amala'* in Yoruba and *'foufou'* in Cameroon which can be eaten with different soups or sauces. The flour is also used for several other traditional dishes ranging from 'Akara', Ukpo Ogede' to soups [10]. The demand for unripe plantain flour has increased tremendously because of its health benefits. Unripe plantain flour has a very high nutrient and source of dietary carbohydrates, vitamins, and minerals. Plantains are seasonal crops with short shelf life. Processing plantains to flour will be a useful method to extend their shelf life. The International Institute of Tropical Agriculture (IITA) has developed several cultivars of plantain and banana, which are pest and disease resistant and high yielding combined with good postharvest qualities. Thus, the study is designed to determine the physicochemical properties and carotenoid contents of unripe plantain flour from selected varieties of plantain cultivars.

2. Materials and Methods

2.1. Materials. The varieties of the hybrid plantain cultivars were collected from IITA Ibadan, Oyo state. Four varieties of plantain were used in this study, two hybrids (PITA 26 and PITA 27), Mbi Egome and *Agbagba* (control) at stage 1 (unripe green) [11]. All analysis was carried at the Food and Nutrition Laboratory of International Institute of Tropical Agriculture (IITA) Ibadan, Oyo state.

2.2. Processing Plantain into Flour. Plantain flour was prepared following the processing steps described by Kure et al. [12]. The plantain fingers were separated from the bunches, washed, peeled manually, sliced (2 mm thickness) using a stainless-steel kitchen slicer, blanched at 80°C for 5 min, and dried in a cabinet drier at 65°C for 48 h. The dried slices were milled, sieved, packaged in a low-density polyethylene bag, sealed, and stored for subsequent use.

2.3. Chemical Composition of Plantain Flours. The moisture, ash, fat, protein, fibre, carbohydrate, sugar, and starch contents of the plantain flour were determined by methods described by AOAC [13].

2.4. Mineral Composition of Plantain Flours. The mineral analysis was determined using inductively coupled plasma optical emission spectrometer (ICP-OES) by the method described by AOAC [13]. About 0.4–0.5 g of plantain flour was mixed with 2 ml of concentrated redistilled nitric acid (HNO_3) in a 50 ml digestion tube and left overnight for cold digestion. The mixture was placed in a digestion block, starting with a temperature of 120°C. As the liquid dries off, 2 ml of concentrated HNO_3 was added. The temperature of the digestion block is increased to 150°C if the sample is still black, indicating the presence of carbon. The last step was repeated until the solution is clear. A solution of 50/50 (v/v) HNO_3 and perchloric acid ($HClO_3$) was added, and the temperature increased to 180°C–220°C with the tap for the washing of the exhaust running. The mixture was heated to dryness to leave a whitish ash-like residue. The digestion tube was removed from the digestion block and cooled to room temperature. The ash residue was redissolved with 1 ml of hydrochloric acid (HCl) and 10 ml of 5% HNO_3, vortexed and transferred into 15 ml centrifuge tubes, ready for analysis. The ash solution was injected into the ICP-OES to determine the minerals content. Each of the mineral content (mg/kg) was calculated as follows:

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$$\text{Mineral content (mg/kg)} = \frac{\text{Conc. (ppm)} \times \text{D.F}}{\text{Sample weight (g)}}, \quad (1)$$

where D. F = Dilution factor.

2.5. Colour Parameters of Plantain Flours. Colour parameters (L^*, a^* and b^*) were measured with a colorimeter (Color-Tec-PCM TM, Omega Engineering Inc., Stanford, CT) by the method described by Liu-Ping et al. [14]. The colorimeter was standardised, and samples were placed in the sample holder. The colour measurement was done in triplicate.

2.6. Functional Properties of Plantain Flours

2.6.1. Bulk Density. Bulk density was determined using the method of Narayana and Narasinga Rao [15]. A calibrated centrifuge tube was weighed and filled with samples to 5 ml by constant tapping until there is no further change in volume. The tube and contents were weighed, and the weight of samples was determined by difference. The bulk density (g/ml) will be calculated as the weight of the flour (g) divided by flour volume (ml).

