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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

The functional and pasting properties of unripe plantain flour, and the sensory attributes of the cooked paste (*amala*) as affected by packaging materials and storage periods

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Abstract: Unripe plantain flour (UPF) is hygroscopic and gets spoilt if not correctly processed, packaged and stored. Thus, the need to study the functional and pasting properties of the UPF, and the sensory attributes of the cooked paste (*amala*) as affected by packaging materials and storage periods. The UPF was produced using the standard method, packaged in a polypropylene woven sack (PPS) and polyvinyl chloride container (PVC), stored for 20-weeks at room temperature and analyzed at 4-weeks intervals. Results showed that the solubility index of UPF packaged in PPS had a significant ($p < 0.05$) positive correlation with the breakdown viscosity ($r = 0.90$), and a negative correlation with moldability ($r = -0.89$), mouthfeel ($r = -0.92$) and the overall acceptability ($r =$ —0.83) of the *amala*. The peak viscosity of the UPF packaged in PPS had a significant ($p < 0.05$) negative correlation with the stretchability ($r =$ —0.93), mouldability ($r = -0.88$), mouthfeel ($r =$ —0.83) and overall acceptability ($r = -0.01$) of the *amala*. The packaging materials and storage periods had significant effect ($p < 0.05$) on the mouldability of the *amala*. The overall acceptability was higher in the *amala* prepared from PPS packaged UPF compared to that of the PVC. Therefore, UPF should be stored in PPS to retain its sensory attributes.

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PUBLIC INTEREST STATEMENT

Unripe plantain flour is hygroscopic and gets spoilt if not correctly processed, packaged and stored. Also, it is envisaged that the sensory acceptability of plantain *amala* may be affected by the changes in the functional and pasting properties of the packaged flour during storage, thus, the need to evaluate the functional and pasting properties of the unripe plantain flour, and the sensory attributes of the cooked paste (amala) as affected by packaging materials and storage periods. Results showed that unripe plantain flour should be stored in lined-polypropylene woven sack (PPS) to retain its sensory attributes, because the overall acceptability of the amala prepared from flour stored in the PPS was higher compared to amala prepared from the flour stored in polyvinyl chloride container. The outcome of this study will assist the consumers of plantain flour in choosing the proper packaging and storage of the product for shelf stability.

Subjects: Sensory Science; Food Packaging; Preservation; Processing

Keywords: plantain flour; plantain amala; packaging materials; storage period; sensory attributes

1. Introduction

Plantain is a popular dietary staple food due to its versatility and excellent nutritional value; it is a starchy, less sweet variety of banana that can be used either ripe or unripe and are an invaluable source of carbohydrate, comparable in nutritive value to yam or potato. They are consumed mainly in Nigeria as snacks in the form of chips, dodo ikire, and or plantain *amala* (Ibeanu et al., 2016). Above 2.3 million metric tons of plantains are produced in Nigeria annually, with about 35 to 60% post-harvest losses reported and attributed to lack of storage facilities and inappropriate technologies for food processing (Food and Agriculture Organization [FAO], 2014). According to FAO (2014), Nigeria is ranked first in Africa and fifth in the world, producing 2,722,000 metric tonnes of plantain in 2011 and consumed by the entire population. Due to its versatility and better nutritional value, plantain is a popular dietary staple food and is a rich source of nutrients containing 35% carbohydrate, 0.2 to 0.5% fats, 1.2% protein, and 0.8% ash (International Institute of Tropical Agriculture [IITA], 2014).

Plantains are highly perishable, with a substantial proportion of the harvested crop lost from the farm gate to the market place, because of poor handling, storage, and transportation of the fruits. Though work has been done on the utilization of plantain fruits for different food uses, losses may occur in peak production periods when farmers do not harvest the entire crop because of market saturation (Adeolu & Enesi, 2013). In Nigeria and many African countries, plantains are used as an inexpensive source of calories (Adegunwa et al., 2017). Approximately 70 million people derive more than 25% of their carbohydrate source from plantain, especially in West and Central Africa (Olumba, 2014). Unripe plantain finger (UPF) is processed traditionally into flour. The flour is used for several traditional dishes ranging from *akara, ukpo ogede*, soups, baked products and may be reconstituted in boiled water to make *amala* which is eaten with any Nigerian soup (Onuoha et al., 2014). *Amala* is a popular traditional thick paste prepared from blanched, fermented or unfermented dried yam, cassava, sweet potato or unripe plantain flour by stirring the flour in boiled water, and consumed with preferred soup immediately after preparation in most African countries (Abiodun & Akinoso, 2014). *Amala* may be wrapped in low-density polyethylene/polypropylene sheet and kept warm in a food flask until ready to serve within 24 h or 48 h (Fetuga et al., 2014), while other consumers in South-west Nigeria may prefer wrapping the *amala* in special local leaves known as *Ewe Eran* (*Thaumatococcus Daniellii*) and *Ewe Gbodogi* (*Megaphrynium Macrostachyum*), and kept warm in a food flask until ready to serve (Akinfenwa, 2018; Awoyale et al., 2020). It is worth to highlight that *amala* produced from UPF is now favoured to cater for the interest of people with diabetes, realizing its low glycemic index (Uzoukwu et al., 2015).

However, deterioration of floury products is usually attributed to the moisture content of the product, and the water activity and relative humidity of the storage room, as well as the permeability of the packaging materials to air and moisture (Adebowale, Owo et al., 2017; Lawal et al., 2014). Awoyale et al. (2016) reported in their study that the oxygen transmission of polyethylene is 500 mm/100 cm^2 in 24 h and 25 °C, polypropylene 160 mm/100 cm^2 in 24 h and 25 °C and polyvinyl chloride between 8 to 160 mm/100 cm^2 in 24 h and 25 °C. The percentage water absorption of the packaging materials is rated as polypropylene > polyethylene > polyvinyl chloride. These researchers also added that the water vapour transmission of polyethylene is between 1–1.5 g/100 cm^2 in 24 h, polypropylene 0.25 g/100 cm^2 in 24 h and polyvinyl chloride 4–10 g/100 cm^2 in 24 h (Awoyale et al., 2016).Various studies have been reported on the effect of different packaging materials (high and low-density polyethylene bags, polypropylene woven sacks and container) and storage conditions on the quality attributes of floury products. For instance, Adebowale, Owo et al. (2017) reported that the best packaging material with less quality losses in the storage of water yam flour at 25 °C and 36% relative humidity for 24 weeks was the plastic container, attributed to its good barrier properties. Yam flour should be packaged in less permeable plastic packaging materials such as polyethylene and polypropylene bags for shelf-life extension, and not in Hessian bags (Lawal et al., 2014). Awoyale et al. (2020) also reported that packaging yam flour in polyvinyl chloride container may keep most of the sensory properties preferred by the consumers when stored for up to 4 months. However, no work has been reported on the sensory acceptability of the *amala* from unripe plantain flour as it relates to the effect of different packaging materials and storage periods.

