Received: 22 April 2020 | Revised: 29 May 2020 | Accepted: 16 June 2020

DOI: 10.1111/jfpp.14732

ORIGINAL ARTICLE

Journal of Food Processing and Preservation | Institute of Food Science + Technology ifst | WILEY

Correlation of the sensory attributes of thick yam paste (*amala*) and the functional and pasting properties of the flour as affected by storage periods and packaging materials

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Funding information
Consultative Group for International Agricultural Research

Abstract

This study aims to evaluate the relationship between the sensory attributes of *amala* and the functional and pasting properties of the yam flour (YF) as affected by storage periods and packaging materials. Results showed that all the functional (except swelling power) and pasting properties of the YF were significantly affected ($p < .05$) by the storage periods. The peak and trough viscosities of polypropylene woven sack (PPS) packaged YF have significant negative correlation with the texture ($r = -.89$ & $r = -.90$; $p < .05$), stretchability ($r = -.87$ & $r = -.83$; $p < .05$), moldability ($r = -.90$ & $r = -.89$; $p < .05$), and overall acceptability ($r = -.90$ & $r = -.89$; $p < .05$) of the *amala*, respectively. *Amala* produced from polyvinyl chloride container (PVC) packaged YF was generally acceptable even at the 16 weeks of storage. Therefore, packaging YF in PVC may keep most of the properties preferred by the consumers when stored for up to 4 months.

Practical applications

This research shows the relationship between the sensory attributes of thick yam paste (*amala*) and the functional and pasting properties of the flour as affected by the storage periods and packaging materials. The use of polypropylene woven sack and polyvinyl chloride container in the storage of yam flour for 20 weeks shows different functional and pasting properties, and thus varying relationships with the sensory attributes of the *amala*. Yam flour should be properly packaged in polyvinyl chloride containers and stored for 4 months, to keep the sensory attributes of the *amala*, with good pasting properties.

1 | INTRODUCTION

Yam (*Dioscorea species*) is one of the extremely regarded food crops in tropical countries of West Africa; it is tightly integrated into the social, cultural, economic, and religious life of the people (Diop, 1998; Ferraro, Piccirillo, Tomlins, & Pintado, 2016). Yam is the second most essential tuber crop in Africa, with Nigeria producing about 34 million tonnes (Food and Agriculture Organization, 2000). Yam tuber is an essential source of carbohydrate and it is also a significant source of income in countries where they are planted. In 2007, 96% of the worldwide production of yam (52 million tons) was from Africa, while 94% of the yam was from West Africa, with Nigeria alone producing 71% (Djeri et al., 2015; Obadina, Babatunde, & Olotu, 2014). Fresh yam tubers are challenging to preserve and are subject to postharvest physiological deterioration during storage due to their moisture content (Afoakwa & Sefa-Dedeh, 2001; Nwaigwe, Okafor, Asonye, & Nwokocha, 2015).

Yam tubers are processed into flour in West African countries like Nigeria, Ghana, and the Republic of Benin to reduce postharvest physiological deterioration due to the high moisture content and seasonal nature (Akissoe et al., 2001; Asiyanbi-Hammed & Simsek, 2018; Babajide & Olowe, 2013; Mestres, Dorthe, Akissoe, & Hounhouigan, 2004). Yam flour is a shelf-stable form of conserving yam tubers to make it available during the off-season (Abiodun & Akinoso, 2014; Oni, 2006), thereby decreasing transportation costs (Iwuoha, 2004). Yam flour is produced by harvesting, sorting, peeling, slicing, blanching, drying, and milling. This is an ancient traditional method of processing yam into dry yam (*gbodo*), and subsequently, yam flour. The quality of the *gbodo* and yam flour differs from the processor location, yam species, processing methods, and conditions, as well as the type of packaging material used for storage (Adejumo, Okundare, Afolayan, & Balogun, 2013; Akissoe, Akissoes, Hounhouigan, & Nago, 2004; Hounhonigan, Kayode, Bricas, & Nago, 2003). Adebowale 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. Lawal, Olaoye, Ibrahim, Sanusi, and Oni (2014) on their own part reported that the Hessian bag should not be used for the storage and preservation of yam flour but that yam flour should be packaged in less permeable plastic packaging materials such as polyethylene and polypropylene bags for shelf-life extension. However, there is presently dearth of information on the effect of packaging materials on the functional and pasting properties of stored yam flour and as it affects the sensory attributes of the cooked thick paste known as *amala*.