2.6.2. Water Absorption. Water absorption capacity was determined by the method described by Solsulski [16]. 1 g of flour was weighed, and 15 ml distilled water was added in a weighed 50 ml centrifuge tube. The tube was agitated on a vortex mixer for 2 min and centrifuge at 4000 rpm for 20 min. The clear supernatant was decanted, and the volume was measured and discarded. The adhering drops of water were removed, and the tube reweighed. Water absorption capacity was expressed as the weight of water bound by 100 g dry flour.

2.6.3. Oil Absorption. Oil absorption capacity was determined by the method described by Sosulski et al. [17]. To 1 g of the flour, 10 ml of refined corn oil was added in a weighed 50 ml centrifuge tube and agitated on a vortex mixer for 2 min and centrifuged at 4000 rpm for 20 min. The volume of free oil was recorded and discarded. The tube was weighed with the content. Oil absorption capacity was expressed as ml oil bound by 100 g dry flour.

2.6.4. Swelling Power Capacity. Swelling power capacity and solubility were determined by the method described by Riley et al. [18]. 1g of flour was weighed into 50 ml centrifuge tube, and 15 ml of distilled water was added and shaken for 5 min at low speed. The slurry was heated in a water bath at 80°C for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a preweighed centrifuge tube, and 7.5 ml distilled water was added. The tubes containing the paste were centrifuged at 2,200 rpm for 20 min. The supernatant was carefully decanted into a preweighed can and dried at 100°C to constant weight. Then cooled in a desiccator and weighed.

$$\text{swelling power} = \frac{\text{wt. of sediment}}{\text{sample wt.} - \text{wt. of soluble}}. \quad (2)$$

2.6.5. Dispersibility. Dispersibility was determined by the method described by Kulkarni et al. [19]. 10 g of the samples was placed in 100 ml measuring cylinder, and distilled water was added to reach a volume of 100 ml. Then it was stirred vigorously and allowed settling for 3 hours. We recorded the volume of steeled particles and subtracted from 100. WE Reported the difference as % dispersibility.

2.7. Pasting Properties of Plantain Flours. The pasting properties of the flours were determined using Rapid Visco Analyser (Model RVA-Super 4, Newport Scientific Perten Instruments AB, Huddinge, Sweden) interfaced with a personal computer equipped with the Thermocline software supplied by the same manufacturer. 3 g of the plantain flour sample was mixed with 25 ml of distilled water inside the RVA test canister, and this was lowered into the RVA system. The slurry was heated from 50 to 95°C and cooled back to 50°C within 12 min, rotating the can at a speed of 160 rpm with continuous stirring of the content with a plastic paddle. The parameters measured were peak viscosity, trough, breakdown viscosity, setback viscosity, final viscosity, pasting temperature, and time [20].

2.8. Total Carotenoid Composition of Plantain Flours. Total carotenoid was determined by the method described by Adegunwa et al. [21]. 2 ml of distilled water was added to 5 g of plantain flour. It was transferred to mortar. 50 ml of cold acetone and 2 g of Cellite were added and crushed with a pestle. The mixture was filtered with suction through Buchner funnel using Filter paper (Watmann 90 mm). The mortar, pestle, and residue were washed with small amounts of acetone, and the washings were received in the funnel. The crushing and filtration were repeated two times (until the residue is colourless). Total carotenoid content was extracted using petroleum ether and quantified using a UV-VIS spectrophotometer at 450 nm. Total carotenoid content (TC spec) was calculated as follows:

$$\text{TC spec } (\mu\text{g/g}) = \frac{A_{\text{total}} \times \text{volume (ml)} \times 104 \times (\text{DF})}{A^{1\%}_{1\text{cm}} \times \text{sample weight}}, \quad (3)$$

where A_{total} = Absorbance at 450 nm, Volume (ml) = Total volume of extract (25 mls), and $A^{1\%}_{1\text{cm}} = 2592$ (absorption coefficient of beta-Carotene in petroleum ether (PE).

2.9. Statistical Analysis. The data generated were analysed using Statistical Analysis Systems version 9.1 software package [22]. Significance of treatment means was tested at 5% probability level using Duncan's new multiple range tests (DNMRT).