It is envisaged that the sensory acceptability of plantain *amala* may be affected by the changes in the functional and pasting properties of the packaged flour during storage, thus, the need to evaluate the functional and pasting properties of the unripe plantain flour, and the sensory attributes of the cooked paste (*amala*) as affected by packaging materials and storage periods.

2. Materials and methods

2.1. Materials

Freshly harvested unripe plantain fingers (*Agbagba*) were obtained from the farms of IITA Ibadan. One hundred and fifty kilograms (150 kg) of the unripe plantain fingers (*Agbagba*) were processed into unripe plantain flour (UPF) according to the methods described by Ndayambaje et al. (2019). The packaging materials (polypropylene woven sack-PPS and polyvinyl chloride container-PVC) were obtained from a local market (Aleshinolye) in Ibadan, Oyo State, Nigeria. The polypropylene woven sack is lined to reduce moisture and air permeability.

2.2. Methods

2.2.1. Processing of unripe plantain fingers into unripe plantain flour

Fresh and healthy green bunches of the plantain fruits were detached from the peduncle. The fruits were de-fingered from the hands and washed to remove adhering dirt and possible chemical residue and latex (which may have exuded from the cut surface of the crown). The plantain fingers were peeled manually with the aid of a stainless knife and submerged in water until the peeling process was completed. The fingers were sliced longitudinally to about 15 mm thickness with a stainless steel knife to enhance dehydration. The sliced plantain was dried in a moisture extraction oven at 60 °C for about 48 h, after which it was milled and sieved to obtain the flour as described by Ndayambaje et al. (2019). The unripe plantain flour (UPF) was then prepared for the storage studies.

2.2.2. Storage studies of unripe plantain flour

Five hundred grams (500 g) of UPF were weighed and packaged separately in PPS and properly sealed, and PVC container sealed with the lid. These packaging materials were stored at room temperature for 20-weeks. The functional and pasting properties of the UPF and the sensory attributes of the *amala* were evaluated every 4-weeks of the 20-weeks storage periods (Awoyale et al., 2020).

2.3. Determination of functional properties of plantain flour

2.3.1. Bulk density

Bulk density was determined using the standard methods described by Ashraf et al. (2012). Flour sample (10 g) was measured into a graduated measuring cylinder (50 mL) and lightly tapped on the workbench (10 times) to attain a constant height. The bulk density was then recorded and expressed as grams per milliliter.

2.3.2. Swelling power and solubility index

For the determination of swelling power and solubility index, aqueous UPF sample dispersions of 2.5% were put in centrifuge tubes, capped to prevent spillage, and heated in a water bath with shaker (Precision Scientific, Model 25: Chicago, USA) at 85°C for 30 min. (Afoakwa et al., 2012). The tubes were cooled to room temperature and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) at 3,000 rpm for 15 min. The weight of the precipitated paste separated from the supernatant was taken (Wp), after which a hot air oven (Memmert GmbH+Co.KG: D-91126, Germany) was used to evaporate the supernatant at 105 °C, and the residue weighed (Wr). The swelling power (SP), and solubility index (SI) was then calculated as:

$$SP = \frac{wt\ of\ precipitated\ paste(W_p)}{wt\ of\ sample(W_o)} - wt\ of\ residue\ in\ supernatant(W_r)$$

$$SI == \frac{Wt\ of\ residue\ in\ supernatant(W_r)}{Wt\ of\ sample(W_o)} \times 100$$

Where W_o is the weight of the sample

2.3.3. Water absorption capacity

The water absorption method (WAC) of the UPF was determined as described by Oyeyinka et al. (2013) with a few modifications. Flour sample of 1 g was weighed into a clean pre-weighed dried centrifuge tube and mixed adequately with 10 ml distilled water by vortexing after which the suspension was allowed to stand for 30 min and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) at 3,500 rpm for 30 min. The supernatant was decanted after centrifugation, with the tube and, the sediment weighed. The weight of water (g) retained in the sample was reported as WAC.

2.3.4. Oil absorption capacity

Flour sample (1 g) was suspended in 5 ml of vegetable oil in a centrifugal tube, after which the slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was decanted and discarded. The adhering drops of oil were removed and reweighed. The oil absorption capacity (OAC) was expressed as the weight of the sediment/initial weight of the sample (g/g) (Niba et al., 2001).

2.3.5. Dispersibility

The method reported by Kulkarni et al. (1991) was used for the determination of the dispersibility. About 10 g of the sample was dispersed in a measuring cylinder (100 ml), and distilled water was added up to the 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted, and the percentage of dispersibility was calculated as:

$$Dispersibility(\%) = \frac{(50 - \text{volume of the settled particle})}{50} \times 100$$

2.3.6. Pasting properties

The pasting properties of the plantain flours were determined using a Rapid Visco Analyser, RVA (Model RVA 4500, Perten Instrument, and Australia) equipped with a 1000 cmg sensitivity cartridge. Plantain flour (3.5 g) was weighed into a dried empty canister, after which 25 ml of distilled water was added. The mixture was thoroughly stirred, and the canister was fitted into the RVA. The slurry was heated from 50 to 95 °C at a rate of 1.5 °C/min., and held at this temperature for 15 min, cooled to 50 °C. Viscosity profile indices recorded were peak viscosity, trough, breakdown, final viscosity, setback, peak time, and pasting temperature was read from the pasting profile using a Thermocline for Windows Software connected to a computer (Falade & Olugbuyi, 2010).