Amala is a traditional thick paste prepared from blanched, fermented or unfermented dried yam flour with a specific texture (Abiodun & Akinoso, 2014; Akissoe, Akissoes, Hounhouigan, & Nago, 2006; Awoyale, Maziya-Dixon, Sanni, & Shittu, 2010). Color and taste are the permanent attributes of *amala* obtained from yam flour (Abiodun & Akinoso, 2014; Akissoe et al., 2004). The decline of these sensory attributes (texture, color, and taste) in the *amala* may be due to the packaging materials used for the storage of the yam flour and the activities of spoilage organisms on the yam flour (Ilouno, Ndimele, Adikwu, & Obiekezie, 2016; Jinadasa, Galhena, & Liyanage, 2015; Okigbo, 2003). *Amala* is usually consumed with preferred soup immediately after preparation or may be wrapped in low-density polyethylene/polypropylene sheet and kept warm in a food flask until ready to serve within 24h or 48h (Fetuga, Tomlins, Henshaw, & Idowu, 2014), while other consumers in Southwest Nigeria may prefer wrapping the *amala* in special local leaves known as *Ewe Eran* (*Thaumatococcus Daniellii*) and *Ewe Gbodogi* (*Megaphrynium Macrostachyum*) (Akinfenwa, 2018), and kept warm in a food flask until ready to serve. The knowledge of the functional and pasting properties of yam *spp* could be used to predict and interpret their behavior under actual cooking and cooling conditions (Hariprakesh & Bala, 1996; Jimoh, Olurin, & Aina, 2009). Therefore, this study aims to evaluate the relationship between the sensory attributes of *amala* and the functional and pasting properties of the yam flour as affected by storage periods and packaging materials.

2 | MATERIALS AND METHODS

2.1 | Materials

White yam tubers (*Dioscorea rotundata*) were purchased from the Bodija market, Ibadan, Oyo State, Nigeria. One hundred and fifty kilograms (150 kg) of the yam tubers were processed into yam flour according to the methods described by Awoyale et al. (2010). The packaging materials (PVC and PPS) were purchased from a local market (Aleshinloye) in Ibadan, Oyo State, Nigeria.

2.2 | Methods

2.2.1 | Production of yam flour

Yam flour was produced using the method described by Awoyale et al. (2010). Fresh and healthy yam tubers were cleaned, washed properly with clean water to remove adhering sand particles. The head of each tuber (1 cm) was cut off and the remaining section peeled manually using a stainless steel knife. The peeled tubers were washed several times with potable water before slicing. The slices were spread in a single layer on drying trays and dried at 65°C for 48 hr in an oven. Dried yam slices were milled into flour using a hammer mill of 250 μm sieve size. The yam flour was then packaged into polypropylene bags and sealed for further study.

2.2.2 | Storage studies of yam flour

The yam flour samples (500 g) were weighed and packaged in polypropylene woven sack (PPS) (25 cm height × 13 cm breadth) and sealed with a stitching machine, and a polyvinyl chloride container (PVC) (6 cm height × 13 cm breadth), and covered with a lid (Awoyale, Maziya-Dixon, Alamu, & Menkir, 2016). These packaging materials were stored at ambient temperature (28–30°C) inside a cupboard without light interference for 20 weeks. The sensory attributes of the *amala* and the functional and pasting properties of the yam flour were evaluated every 4 week of the 20 weeks of storage periods.