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3. Results and Discussion

3.1. Chemical Composition. The result of the chemical composition of the plantain flours is presented in Table 1. The moisture content ranged from 6.15 to 7.27%; Pita 26 had the least value, and Agbagba (control) recorded highest. A similar result (4.45–6.75%) was reported for hybrid plantain flours [1]. Agbagba was significantly different ($p < 0.05$) from other cultivars. The moisture content influences the keeping quality of plantain flour. 10% of moisture content was reported to be ideal for good keeping quality [2]. Thus, moisture content obtained in this research suggests that flours made from plantain hybrids may keep longer. The ash content ranged from 2.01 to 3.69%. Mbi egome showed the least value, and Pita 27 recorded the highest value. A similar result of 1.47–4.15% was reported for hybrid plantain flours by Adeniji et al. [1]. The fat contents were generally low and ranged from 0.49 to 1.20%. Agbagba (control) had the least value, and Pita 27 had the highest value. The values were much lower compared to 1.47–4.20% reported by Adeniji et al. [1] for hybrid plantain flours. Protein content ranged from 2.47 to 2.99%. Agbagba had the least value, while Pita 27 recorded the highest value. Generally, plantains are not a significant source of protein [2]. The fibre content of the plantain hybrids flours was generally low from 0.73 to 0.99%. The values were much lower compared to 2.26–7.81% reported for hybrid plantain flour by Adeniji et al. [1]. The carbohydrate (85.27–86.95%) and starch (81.22–93.96%) contents were generally high, suggesting that the plantain hybrids cultivars may constitute critical raw materials in the formulation of high energy foods. The carbohydrate (86.955%), sugar (9.33%), and total carotenoid (24.19 μg/g) found in Mbi egome flours were significantly ($p < 0.05$) higher than those in other cultivars. In this present study, the high total carotenoid content (24.19 μg/g) found in Mbi egome flour was influenced by the degree of yellowness b^* (17.26), iron (0.85 mg/kg) and copper (0.39 mg/kg) content. This suggests that the cultivar (Mbi egome) is a good source of carotenoid and its flour can meet daily provitamin A requirements of the individual. It has been reported that individuals with low carotenoid (provitamin A) intake have an increased risk of degenerative diseases [23].

3.2. Mineral Concentration. The data of the mineral profile of the plantain flours showed that potassium and calcium contents of all the cultivars evaluated differed significantly ($p < 0.05$) from the local landrace Agbagba (control). In contrast, Agbagba differed significantly ($p < 0.05$) from the hybrids in sodium (Table 2). The potassium (528.50 mg/kg), calcium (11.98 mg/kg), and magnesium (29.11 mg/kg) found in Pita 27 plantain flour were significantly ($p < 0.05$) higher than those in other cultivars. Generally, the manganese, iron, copper, zinc, and aluminium of all the cultivars are significantly low. The manganese ranged from 0.03 to 0.15 mg/kg, iron ranged from 0.66 to 0.85 mg/kg, copper ranged from 0.25 to 0.40 mg/kg, zinc ranged from 0.12 to 0.19 mg/kg while aluminium ranged from 0.53 to 0.77 mg/kg. As expected, the plantain hybrids flours had very high levels of potassium, Pita 27 having the highest value of 528.50 mg/kg.

Conversely, the plantain hybrids flours are low in sodium, ranging from 6.30 mg/kg in PITA 26 and PITA 27 to 7.24 mg/kg in Agbagba (control). The potassium and sodium contents obtained indicated good dietary profile for the hybrids. The new plantain hybrids may be recommended for low sodium diets while the protective effect of high potassium may be advantageous against excessive intake of sodium. The data revealed that Pita 27 plantain flour could contribute a higher nutrients level in the human diet. The new plantain hybrids may, therefore, constitute critical raw materials in food product development with improved levels of mineral nutrients [1].

3.3. Colour Parameters. The data of the colour parameters showed a significant difference ($p < 0.05$) in the lightness, redness, yellowness, and colour intensity of the plantain flours (Table 3). Generally, all plantain flour samples showed a high degree of lightness L^* (62.88–67.00), low degree of redness a^* (−4.17 to −6.78), low degree of yellowness b^* (12.12–17.26) values, and moderately high ΔE (34.74–39.71). The lightness, redness, yellowness, and colour intensity values from Mbi egome flour differed significantly ($p < 0.05$) from plantain flour of other cultivars used for this work. The difference in lightness (L^*) could be attributed to the effect of enzymatic browning, which occurred under conditions prevailing during the drying process, which favours colour change [24].