2.3.7. Preparation of plantain amala for sensory evaluation

The UPF was made into *amala* using the method described by Awoyale et al. (Awoyale et al., 2020). One part of the flour was mixed with approximately 1.5 parts of boiling water (v/v) in a stainless-steel pot. The paste was heated (with stirring for 5 min), using an electric cooker set at medium temperature until it is properly cooked. The *amala* was allowed to cool to between 40 to 45 °C in a food flask, and scooped adequately with a spoon for evaluation. The sensory evaluation of the *amala* was carried out using twelve trained panelists from the staff and graduate students of the International Institute of Tropical Agriculture (IITA), Nigeria. They panelist were selected on the basis of their being conversant with eating of plantain *amala* regularly, interest, availability and ability to articulate. A pre-screening exercise was done in which the panelist were screened for normal sensory acuity through basic taste test using solutions of sucrose (sweetness), sodium chloride (saltiness), citric acid (sourness) and quinine sulphate (bitterness), an odour recognition test and an intensity ranking tests as described by Watts et al. (1989). Panelist's sensitivity, which is their ability to discriminate between levels of particular sensory characteristics, was also tested by giving them four consecutive samples from the hardness scale presented in random order and asked to grade the samples in order of increasing hardness. Panelists who passed this pre-screening test were selected for further training. The panelists were trained in a quiet, conducive, comfortable well lit, ventilated, spacious room with a large table and chairs to seat at least 14 people round the table with a white board for illustrations. Six one-hour training sessions was conducted for panelists two weeks before the actual sensory evaluation takes place. The first training session was devoted to explaining the simple definition of the sensory attributes (colour/appearance, texture, stretchability, mouldability, flavour, mouthfeel, and overall acceptability) and familiarizing the panelists with the nature and the differences between basic sensory attributes. The second training involves asking the panelists to describe the attributes of plantain *amala* separately. The third training session involves differentiating the sensory attributes from each other. The sensory attributes considered are colour/appearance, texture, stretchability, mouldability, flavour, mouthfeel, and overall acceptability. The panelists were asked to rank the plantain *amala* produced from the UPF before and during storage (every 4 weeks) for 20-weeks, using a 9-point hedonic scale; 1- corresponds to disliked extremely and 9-liked extremely (Iwe, 2002).

2.3.8. Statistical analysis
The analysis of variance (ANOVA) and separation of the mean values (using Duncan's Multiple Range Test at $p < .05$) were calculated using Statistical Package for Social Scientists (SPSS) software (version 21.0).

3. Results & discussion

3.1. Effect of storage periods and packaging materials on the functional properties of unripe plantain flour
The functional properties of a material are parameters that determine its application and end-use. (Adeleke & Odedeji, 2010). That is, the functional properties indicate how the food materials under examination will interact with other food components directly or indirectly, affecting the processing applications, food quality, and ultimate acceptance. The effect of storage periods and packaging materials on the functional properties of the UPF is presented in Table 1.

The water absorption capacity (WAC) represents the ability of a product to associate with water under conditions where water is limited (Adebowale, Sanni et al., 2008), and it was observed to be significantly ($p < 0.001$) affected by storage periods. The WAC of the UPF increased from 140.31% (zero weeks) to 265.30% (8-weeks) in PPS, and to 235.39% (12-weeks) in PVC, which were similar to the value (299.31%) reported by Ohizua et al. (2017) but higher than the values (131.75%) recorded by Adegunwa et al. (2017), and that of Arinola et al. (2016) (130.00% to 180.00% ml/100 g) for UPF. The WAC was observed to be highest in UPF stored in PPS than in PVC, and this may be attributed to the differences in the percentage water absorption of the packaging materials, which is rated as polypropylene > polyethylene > polyvinyl chloride (Awoyale et al., 2016).

The oil absorption capacity (OAC) is a measure of the ability of food material to absorb oil. A significant difference ($p < 0.05$) was observed in the OAC of UPF stored in PPS, with no significant difference ($p > 0.05$) for that stored in PVC. The OAC of the UPF decreased from 150.04% (zero

Table 1. Effect of storage period and packaging materials on the functional properties of unripe plantain flour

Parameters		Plantain stored in PPS	Plantain stored in PVC			
	Storage wks.	Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
WAC (%)	0	140.31 ± 2.74a	140.31 ± 2.74a			
	4	167.77 ± 3.51ab	139.81 ± 4.19a	NS	***	NS
	8	265.30 ± 1.61c	203.18 ± 7.17ab	NS	***	NS
	12	190.92 ± 3.00b	235.39 ± 6.44b	NS	***	NS
	16	150.20 ± 1.21ab	140.32 ± 3.98a	NS	***	NS
	20	169.76 ± 1.14ab	167.58 ± 0.32ab	NS	***	NS
OAC (%)	0	150.04 ± 2.46ab	150.04 ± 2.46a			
	4	154.14 ± 8.86bc	154.00 ± 4.16a	NS	***	NS
	8	167.24 ± 8.98c	169.0 ± 6.86a	NS	***	NS
	12	139.33 ± 0.47ab	151.23 ± 2.28a	NS	***	NS
	16	143.31 ± 9.53ab	148.93 ± 4.84a	NS	***	NS
	20	133.19 ± 0.19a	134.56 ± 2.45a	NS	***	NS
SWP (%)	0	15.02 ± 0.67a	15.02 ± 0.67a			
	4	14.84 ± 2.18a	15.00 ± 2.10a	NS	NS	NS
	8	15.04 ± 0.06a	15.51 ± 1.04a	NS	NS	NS
	12	13.66 ± 2.56a	15.36 ± 0.02a	NS	NS	NS
	16	14.84 ± 1.13a	13.32 ± 1.20a	NS	NS	NS
	20	14.43 ± 0.10a	14.41 ± 0.35a	NS	NS	NS
SI (%)	0	26.07 ± 1.23b	26.07 ± 0.23c			
	4	16.84 ± 0.53ab	18.81 ± 1.99ab	NS	***	NS
	8	13.56 ± 0.20a	13.47 ± 0.97a	NS	***	NS
	12	17.10 ± 7.21ab	23.33 ± 3.22bc	NS	***	NS

(*Continued*)

Table 1. (*Continued*)