2.2.3 | Preparation of yam *amala* for sensory evaluation

The yam flour was made into *amala*, as reported by Awoyale et al. (2010). The yam flour (1 part) was mixed with boiling water (approximately 1.5 parts v/v) in a stainless-steel cooking pot. Each sample of *amala* was prepared by pouring the yam flour into boiling water (100°C) in the stainless-steel cooking pot with continuous stirring until a homogenous thick paste was formed. The paste was covered and left on the electric cooker set at medium temperature for about 3 min to cook before another stirring to get a good textured paste. The *amala* was scooped adequately with a spoon and wrapped in polyethylene nylon before evaluation. The preparation of each of the *amala* samples was performed three times for each panelist. The sensory evaluation was carried out using trained panelists (twelve) from the staff and graduate students IITA, Nigeria, who consumed yam *amala* regularly based on attributes such as color/appearance, texture, stretchability, moldability, flavor, mouthfeel, and overall acceptability. The panelists were asked to rank the *amala* produced from the yam flour before and during storage (every 4 weeks) for 24 weeks, using a 9-point hedonic scale; 1- corresponds to disliked extremely and 9-liked extremely (Iwe, 2002; Nkama & Filli, 2006).

2.2.4 | Yam flour functional properties

Bulk density

Flour samples (10 g) were measured into a 50 ml graduated measuring cylinder and gently tapped on the bench 10-times to achieve a constant height. The volume of the sample was recorded and expressed as grams per milliliter (Ashraf et al., 2012).

Swelling power and solubility index

The method reported by Afoakwa, Budu, Asiedu, Chiwona-Karltun, and Nyirenda (2012) was used for the determination of the swelling power (SWP) and solubility index (SI) of the samples. About 2.5% aqueous starch dispersion was put in centrifuge tubes, capped to prevent spillage, and heated in a water bath with shaker (Precision Scientific, Model 25: Chicago, USA) at a temperature of 85°C for 30 min. The tubes were allowed cooled to room temperature and centrifuged after heating (Thelco GLC- 1, 60647: Chicago, USA) at 3,000 rpm for 15 min. The paste was separated from the supernatant and weighed. The liquid above the sediment was evaporated in a hot air oven (Mmert GmbH + Co.KG: D-91126, Germany) at a temperature of 105°C, and the residue weighed. All determinations were performed in duplicates, and the SWP and SI were calculated as:

$$\text{SWP} = \frac{\text{Wt of precipitated paste}}{\text{Wt of sample}} - \text{wt of residue in supernatant} \times 100$$

$$\text{SI} = \frac{\text{Wt of residue in supernatant}}{\text{Wt of sample}} \times 100.$$

Water absorption capacity

About 1 g of flour sample was weighed into a clean pre-weighed dried centrifuge tube and mixed adequately with distilled water (10 ml) by vortexing. The suspension was allowed to stand for 30 min and Centrifuged (Thelco GLC-1, 60647: Chicago, USA) at 3,500 rpm for 30 min. After centrifuging, the supernatant was decanted, and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as the WAC (Oyeyinka et al., 2013).

Oil absorption capacity

Flour sample (1 g) was suspended in vegetable oil (5 ml) inside a centrifugal tube. The slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3,000 rpm for 10 min. The supernatant was decanted and discarded. The adhering drops of oil were removed and reweighed. The OAC was expressed as the weight of the sediment/initial weight of the sample (g/g) (Akinwale, Shittu, Adebowale, Adewuyi, & Abass, 2017; Asouzu & Umerah, 2020; Niba, Bokonga, Jackson, Schlimme, & Li, 2001).

Dispersibility

A sample of 10 g was dispersed in distilled water in a 100 ml measuring cylinder, and distilled water was added up to 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 hr. The volume of settled particles was noted and the percentage was calculated (Asaam, Adubofuor, Amoah, & Apeku, 2018; Kulkarni & Ingle, 1991).

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

2.2.5 | Pasting properties of yam flour

The pasting properties of yam flour were measured using a Rapid Visco Analyzer (Model RVA 4500, Perten Instruments, and Australia) equipped with a 1,000 cmg sensitivity cartridge. Yam flour (3.5 g) was weighed into a dried empty canister and 25 ml of distilled water was added. The mixture was thoroughly stirred and the canister was fitted into the RVA as recommended. The slurry was heated from 50 to 95°C at a rate of 1.5°C/min, held at this temperature for 15 min, cooled to 50°C. Viscosity profile indices recorded from the pasting profile with the aid of Thermocline for Windows Software connected to a computer were peak viscosity, trough, breakdown, final viscosity setback, peak time, and pasting temperature (Akonor, Tortoe, & Buckman, 2017; Donaldben, Tanko, & Hussaina, 2020; Falade & Olugbuyi, 2010).