3.4. Functional Properties. The functional properties of the plantain flour samples are presented in Table 4. Water absorption capacity is a measure of the volume occupied by the starch granules after swelling in excess water and results obtained from this study indicate good water absorption capacity for all the flours [25]. The water absorption capacity ranged from 143.59 to 174.08% with a significant difference ($p < 0.05$) between the flours.

The water absorption capacity was observed highest in *Agbagba* plantain flour and lowest in Mbi egome flour. The water absorption capacity of PITA 26 and PITA 27 flours are 172.54 and 161.31% respectively, which are smaller than that of the control (*Agbagba*). The highest WAC of plantain flour could be attributed to the presence of a higher amount of carbohydrates (starch) and fibre in this flour, and this could be because starch and fibre have good ability to associate with water under limited water condition (high hydration properties). Swelling power indicates the degree of exposure of the internal structure of the starch granules to the action of water, that is a measure of hydration capacity [26]. The swelling power capacity ranged from 10.63 to 11.82%, PITA 26 flour had the highest value, and Agbagba flour (control) had the least value. PITA 27 and Mbi egome flour had 11.61% and 11.69%, respectively, which are still higher than the control (Agbagba). The solubility index of the flour samples ranged from 5.58 to 6.71%, the control (Agbagba) flour had the highest value, and PITA 26 flour had the least value. A similar result of solubility index 6.72% was reported

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Table 1: Chemical composition of plantain flours of selected varieties of plantain cultivars.

Sample	Moisture %	Ash %	Fat %	Protein %	Fibre %	CHO %	Sugar %	Starch %	Carotenoid μg/g
Pita 26	6.15 ± 0.05^{c}	3.33 ± 0.01^{b}	1.20 ± 0.01^{a}	2.93 ± 0.01^{b}	0.73 ± 0.00^{d}	85.66 ± 0.04^{b}	6.29 ± 0.05^{d}	89.37 ± 0.31^{b}	2.92 ± 0.01^{d}
Pita 27	6.47 ± 0.06^{b}	3.69 ± 0.05^{a}	0.78 ± 0.01^{b}	2.99 ± 0.06^{a}	0.81 ± 0.00^{c}	85.27 ± 0.06^{b}	8.59 ± 0.03^{b}	81.22 ± 0.20^{d}	5.89 ± 0.04^{b}
Mbi egome	6.48 ± 0.17^{b}	2.01 ± 0.01^{c}	0.80 ± 0.07^{b}	2.86 ± 0.11^{c}	0.90 ± 0.01^{b}	86.95 ± 0.13^{a}	9.33 ± 0.05^{a}	84.34 ± 0.31^{c}	24.19 ± 0.05^{a}
Agbagba	7.27 ± 0.06^{a}	3.34 ± 0.01^{b}	0.49 ± 0.07^{c}	2.47 ± 0.00^{d}	0.97 ± 0.03^{a}	85.46 ± 0.16^{b}	6.75 ± 0.05^{c}	93.96 ± 0.31^{a}	$4.87..0.03^{c}$

Mean values in the same column with different superscripts are significantly different at ($p < 0.05$).

Table 2: Mineral composition of plantain flours of selected varieties of plantain cultivars (mg/kg).

Sample	Ca	Mg	K	Na	Mn	Fe	Cu	Zn	Al
Pita 26	10.77 ± 2.15^{b}	24.73 ± 5.02^{d}	366.45 ± 38.81^{c}	6.30 ± 0.44^{c}	0.15 ± 0.04^{a}	0.66 ± 0.24^{b}	0.25 ± 0.14^{b}	0.12 ± 0.09^{c}	0.59 ± 0.07^{b}
Pita 27	11.98 ± 2.09^{a}	29.11 ± 0.47^{a}	528.50 ± 72.97^{a}	6.30 ± 0.05^{c}	0.03 ± 0.01^{b}	0.67 ± 0.10^{b}	0.40 ± 0.29^{a}	0.29 ± 0.24^{a}	0.68 ± 0.20^{a}
Mbi egome	10.08 ± 1.63^{c}	28.99 ± 0.06^{b}	380.65 ± 7.85^{b}	6.48 ± 0.66^{b}	0.09 ± 0.00^{b}	0.85 ± 0.02^{a}	0.39 ± 0.29^{a}	0.18 ± 0.03^{b}	0.77 ± 0.27^{a}
Agbagba	9.46 ± 1.30^{d}	27.25 ± 4.09^{c}	328.30 ± 92.63^{d}	7.24 ± 1.37^{a}	0.15 ± 0.03^{a}	0.84 ± 0.13^{a}	0.30 ± 0.06^{b}	0.19 ± 0.04^{b}	0.53 ± 0.07^{b}