Parameters		Plantain stored in PPS	Plantain stored in PVC			
	Storage wks.	Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
	16	14.00 ± 5.59a	15.12 ± 3.52a	NS	***	NS
	20	18.16 ± 0.46ab	26.75 ± 0.38c	NS	***	NS
BD (g/ml)	0	0.63 ± 0.01b	0.63 ± 0.01c			
	4	0.63 ± 0.01b	0.53 ± 0.01a	***	***	***
	8	0.55 ± 0.27a	0.57 ± 0.00ab	***	***	***
	12	0.59 ± 0.03ab	0.57 ± 0.00ab	***	***	***
	16	0.59 ± 0.03ab	0.59 ± 0.03bc	***	***	***
	20	0.59 ± 0.03ab	0.64 ± 0.04c	***	***	***
Dispersibility (%)	0	71.25 ± 0.35ab	71.25 ± 0.35abc			
	4	70.75 ± 0.35a	69.75 ± 0.35a	NS	***	***
	8	72.00 ± 0.0cd	72.00 ± 0.00c	NS	***	***
	12	71.50 ± 0.00bc	72.00 ± 0.00c	NS	***	***
	16	72.25 ± 0.35d	71.50 ± 0.71bc	NS	***	***
	20	71.75 ± 0.35bcd	70.00 ± 1.41ab	NS	***	***

WAC: Water absorption index, OAC: Oil absorption capacity, SP: solubility power, SI: Solubility index, BD: Bulk density, PPS: Polypropylene woven sack, PVC: Polyvinyl chloride container. NS: not significant ($p > 0.05$); *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Means in the same row and followed by the same letters are not significantly different from each other ($p > 0.05$).

weeks) to 133.19% (20-week) in PPS, and 134.56% (20-weeks) in PVC. These results were higher than the values (111.06% and 129.73%) earlier reported by Ohizua et al. (Ohizua et al., 2017) and Adegunwa et al. (2017), respectively. The high value of OAC obtained for this study may be linked to the fact that the presence of protein might have exposed more non-polar amino acids to the fat and enhances hydrophobicity as a result of which the UPF absorbs more oil (Oluwalana et al., 2011). However, the reduction in OAC in the UPF for both packaging materials was noticed as storage progress (Table 1), and this may be as a result of the reduced ability of the flour to entrap fat to the polar end of its protein chain, which may be attributed to a decrease in its protein content (Abeshu et al., 2016). Thus, UPF having the highest OAC may be useful in the baking industry or pastry as a flavour retainer and, the ability of this flour to bind with oil makes it useful in a food system where optimum absorption is desired. Additionally, the OAC also makes the meal suitable in facilitating enhancement in flavour and mouthfeel when used in food preparation (Adegunwaet al., 2017).

Swelling power (SWP) indicates the degree of exposure of the inner structure of starch granules to the action of water, i.e., a measure of hydration capacity (Kumar & Khatkar, 2017). This study showed no significant difference ($p > 0.05$) in the SWP of the UPF during the storage periods. Similarly, there was no significant ($p > 0.05$) effect of storage periods and packaging materials on the stored UPF. The SWP of the UPF decreased from 15.02% (zero weeks) to 13.66% (12-weeks) in PPS, and to 13.32% (16-weeks) in PVC (Table 1). Thus, the differences in packaging materials and storage periods may be responsible for the changes in SWP during storage. The Solubility index (SI) on the other hand, is related to the extent of leaching of amylose out of starch granules during swelling and affected by intermolecular forces and the presence of surfactants and other associated substances (Kumar & Khatkar, 2017). The SI of the UPF decreased from 26.07% (zero weeks) to 13.56% (8-weeks) in PPS, and to 13.47% (8-weeks) in PVC, though the SI of the PVC packaged UPF later increased to 26.75% at 20-weeks storage period. A significant difference ($p < 0.05$) exist in the SI during the storage periods. The SI of UPF packaged in PPS had a significant positive correlation ($p < 0.05$, $r = 0.90$) with the breakdown viscosity, and a negative ($p < 0.05$) correlation with mouldability ($r = -0.89$), mouthfeel ($r = -0.92$) and the overall acceptability ($r = —0.83$) of the *amala* (Table 4). The SI of the PVC packaged UPF on the other hand, has a negative but not significant ($p > 0.05$) correlation with the stretchability, mouldability, mouthfeel and overall acceptability of the *amala* (Table 5).

To evaluate floury products regarding its weight, handling requirement and the type of packaging materials suitable for storage and transportation of food materials, the bulk density (BD) is critical (Oppong et al., 2015). Similarly, BD of a product is an essential parameter in determining packaging materials and materials handling during food processing (Adebowale Sanni et al., 2011). The BD of the UPF decreased from 0.63 g/cm^3 (zero weeks) to 0.55 g/cm^3 (8-weeks) in PPS, and to 0.53 g/cm^3 (4-weeks) in PVC, although the BD of the UPF stored in PVC later increased to 0.64 g/cm^3 (Table 1). A similar trend was reported by Uzoukwu et al. (2015) for UPF. Abeshu et al. (2016) stated that low BD would be an advantage in the formulation of complementary foods. This implied that UPF with lower BD might be used as complementary foods in composite with other foods rich in protein. The storage periods and packaging materials had a significant ($p < 0.001$) effect on the BD of UPF. A similar significant ($p < 0.01$) trend was observed for the combined interactive effect of the storage periods and packaging materials on the UPF. The BD of the UPF packaged in PPS was negatively correlated ($p < 0.05$, $r = -0.85$) with the texture of the cooked paste (Table 4), while that of the UPF packaged in PVC had a positive and not significant correlation with the texture ($p < 0.05$, $r = 0.46$) of the *amala* (Table 5). However, a significant positive correlation ($p < 0.05$, $r = 0.91$) exists between the BD of the UPF packaged in PVC and the color of the *amala* (Table 5).

Dispersibility is a measure of the reconstitution of floury products in water, and the higher the dispersibility, the better the samples reconstitute in water (Adebowale, Sanni et al., 2008; Kulkarni et al., 1991). The dispersibility of the UPF slightly increased from 71.25% (zero weeks) to 72.25%

(16-weeks) in PPS, and to 72% (8- and 12-weeks) in PVC (Table 1). These results agree with an earlier study reported by Fadimu et al. (2018) (70.00%) on UPF. Also, the UPF stored in PPS showed significantly higher dispersibility value than the UPF stored in PVC, which implies that UPF stored in PPS may reconstitute faster without lump formation than the UPF stored in PVC (Adebowale, Sanni et al., 2008). The storage periods significantly ($p < 0.001$) affected the dispersibility of the UPF while the packaging materials had no significant ($p > 0.05$) effect on the dispersibility of the UPF. However, the dispersibility of the UPF packaged in PPS had a significant ($p < 0.05$) positive correlation with the texture ($r = 0.88$), stretchability ($r = 0.84$), and overall acceptability ($r = 0.84$) of the *amala* (Table 4). But the correlation of these sensory attributes with the dispersibility of the UPF packaged in PVC was positive, but not significant ($p > 0.05$) (Table 5).