2.2.6 | 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 AND DISCUSSIONS

3.1 | Effect of packaging materials and storage periods on the sensory attributes of *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 (Sharif, Butt, Sharif, & Nasir, 2017). The sensory attributes of the *amala* prepared from yam flour packaged in different packaging materials (PPS and PVC) and stored for 20 weeks are shown in Table 1. The results depict that the storage periods and packaging materials have no significant effect ($p > .05$) on the sensory attributes of the *amala* except for the moldability, which was significantly ($p < .05$) affected by the storage periods. The moldability of the *amala* prepared from PPS packaged yam flour moved from the slightly disliked scale (zero weeks) to somewhat liked scale (12 weeks). The PVC packaged yam flour moved from somewhat disliked scale (zero weeks) to moderately liked scale (16 weeks), although there was no significant difference ($p > .05$) in the moldability of the *amala* prepared from PPS packaged yam flour stored for between 4 and 12 weeks, as well as the moldability of the *amala* made from the PVC, packaged yam flour stored for 4, 8, and 16 weeks (Table 1). This implied that the moldability of *amala* might improve from dislike to like if yam flour is packaged in PPS and stored for 12 weeks, or in PVC and stored for 16 weeks. The interactions between the storage periods and packaging materials had no significant effect ($p > .05$) on the *amala* (Table 1). The overall acceptability of the *amala* moved from neither liked nor disliked scale (zero weeks) to moderately liked scale in PPS packaged yam flour (4 and 12 weeks) and in PVC packaged yam flour (4, 8, and 16 weeks) (Table 1). However, the panelists generally preferred *amala* prepared from PVC packaged yam flour compared to that packaged in PPS. Therefore, packaging yam flour in PVC may keep most of the properties preferred by the consumers when stored for up to 4 months.

3.2 | Effect of storage periods and packaging materials on the functional properties of yam flour

The functional properties of a particular food describe the physical and chemical characteristics that impact the behavior of the protein in food systems during processing, cooking, storage, and consumption (Mahajan & Dua, 2002). The functional properties of yam flour as affected by storage period and packaging materials are shown in Table 2. The results revealed that all the functional properties of the yam flour were significantly affected by the storage periods ($p < .001$) except the swelling power, which was not significantly affected ($p > .05$). The packaging materials, moreover, have no significant effect ($p > .05$) on all the functional properties of the yam flour except the bulk density, which was significantly affected ($p < .001$). The bulk density and the dispersibility of the yam flour were significantly affected ($p < .001$) by the interactions between the storage period and the packaging materials (Table 2).

Water absorption capacity (WAC) represents the ability of a product to associate with water under conditions where the water is limited (Singh, 2001). The WAC is desirable in food systems to improve yield, consistency, and give body to the food (Osundahunsi, Fagbemi, Kesselman, & Shimoni, 2003). The WAC increased from 145.16% (zero weeks) to 193.45% (8 weeks) in PPS packaged yam flour, and to 203% (8 weeks) in PVC packaged yam flour. There was no significant difference ($p > .05$) in the WAC of the PPS packaged yam flour stored for the different storage periods except for the 8 weeks of storage, which was significantly different ($p < .05$). The WAC of the PVC packaged yam flour stored for 8 weeks was not significantly different ($p > .05$) from those stored for 12 and 20 weeks (Table 2). The texture ($r = .25$), stretchability ($r = .23$), moldability ($r = .23$), and overall acceptability ($r = .37$) of the *amala* prepared from the PPS packaged yam flour were positively correlated with the WAC of the yam flour, though not significant ($p > .05$) (Table 3). In contrast, the WAC of the PVC packaged yam flour has a negative but not significant correlation ($p > .05$) with the texture ($r = -.12$), stretchability ($r = -.21$), and moldability ($r = -.19$) of the *amala* (Table 4). The correlation between the WAC of the PVC packaged yam flour and the overall acceptability ($r = .09$) of the *amala* was also positive and not significant ($p > .05$) (Table 4). Generally, the WAC increased with an increase in the storage period in both the PPS and PVC packaging materials. This observation suggests that storage may affect the affinity of yam flour to absorb water when held for a very long time, and which may be attributed to the loose of association of amylose and amylopectin, and weaker associative forces maintaining the structure of the granules that takes place during storage (Adebowale et al., 2017; Lorenz & Collins, 1990).