Mean values in the same column with different superscripts are significantly different at ($p < 0.05$); CHO = total carbohydrate.

Table 3: Colour parameters of plantain flours of selected varieties of plantain cultivars.

Sample	L^*	a^*	b^*	ΔE
Pita 26	62.88 ± 0.08^{d}	-4.17 ± 0.01^{c}	12.12 ± 0.04^{c}	34.74 ± 0.08^{d}
Pita 27	63.24 ± 0.06^{c}	-5.22 ± 0.03^{b}	13.36 ± 0.03^{b}	35.36 ± 0.06^{c}
Mbi egome	67.00 ± 0.03^{a}	-6.78 ± 0.01^{a}	17.26 ± 0.01a	39.71 ± 0.30^{a}
Agbagba	65.60 ± 0.02^{b}	-5.55 ± 0.01^{b}	13.69 ± 0.00 b	37.76 ± 0.02^{b}

Mean values in the same column with different superscripts are significantly different at ($p < 0.05$)

Table 4: Functional properties of plantain flours from selected varieties of plantain cultivars.

Sample	Water absorption capacity (%)	Swelling capacity (%)	Solubility index (%)	Bulk density (g/cm^3)	Oil absorption capacity (%)	Dispersibility (%)
PITA 26	172.54 ± 2.91^{b}	11.82 ± 0.06^{a}	5.58 ± 0.09^{c}	0.77 ± 0.00^{a}	99.23 ± 0.21^{b}	86.50 ± 0.00^{a}
PITA 27	161.31 ± 0.76^{c}	11.61 ± 0.13^{a}	6.03 ± 0.18^{b}	0.72 ± 0.00^{b}	99.56 ± 2.86^{b}	87.00 ± 0.00^{a}
Mbi egome	143.59 ± 0.83^{d}	11.69 ± 0.03^{a}	5.66 ± 0.07^{c}	0.73 ± 0.00^{b}	98.07 ± 0.37^{b}	88.00 ± 0.00^{a}
Agbagba	174.08 ± 2.50^{a}	10.63 ± 0.19^{b}	6.71 ± 0.37^{a}	0.73 ± 0.00^{b}	100.66 ± 0.08^{a}	87.50 ± 0.00^{a}

Mean values in the same column with different superscripts are significantly different at ($p < 0.05$).

by Adegunwa et al. [27] for plantain flour. Bulk density of the flour samples had no significant difference ($p > 0.05$), and the value ranged from 0.72 to 0.77 g/cm^3. Pita 26 flour recorded the highest value, and Pita 27 had the lowest value. The bulk density of Mbi egome and Agbagba flour were the same (0.73 g/cm^3), lower than that of the hybrids flours. Generally, higher bulk density is desirable in that it offers more significant packaging advantage as greater quantity may be packaged within a constant volume [24]. The oil absorption capacity of flour sample is essential because oil helps to retain flavour and improve mouth feel when used in food preparation. Flavour retention increases the palatability of food [28]. Oil absorption capacity ranged from 98.07 to 100.66%, and there was no significant difference ($p > 0.05$) between the flour samples. Amongst the flour samples, Agbagba plantain flour (control) recorded the highest value, and Mbi egome plantain flour had the least value. Dispersibility of the plantain flour samples ranged from 86.50 to 88.00%, Pita 26 had the least, and Mbi egome had the highest value. There was no significant difference ($p > 0.05$) between the plantain flour samples. A similar result of dispersibility 70.00 to 80.50 was reported by Fadimu et al. [24].