3.2. Effect of storage periods and packaging materials on the pasting properties of unripe plantain flour

The pasting properties of flours are used in assessing the suitability of its application as a functional ingredient in food and other industrial product, and also affect the sensory acceptability of cooked starchy products (Oluwalana et al., 2011). Table 2 shows the effect of storage periods and packaging materials on the pasting properties of UPF. The results revealed that packaging materials had no significant ($p > 0.05$) effect on the pasting properties of the UPF, while storage periods had a significant impact ($p < 0.05$) on the pasting properties of the UPF.

The peak viscosity (PV) is the maximum viscosity developed during or soon after the heating of the floury product (Adebowale, Sanni et al., 2008). The PV of the UPF reduced from 723.63RVU (zero weeks) to 372.33 RVU (20-weeks) in PPS, and to 371.13 RUV (16-weeks) in PVC (Table 2). These results are in range with the values reported by Maziya-Dixon et al. (2007) (413.04 RVU), Adegunwa et al. (2017) (509.09 RVU) and Fadimu et al. (Fadimu et al., 2018) (461.37 RVU), for UPF. There was a significant interactive effect ($P < 0.05$) between the storage periods and the packaging materials on the PV of the UPF. The PV of the UPF packaged in the PPS and PVC packaging materials was noticed to decrease as the storage periods increased. However, the PV is often related to the final product quality, as it indicates the viscous load faced during mixing [46]. The PV of the UPF packaged in PPS had a significant negative correlation with the stretchability ($p < 0.01$, $r = —0.93$), mouldability ($p < 0.05$, $r = -0.88$), mouthfeel ($p < 0.05$, $r = —0.83$) and overall acceptability ($p < 0.01$, $r = -0.92$) of the *amala* (Table 4). Similar significant correlations were observed between the PV of the PVC packaged UPF and these sensory attributes of the *amala* (Table 5).

Trough viscosity (TV) is the viscosity at the end of holding time at 95 °C (Adebowale, Sanni et al., 2008). The TV of the UPF reduced from 227.75 RVU (zero weeks) to 121.46 RVU (16-weeks) in PPS, and 154.59 RVU (16-weeks) in PVC (Table 2). The reduction in the TV of the UPF during storage may be because of the difference in the properties of the packaging materials used (Awoyale et al., 2016). The PV of this study corroborates the values recorded by Ohizua et al. (2017) (254.96 RVU) and Fadimu et al. (2018) (251.08 RVU) but lower than the value reported by Adegunwa et al., 2017) (312.50 RVU) for UPF. The differences in plantain varieties, packaging materials and different storage periods may be responsible for these variations. Of all the sensory attributes of the plantain *amala* prepared from PPS packaged UPF, it was only stretchability that has a significant negative correlation ($p < 0.05$, $r = —0.83$) with the TV (Table 4). However, the TV of the PVC packaged UPF had a similar correlation but was not significant ($p > 0.05$, $r = -0.65$) (Table 5).

Breakdown viscosity (BDV) describes the ability of the floury product to withstand heating and shear stress during cooking (Adebowale, Sanni et al., 2008). The BDV of the UPF reduced from 445.88 RVU (zero weeks) to 229.75 RVU (20-weeks) in PPS, and 216.54 RVU (16-weeks) in PVC (Table 2). The BDV of the UPF was generally noticed to decrease with the storage periods in the two packaging materials. The BDV of the UPF packaged in PPS has a significant but negative correlation ($p < 0.05$, $r = -0.83$) with the moldability of the *amala* (Table 4). In addition to the significant negative correlation that exists between the BDV of the UPF packaged in PVC and the moldability

Table 2. Effect of storage periods and packaging materials on pasting properties of plantain flour

Parameters	Storage wks.	Plantain stored in PPS	Plantain stored in PVC			
		Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
Peak viscosity (RVU)	0	723.63 ± 36.71c	723.63 ± 36.71c			
	4	542.92 ± 4.95b	541.13 ± 3.47b	NS	***	*
	8	495.54 ± 26.11b	515.34 ± 0.23b	NS	***	*
	12	517.92 ± 2.95b	497.42 ± 7.78b	NS	***	*
	16	378.09 ± 35.48a	371.13 ± 7.95a	NS	***	*
	20	372.33 ± 13.79a	391.30 ± 22.80a	NS	***	*
Trough viscosity (RVU)	0	277.75 ± 12.02d	277.75 ± 12.02c			
	4	286.34 ± 0.83d	283.67 ± 15.44c	NS	***	**
	8	259.50 ± 9.90c	261.88 ± 2.06bc	NS	***	**
	12	249.71 ± 0.65c	241.75 ± 4.60b	NS	***	**
	16	121.46 ± 4.54a	154.59 ± 12.50a	NS	***	**
	20	142.58 ± 3.54b	156.17 ± 0.35a	NS	***	**
Breakdown viscosity (RVU)	0	445.88 ± 24.69b	445.88 ± 24.69c			
	4	256.59 ± 4.12a	257.46 ± 11.96b	NS	***	NS
	8	236.04 ± 16.21a	253.46 ± 1.82ab	NS	***	NS
	12	268.21 ± 2.30a	255.67 ± 3.18b	NS	***	NS
	16	256.63 ± 30.94a	216.54 ± 4.54a	NS	***	NS
	20	229.75 ± 10.25a	235.13 ± 23.16ab	NS	***	NS
Final viscosity (RVU)	0	407.80 ± 8.31a	407.80 ± 8.31ab			
	4	425.84 ± 0.83a	428.54 ± 6.07b	NS	**	NS
	8	410.79 ± 3.95a	408.09 ± 0.23ab	NS	**	NS

(*Continued*)

Table 2. (*Continued*)