The oil absorption capacity (OAC) is a measure of the ability of food material to absorb oil. High OAC is desired in the retention of flavor, improvement of palatability, an extension of shelf life of bakery products, baked goods, meat extenders, doughnuts, pancakes, and soup mixes (Okpala, Okoli, & Udensi, 2013; Seena & Sridhar, 2005). The OAC of the PPS packaged yam flour reduced from 136.49% (zero weeks) to 92.58% (20 weeks), and 93.42% (20 weeks) in PVC packaged yam flour, but there was no significant difference ($p > .05$) in the OAC of the yam flour at zero weeks and 8 weeks of storage period for both packaging materials (Table 2). However, a general reduction of the OAC was observed as the storage periods increased for the two packaging materials. The flavor of *amala* produced from the PPS ($r = .76\%$, $p > .05$) and PVC ($r = .81$, $p < .05$) packaged yam flour had a positive correlation with the OAC (Tables 3 and 4). This implied that freshly produced yam flour would retain more flavor than the stored ones, notwithstanding the packaging materials used for storage (Seena & Sridhar, 2005). A negative but not significant correlation ($p > .05$) exists between the mouthfeel of the *amala* produced from the PPS ($r = -.41$) and PVC ($r = -.03$) packaged yam flour (Tables 3 and 4).

The swelling power (SWP) is an indication of the water absorption index of the starch granules during heating (Chinma, Ariahu, & Abu, 2013; Loos, Hood, & Graham, 1981). The SWP of the PPS packaged yam flour increased from 12.86% (zero weeks) to 13.95%

TABLE 1 Effect of storage periods and packaging materials on the sensory attributes of *amala*

Parameters	Storage weeks	Yam stored in PPS	Yam stored in PVC	P of package	P of storage periods	P of storage period × package
Texture	0	4.92 ± 2.87ba	4.92 ± 2.87a			
	4	6.69 ± 1.60b	6.85 ± 1.77b	NS	NS	NS
	8	5.92 ± 2.10ab	6.00 ± 2.00ab	NS	NS	NS
	12	6.69 ± 1.10b	4.38 ± 2.06a	NS	NS	NS
	16	4.69 ± 2.13a	6.92 ± 1.66b	NS	NS	NS
	20	4.62 ± 2.43a	4.62 ± 2.40a	NS	NS	NS
Color	0	7.15 ± 1.57a	7.15 ± 1.57a			
	4	7.08 ± 1.55a	7.46 ± 0.88a	NS	NS	NS
	8	6.85 ± 1.28a	6.85 ± 1.14a	NS	NS	NS
	12	7.38 ± 1.04a	7.38 ± 1.12a	NS	NS	NS
	16	6.77 ± 1.17a	7.31 ± 0.63a	NS	NS	NS
	20	6.85 ± 0.90a	7.08 ± 1.19a	NS	NS	NS
Stretchability	0	3.62 ± 2.33a	3.62 ± 2.33a			
	4	5.77 ± 1.88b	6.31 ± 1.97b	NS	NS	NS
	8	4.92 ± 2.78ab	5.00 ± 2.44ab	NS	NS	NS
	12	6.00 ± 2.04b	3.85 ± 2.27a	NS	NS	NS
	16	3.92 ± 2.02a	6.69 ± 1.25b	NS	NS	NS
	20	3.62 ± 1.80a	4.15 ± 2.23a	NS	NS	NS
Moldability	0	3.53 ± 2.47ab	3.54 ± 2.47a			
	4	5.92 ± 2.63c	6.54 ± 2.60b	NS	*	NS
	8	5.00 ± 2.71bc	5.00 ± 2.61ab	NS	*	NS
	12	6.46 ± 2.11c	3.46 ± 2.03a	NS	*	NS
	16	3.62 ± 2.14ab	6.69 ± 1.38b	NS	*	NS
	20	2.85 ± 1.68a	3.38 ± 2.18a	NS	*	NS
Flavor	0	7.15 ± 1.77a	7.15 ± 1.77a			
	4	6.62 ± 1.98a	7.08 ± 1.12a	NS	NS	NS
	8	6.54 ± 1.61a	6.92 ± 2.102a	NS	NS	NS
	12	6.69 ± 1.89a	6.92 ± 1.23a	NS	NS	NS
	16	6.15 ± 1.57a	6.54 ± 1.13a	NS	NS	NS
	20	5.92 ± 1.75a	6.23 ± 1.36a	NS	NS	NS
Mouthfeel	0	5.69 ± 2.66a	5.69 ± 2.66a			
	4	6.85 ± 1.59a	6.92 ± 1.66a	NS	NS	NS
	8	6.23 ± 2.20a	6.69 ± 1.60a	NS	NS	NS
	12	6.92 ± 1.38a	6.31 ± 1.84a	NS	NS	NS
	16	6.15 ± 1.57a	6.69 ± 1.60a	NS	NS	NS
	20	6.00 ± 1.73a	5.92 ± 1.12a	NS	NS	NS
OA	0	4.85 ± 1.82ab	4.85 ± 1.82a			
	4	6.77 ± 1.79c	7.15 ± 1.91c	NS	NS	NS
	8	6.23 ± 1.96bc	6.62 ± 1.76bc	NS	NS	NS
	12	6.69 ± 1.44c	5.38 ± 1.93ab	NS	NS	NS
	16	4.46 ± 2.15a	6.92 ± 1.32c	NS	NS	NS
	20	4.77 ± 1.92ab	5.15 ± 1.72a	NS	NS	NS