3.5. Pasting Properties. The pasting properties of the various samples are presented in Table 5. Peak viscosity reflects the maximum viscosity developed during cooking and indicates the viscous load to be encountered during mixing [29]. The peak viscosity values obtained ranged from 568.17 to 761.64 RVU. Pita 27 plantain flour had the lowest value, and Mbi egome flour had the highest value. Generally, there was a significant difference between the peak viscosities of the

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Table 5: Pasting properties of plantain flours from selected varieties of plantain cultivars.

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Set back viscosity (RVU)	Peak time (min)	Pasting temp. (°C)
PITA 26	607.36^{c}	286.14^{c}	321.22^{b}	378.53^{d}	92.39^{d}	4.60^{b}	81.62^{c}
PITA 27	568.17^{d}	284.36^{d}	283.80^{d}	390.94^{c}	106.58^{c}	4.69^{b}	81.82^{c}
Mbi egome	761.64^{a}	376.19^{b}	385.45^{a}	485.75^{b}	109.56^{b}	4.65^{b}	83.23^{a}
Agbagba	677.14^{b}	381.06^{a}	296.17^{c}	496.58^{a}	115.53^{a}	4.80^{a}	82.18^{b}

Mean values in the same column with different superscripts are significantly different at ($p < 0.05$).

plantain flour samples. The trough viscosity is the minimum viscosity after the initial peak and occurs after the commencement of the sample cooling. The trough viscosity ranged from 284.36 to 381.06 RVU. Pita 27 plantain flour had the lowest, and Agbagba plantain flour had the highest value. There was no significant difference between the trough viscosities of Agbagba and Mbi egome plantain flour as well as between PITA 26 and PITA 27 plantain flour. The breakdown viscosity measures the ability of a sample to withstand this breakdown in viscosity, i.e., withstand heating and mechanical shear stress that is usually encountered during processing. There was a significant difference ($p < 0.05$) in the breakdown viscosity of the four plantain flour samples, which ranged from 283.80 to 385.45 RVU, and Pita 27 recorded the lowest value. In contrast, Mbi egome plantain flour had the highest value. The final viscosity indicates the ability of starchy foods to form viscous paste after cooking [30]. It ranged from 378.53 to 496.58 RVU. Pita 26 plantain flour had the lowest value, and Agbagba plantain flour had the highest value. Set back viscosity affects the retrogradation or reordering of starch molecules occurs [31]. It ranged from 92.39 to 115.53 RVU. Agbagba plantain flour had the highest value, and Pita 26 plantain flour had the lowest value. Peak time is a measure of the cooking time [32], and it ranged from 4.60 to 4.80 minute with no significant difference ($p > 0.05$). Agbagba plantain flour had the highest value, while Pita 26 plantain flour had the lowest value. Pasting temperature measures the minimum temperature needed to cook a given food sample [33]. The pasting temperature ranged from 81.62 to 83.23°C with Mbi egome plantain flour recording the highest while Pita 26 had the lowest value.

4. Conclusion

Plantain flours obtained from the hybrid cultivars (Pita 27 and Pita 26) is a better alternative to Agbagba (control) plantain flour in terms of chemical composition. Pita 27 plantain flour had the highest values of potassium, calcium, and magnesium but low sodium content. The flour from Mbi egome cultivar had the highest value for all the colour parameters and total carotenoid content. However, Agbagba plantain flour had the highest trough, final and setback viscosities but showed the lowest breakdown viscosity. However, to obtain flour of high water absorption capacity, oil absorption capacity, solubility, and dispersibility, the hybrid cultivars would likely be suitable. Besides, the hybrid plantain cultivars could be used to produce good quality plantain flours with improved physicochemical and pasting properties.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

Oluchukwu Anajekwu was responsible for visualisation, investigation, data curation, and writing original draft preparation. Busie Maziya-Dixon was accountable for conceptualisation, methodology, investigation, supervision, as well as writing, reviewing, and editing. Rahman Akinoso was responsible for supervision, methodology, investigation, as well as writing, reviewing, and editing. Wasiu Awoyale was responsible for visualisation, data curation, software, as well as writing, reviewing, and editing. Emmanuel Alamu performed visualisation, validation, writing, reviewing, and editing.

Conflicts of Interest

The authors reported no potential conflicts of interest.

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