Parameters	Storage wks.	Plantain stored in PPS	Plantain stored in PVC			
		Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
	12	421.29 ± 4.19a	406.08 ± 3.54a	NS	**	NS
	16	460.67 ± 14.97a	494.54 ± 4.54c	NS	**	NS
	20	454.38 ± 47.91a	476.33 ± 17.32c	NS	**	NS
Setback viscosity (RVU)	0	130.05 ± 3.71a	130.05 ± 3.71a			
	4	139.50 ± 1.65a	144.88 ± 9.37ab	NS	*	NS
	8	151.29 ± 5.95a	146.21 ± 1.82ab	NS	*	NS
	12	171.58 ± 3.54a	164.33 ± 1.06b	NS	*	NS
	16	339.21 ± 10.43b	339.96 ± 7.96c	NS	*	NS
	20	311.80 ± 44.37b	320.17 ± 17.68c	NS	*	NS
Peak time (Min)	0	4.64 ± 0.05a	4.64 ± 0.05a			
	4	4.70 ± 0.04a	4.70 ± 0.04a	NS	***	NS
	8	4.64 ± 0.05a	4.60 ± 0.00a	NS	***	NS
	12	4.64 ± 0.05a	4.60 ± 0.00a	NS	***	NS
	16	4.73 ± 0.00a	4.84 ± 0.05b	NS	***	NS
	20	4.87 ± 0.00b	4.83 ± 0.14b	NS	***	NS
Pasting temperature (°C)	0	83.63 ± 0.53a	83.63 ± 0.53a			
	4	83.68 ± 0.53a	83.33 ± 0.04a	NS	***	NS
	8	83.73 ± 0.60a	83.30 ± 0.14a	NS	***	NS
	12	83.33 ± 0.04a	83.30 ± 0.07a	NS	***	NS
	16	83.28 ± 0.04a	83.30 ± 0.00a	NS	***	NS
	20	83.28 ± 0.04a	83.28 ± 0.11a	NS	***	NS

PP: Polypropylene woven sack, PVC: Polyvinyl chloride container; NS: non-significant; *$P < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Means in the same row and followed by the same letters are not significantly different from each other ($p > 0.05$)

of the *amala* ($p < 0.05$, r = —0.84); the stretchability ($p < 0.05$, r = —0.85) and mouthfeel ($p < 0.01$, $r = -0.95$) of the PVC packaged UPF *amala* were significantly correlated with the BDV of the *amala* negatively (Table 5), which is similar to the correlation between the BDV of the PPS packaged UPF, and the stretchability ($p > 0.05$, $r = -0.74$) and mouthfeel ($p > 0.05$, $r = -0.79$) of the *amala*, but which was not significant (Table 4).

Final viscosity (FV) is the ability of the floury product to form viscous paste or gel after cooking and cooling [46]. The FV of the UPF increased from 407.80 RVU (zero weeks) to 460.67 RVU (16-weeks) in PPS, and to 494.54 RVU (16-weeks) in PVC (Table 2). This implied that UPF packaged in PVC and stored for up to 4 months, have the tendency of higher FV when prepared into *amala* compared to that packaged in PPS. However, the FV of the UPF was positively correlated (not significant) to all the sensory attributes ($p > 0.05$) notwithstanding the type of packaging materials used during storage (Tables 4 and 5). This correlation validates the fact that the FV affects starchy gel formation during cooking and cooling (Maziya-Dixon et al., 2007) and maybe one of the important quality parameters that may influence the consumer acceptability of the UPF *amala*.

Setback viscosity (SBV) gives an idea of the retrogradation tendency of starch in the flour sample after 50 °C (Fadimu et al., 2018). The SBV of the UPF increased from 130 RVU (zero weeks) to 339 RVU (16-weeks) in PPS, and to 339.96 RVU (16-weeks) in PVC (Table 2). However, high SBV values have been reported to affect paste digestibility (Shittu et al., 2001), while lower value, which was recorded for zero storage, is important as it indicates a lower tendency for retrogradation, thus, increasing the starch digestibility (Sandhu et al., 2007). This implied that storing of the UPF for 4 months may increase the retrogradation of the *amala*, which may not be desirable to the consumers because of the possible reduction in starch digestibility. But, a significant positive correlation exists between the stretchability and the overall acceptability of the *amala* produced from the PPS packaged UPF ($p < 0.01$, $r = 0.98$) (Table 4), and that of the PVC packaged UPF ($p < 0.05$, $r = 0.91$) (Table 5). However, it is imperative to add that the SBV of the UPF packaged in both PPS (Table 4) and PVC (Table 5) was positively correlated with all the sensory attributes, but not significant ($p > 0.05$) except for the correlation between the SBV of the PPS packaged UPF and the stretchability of the *amala*, which was significant ($p < 0.05$, $r = 0.82$) (Table 4). These variations in the SBV may be attributed to the differences in the properties of the packaging materials used for the flour storage (Awoyale et al., 2016).

The temperature at which the first detectable increase in viscosity is measured and an index characterized by the first change due to swelling of starch is called the pasting temperature (PT) (Julanti et al., 2017). The PT of the UPF slightly decreased from 83.63 °C (zero weeks) to 83.28 °C (20-weeks) for both the PPS and the PVC packaged UPF, which was not significant ($p > 0.05$) (Table 2). The differences in the percentage water absorption of the packaging materials, rated as polypropylene > polyethylene > polyvinyl chloride, may be responsible for the PT behaviour of the flour in the two packaging materials (Awoyale et al., 2016). The results of this study were within the range of values reported by Adegunwa et al. (2017) (82.38 °C) for UPF. The correlation between the PT and all the sensory attributes of PPS packaged UPF *amala* was also negative but not significant (Table 4). The PT of the UPF packaged in PVC has a significant and negative correlation with the stretchability ($p < 0.05$, $r = -0.87$), mouldability ($p < 0.05$, $r = -0.85$) and mouthfeel ($p < 0.01$, $r = -0.96$) of the *amala* (Table 5). The peak time on the other hand, which is a measure of the cooking time of the flour (Adebowale, Sanni et al., 2008), was approximately 5 min for all the UPF packaged in PPS and PVC and stored for 20-weeks (Table 2). This implied that all the UPF would be prepared into *amala* in approximately <5 mins, thus, reducing the cost of energy. A positive but not significant correlation ($p > 0.05$) exist between the peak time of the UPF and all the sensory attributes of the *amala* (Tables 4 & 5).