Note: Means with different letters within the same column are significantly different ($p < .05$).

Abbreviations: NS, non-significant; OA, overall acceptability; PPS, polypropylene woven sack; PVC, polyvinyl container.

*$p < .05$.

TABLE 2 Effect of storage period and packaging materials on the functional properties of yam flour

Parameters	Storage weeks	Yam stored in PPS	Yam stored in PVC	Package	Storage periods	Storage period × Package
Water absorption capacity (%)	0	145.16 ± 2.43a	145.16 ± 2.43a			
	4	148.55 ± 2.50a	145.74 ± 4.06a	NS	***	NS
	8	193.45 ± 2.32b	203.23 ± 4.55b	NS	***	NS
	12	158.45 ± 3.39a	160.57 ± 4.82bc	NS	***	NS
	16	147.24 ± 3.40a	140.00 ± 1.08a	NS	***	NS
	20	155.93 ± 2.78a	158.40 ± 0.72bc	NS	***	NS
Oil absorption capacity (%)	0	136.49 ± 0.63c	136.49 ± 0.63c			
	4	108.61 ± 3.83b	116.06 ± 7.53a	NS	***	NS
	8	130.38 ± 1.36c	124.23 ± 1.37bc	NS	***	NS
	12	103.83 ± 0.53b	110.56 ± 7.82b	NS	***	NS
	16	107.55 ± 8.25b	115.29 ± 1.52b	NS	***	NS
	20	92.58 ± 3.67a	93.42 ± 5.01a	NS	***	NS
Swelling power (%)	0	12.86 ± 0.47b	12.86 ± 0.47a			
	4	13.33 ± 0.28b	14.36 ± 1.52a	NS	NS	NS
	8	13.95 ± 0.53b	14.23 ± 0.14a	NS	NS	NS
	12	13.52 ± 1.08b	13.75 ± 0.80a	NS	NS	NS
	16	13.34 ± 0.40b	13.14 ± 1.32a	NS	NS	NS
	20	11.17 ± 0.87a	13.60 ± 0.53a	NS	NS	NS
Solubility index (%)	0	17.70 ± 0.24b	17.70 ± 0.24d			
	4	16.46 ± 0.63ab	16.22 ± 0.04c	NS	***	NS
	8	19.10 ± 1.56b	19.42 ± 0.17e	NS	***	NS
	12	17.73 ± 0.83a	18.56 ± 0.79de	NS	***	NS
	16	14.23 ± 1.96a	12.32 ± 0.13a	NS	***	NS
	20	13.67 ± 1.37a	14.70 ± 0.50b	NS	***	NS
Bulk density (%)	0	86.00 ± 0.01b	86.00 ± 0.01c	***	***	***
	4	79.00 ± 0.14a	166.00 ± 0.12d	***	***	***
	8	76.00 ± 0.05a	80.00 ± 0.00bc	***	***	***
	12	80.00 ± 0.04ab	80.00 ± 0.00bc	***	***	***
	16	75.00 ± 0.03a	76.00 ± 0.05ab	***	***	***
	20	76.00 ± 0.05a	70.00 ± 0.04a	***	***	***
Dispersibility (%)	0	74.00 ± 1.41b	74.00 ± 1.41bc			
	4	71.75 ± 0.35a	72.25 ± 0.35a	NS	***	***
	8	71.50 ± 0.71a	73.00 ± 0.00ab	NS	***	***
	12	76.00 ± 0.00b	75.50 ± 0.00c	NS	***	***
	16	75.00 ± 1.41b	72.00 ± 0.00a	NS	***	***
	20	74.00 ± 0.00b	71.50 ± 0.71a	NS	***	***