Table 3. Effect of storage periods and packaging materials on the sensory attributes of unripe plantain *amala*

Parameters	Storage wks.	Plantain stored in PPS	Plantain stored in PVC			
		Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
Texture	0	5.00a±2.35a	5.00 ± 2.35ab			
	4	5.08 ± 2.10a	4.54 ± 2.22a	NS	NS	NS
	8	6.23 ± 1.74a	5.92 ± 1.80ab	NS	NS	NS
	12	6.00 ± 2.04a	5.92 ± 2.01ab	NS	NS	NS
	16	6.38 ± 1.60a	5.62 ± 1.80ab	NS	NS	NS
	20	5.62 ± 2.10a	6.31 ± 1.32b	NS	NS	NS
Colour	0	5.77 ± 2.13a	5.77 ± 2.13a			
	4	5.92 ± 1.32a	5.15 ± 1.95a	NS	NS	NS
	8	5.62 ± 1.76a	5.31 ± 2.21a	NS	NS	NS
	12	5.23 ± 2.09a	5.38 ± 2.29a	NS	NS	NS
	16	6.54 ± 19.4a	5.85 ± 1.46a	NS	NS	NS
	20	5.77 ± 1.24a	6.08 ± 1.44a	NS	NS	NS
Stretchability	0	4.00 ± 1.91a	4.00 ± 1.92a			
	4	4.54 ± 1.61ab	4.62 ± 1.85ab	NS	NS	NS
	8	5.77 ± 1.96bc	5.77 ± 2.09b	NS	NS	NS
	12	5.54 ± 2.10abc	5.62 ± 2.02b	NS	NS	NS
	16	6.54 ± 1.76c	5.69 ± 1.75b	NS	NS	NS
	20	6.15 ± 2.08bc	5.77 ± 1.17b	NS	NS	NS
Mouldability	0	3.62 ± 2.36a	3.62 ± 2.36a			
	4	5.08 ± 1.98ab	4.62 ± 2.14ab	NS	*	NS
	8	6.46 ± 2.22bc	6.15 ± 2.19bc	NS	*	NS
	12	6.46 ± 2.14bc	6.62 ± 1.80c	NS	*	NS

(Continued)

Table 3. (*Continued*)

Parameters	Storage wks.	Plantain stored in PPS	Plantain stored in PVC			
		Mean	Mean	P of Package	P of Storage periods	P of Storage period x Package
	16	7.23 ± 1.30c	6.54 ± 1.85c	NS	*	NS
	20	6.15 ± 2.34bc	6.08 ± 2.06c	NS	*	NS
Flavour	0	6.15 ± 2.11a	6.15 ± 2.12a			
	4	5.85 ± 1.68a	6.00 ± 1.68a	NS	NS	NS
	8	6.46 ± 2.03a	6.00 ± 1.96a	NS	NS	NS
	12	5.38 ± 2.21a	5.62 ± 1.89a	NS	NS	NS
	16	7.00 ± 1.58a	6.15 ± 1.95a	NS	NS	NS
	20	6.00 ± 2.00a	6.23 ± 1.42a	NS	NS	NS
Mouthfeel	0	4.39 ± 2.02a	4.39 ± 2.02a			
	4	5.38 ± 1.66ab	5.23 ± 1.83a	NS	NS	NS
	8	6.31 ± 1.65b	5.77 ± 1.74a	NS	NS	NS
	12	5.38 ± 1.98ab	5.54 ± 1.94a	NS	NS	NS
	16	6.62 ± 1.56b	5.69 ± 1.49a	NS	NS	NS
	20	5.69 ± 1.75ab	5.62 ± 1.26a	NS	NS	NS
OA	0	4.92 ± 1.80a	4.92 ± 1.80a			
	4	5.38 ± 1.66ab	5.23 ± 2.09a	NS	NS	NS
	8	6.08 ± 1.55ab	5.69 ± 2.10a	NS	NS	NS
	12	5.77 ± 1.88ab	6.23 ± 1.48a	NS	NS	NS
	16	6.54 ± 1.85b	6.08 ± 1.26a	NS	NS	NS
	20	6.08 ± 1.71ab	5.92 ± 1.12a	NS	NS	NS

PPS: Polypropylene woven sack; PVC: polyvinyl chloride container; OA: overall acceptability;

NS: Non-significant; *P < 0.05

Means in the same row and followed by the same letters are not significantly different from each other ($p > 0.05$).

Table 4. Pearson correlation of the functional, pasting and sensory properties of plantain flour packaged in a polypropylene woven sack and stored for 20 weeks

	SI	BD	Disp.	PV	TV	BDV	FV	SBV	Ptime	Ptemp	Text	Col	Stre tch	Mo uld	Flav	Mou thf	OA
SI	1.00																
BD	0.69	1.00															
Disp.	−0.50	−0.78	1.00														
PV	0.77	0.55	−0.62	1.00													
TV	0.35	0.30	−0.72	0.82*	1.00												
BDV	0.90*	0.60	−0.35	0.86*	0.41	1.00											
FV	−0.40	−0.09	0.47	−0.84*	−0.93**	−0.5	1.00										
SBV	−0.37	−0.25	0.67	−0.83*	−1.00**	−0.44	0.96**	1.00									
Ptime	−0.12	−0.01	0.20	−0.68	−0.74	−0.43	0.80	0.76	1.00								
Ptemp	0.16	0.11	−0.46	0.64	0.82*	0.30	−0.79	−0.82*	−0.58	1.00							
Text	−0.78	−0.85*	0.88*	−0.67	−0.54	−0.59	0.37	0.50	−0.01	−0.42	1.00						
Col	−0.21	0.16	0.32	−0.35	−0.57	−0.05	0.64	0.60	0.33	−0.18	0.15	1.00					
Stretch	−0.75	−0.73	0.84*	−0.93**	−0.83*	−0.74	0.73	0.82*	0.49	−0.67	0.87*	0.29	1.00				
Mould	−0.89*	−0.74	0.74	−0.88*	−0.64	−0.83*	0.59	0.64	0.26	−0.56	0.92**	0.19	0.94**	1.00			
Flav	−0.30	−0.29	0.66	−0.32	−0.52	−0.04	0.40	0.49	0.11	−0.01	0.44	0.83*	0.42	0.30	1.00		
Mouthf	−0.92**	−0.73	0.75	−0.83*	−0.6	−0.79	0.56	0.60	0.25	−0.28	0.86*	0.45	0.87*	0.91*	0.6	1.00	
OA	−0.83*	−0.73	0.84*	−0.92**	−0.79	−0.77	0.71	0.78	0.42	−0.56	0.89*	0.39	0.98**	0.96**	0.52	0.95**	1.00

*$p < 0.05$; **$p < 0.01$; SI: Solubility index; BD: Bulk density; Disp: Dispersibility; PV: Peak viscosity; TV: Trough viscosity; BDV: Breakdown viscosity; FV: Final viscosity; SBV: Setback viscosity; Ptime: Peak time; Ptemp: Pasting temperature; Text: Texture; Col: Colour; Stretch: Stretchability; Mould: Mouldability; Flav: Flavour; Mouthf: Mouthfeel; OA: Overall acceptability

Table 5. Pearson correlation of the functional, pasting and sensory properties of plantain flour packaged in polyvinyl chloride container and stored for 20 weeks

	SI	BD	Disp.	PV	TV	BDV	FV	SBV	Ptime	Pte mp	Text	Col	Stre tch	Mould	Flav	Mou thf	OA
SI	1.00																
BD	0.62	1.00															
Disp.	−0.35	−0.02	1.00														
PV	0.3	0.03	0.09	1.00													
TV	−0.04	−0.48	0.09	0.83*	1.00												
BDV	0.48	0.39	0.08	0.9**	0.55	1.00											
FV	−0.09	0.31	−0.35	−0.77	−0.90*	−0.52	1.00										
SBV	−0.01	0.43	−0.2	−0.83*	−0.99**	−0.55	0.96**	1.00									
Ptime	0.05	0.36	−0.51	−0.68	−0.85*	−0.43	0.98**	0.92**	1.00								
Ptemp	0.43	0.4	0.06	0.88*	0.45	0.99**	−0.41	−0.46	−0.31	1.00							
Text	0.08	0.46	0.35	−0.60	−0.65	−0.45	0.28	0.51	0.19	−0.51	1.00						
Col	0.47	0.91*	−0.14	−0.30	−0.77	0.09	0.67	0.75	0.70	0.15	0.46	1.00					
Stretch	−0.36	−0.03	0.29	−0.86*	−0.65	−0.85*	0.42	0.57	0.28	−0.87*	0.84*	0.15	1.00				
Mould	−0.36	−0.11	0.38	−0.85*	−0.63	−0.84*	0.39	0.54	0.24	−0.85*	0.77	0.09	0.97**	1.00			
Flav	0.06	0.56	−0.48	−0.08	−0.4	0.16	0.59	0.48	0.67	0.25	−0.05	0.65	−0.17	−0.33	1.00		
Mouthf	−0.53	−0.28	0.16	−0.88*	−0.54	−0.95**	0.41	0.5	0.28	−0.96**	0.65	−0.06	0.96**	0.92**	−0.19	1.00	
OA	−0.18	−0.03	0.35	−0.83*	−0.67	−0.77	0.42	0.59	0.28	−0.78	0.77	0.18	0.91*	0.97**	−0.37	0.83*	1.00

*$p < 0.05$; **$p < 0.01$; SI: Solubility index; BD: Bulk density; Disp: Dispersibility; PV: Peak viscosity; TV: Trough viscosity; BDV: Breakdown viscosity; FV: Final viscosity; SBV: Setback viscosity; Ptime: Peak time; Ptemp: Pasting temperature; Text: Texture; Col: Colour; Stretch: Stretchability; Mould: Mouldability; Flav: Flavour; Mouthf: Mouthfeel; OA: Overall acceptability.

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3.3. Effect of storage conditions and packaging materials on the sensory acceptability of cooked plantain amala

Sensory evaluation is an expression of an individual likes or dislikes for a product as a result of biological variation in humans and how people perceive sensory attributes (Iwe, 2002). Table 3 shows the sensory attributes of the plantain *amala* prepared from UPF packaged in different packaging materials; PPS and PVC. The results show that the storage periods and packaging materials have no significant effect ($p > 0.05$) on the sensory attributes of the plantain *amala* except for the mouldability, which was significantly ($p < 0.05$) affected. The mouldability of the *amala* prepared from PPS packaged UPF move from slightly disliked scale (zero weeks) to moderately liked scale (16-weeks), while that of PVC packaged UPF moved from slightly dislike scale (zero weeks) to slightly liked scale (12-weeks). The changes in the mouldability of the *amala* prepared from the flour stored in the two packaging materials may be attributed to the difference in the percentage water absorption of the packaging materials (Awoyale et al., 2016). The significant negative correlation between the mouldability of the *amala* and the solubility index ($r = -0.89$, $p < 0.05$), peak viscosity ($r = -0.88$, $p < 0.05$) and breakdown viscosity ($r = -0.83$, $p < 0.05$) of the UPF packaged in PPS may be responsible for the changes in the mouldability during storage (Table 4). Also, the significant negative correlation between the mouldability of the *amala* and the peak viscosity ($r = -0.85$, $p < 0.05$) and breakdown viscosity ($r = -0.84$, $p < 0.05$) of the UPF packaged in PVC may be responsible for the changes in the mouldability during storage (Table 5). The interactions between the storage periods and packaging materials had no significant effect ($p > 0.05$) on the sensory attributes of the plantain *amala* (Table 3). The overall acceptability of the *amala* prepared from PPS packaged UPF moved from neither liked nor disliked scale (zero weeks) to moderately liked scale (16-weeks) and that of the PVC packaged UPF moved from neither liked nor disliked scale (zero weeks) to the slightly liked scale at 12-weeks of storage. However, the panelists preferred all the sensory attributes of the plantain *amala* prepared from PPS packaged UPF compared to that packaged in PVC. Therefore, packaging UPF in PPS may keep most of the properties preferred by the consumers when stored for up to 5 months.

4. Conclusion

The study showed that the packaging materials had no significant effect on all the functional (except bulk density) and pasting properties of the stored unripe plantain flour (UPF). Also, the storage periods and packaging materials had no significant effect on the sensory attributes of the *amala* except for the mouldability, which was significantly affected. The solubility index of the UPF packaged in PPS had a significant positive correlation with the breakdown viscosity, and a negative correlation with mouldability, mouthfeel, and the overall acceptability of the *amala*. The dispersibility of the UPF packaged in PPS had a significant positive correlation with the texture, stretchability, and overall acceptability of the *amala*. The peak viscosity of the UPF packaged in PPS had a significant negative correlation with the stretchability, mouldability, mouthfeel and overall acceptability of the *amala*. The overall acceptability was higher in the *amala* prepared from UPF packaged in PPS compared to that packaged in PVC. Therefore, UPF should be stored in PPS to retain its sensory attributes.

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Conflicts of interest

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