Note: Means with different letters within the same column are significantly different ($p < .05$).
Abbreviations: NS, not significant; PPS, Polypropylene woven sack, PVC, Polyvinyl chloride container.
***$p < .001$.

(8 weeks), and to 14.36% (4 weeks) in PVC packaged yam flour. It is imperative to add that the SWP of the PPS packaged yam flour later reduced to 11.17%, while that of the PVC packaged yam flour reduced to 13.60% at 20 weeks of storage period. The reduction in SWP at the end of the storage period was more pronounced in the PPS packaged yam flour because significant differences exist in the SWP between the flour stored for 20 weeks and the other storage periods (Table 2). This means that yam flour packaged in PPS and stored for 20 weeks may exhibit a reduced water absorption index when used for *amala* compared to that packaged in PVC (Loos et al., 1981). The SWP obtained in this study was in range with the values (10.48–13.33) reported by Ogunlakin, Oyeyinka, Ojo, and Oyeyinka (2013) and Tortoe, Dowuona, Akonor, and Dziedzoave (2017) for *D. rotundata*. The SWP of the PPS and PVC packaged

TABLE 3 Pearson correlation between the sensory attributes of *amala* and the functional and pasting properties of yam flour packaged in polypropylene woven sack and stored for 20 weeks

Parameters	Texture	Color	Stretchability	Moldability	Flavor	Mouthfeel	Overall acceptability
Water absorption capacity	0.25	−0.24	0.23	0.23	−0.08	0.06	0.37
Oil absorption capacity	−0.00	0.07	−0.13	0.00	0.76	−0.41	0.02
Swelling power	0.59	0.22	0.59	0.68	0.49	0.43	0.54
Solubility index	0.59	0.48	0.49	0.59	0.77	0.20	0.62
Bulk density	0.10	0.69	−0.03	0.08	0.88*	−0.20	0.05
Dispersibility	−0.23	0.36	−0.13	−0.10	−0.08	0.01	−0.33
Peak viscosity	−0.89*	−0.61	−0.87*	−0.90*	−0.42	−0.71	−0.90*
Trough viscosity	−0.90*	−0.73	−0.83*	−0.89*	−0.69	−0.62	−0.89*
Breakdown viscosity	−0.45	−0.09	−0.54	−0.51	0.32	−0.54	−0.49
Final viscosity	−0.39	−0.79	−0.43	−0.48	−0.30	−0.40	−0.33
Setback viscosity	0.77	0.33	0.67	0.71	0.60	0.45	0.80
Peak time	−0.23	−0.27	−0.37	−0.33	0.39	−0.50	−0.20
Pasting temperature	−0.20	0.06	−0.31	−0.35	0.13	−0.29	−0.17

*$p < .05$.

TABLE 4 Pearson correlation between the sensory attributes of *amala* and the functional and pasting properties of yam flour packaged in polyvinyl chloride container and stored for 20 weeks

Parameters	Texture	Color	Stretchability	Moldability	Flavor	Mouthfeel	Overall acceptability
Water absorption capacity	−0.12	−0.77	−0.21	−0.19	0.05	0.18	0.09
Oil absorption capacity	0.21	−0.14	−0.04	0.13	0.81*	−0.03	0.05
Swelling power	0.27	−0.02	0.28	0.29	0.16	0.68	0.54
Solubility index	−0.42	−0.35	−0.58	−0.46	0.65	−0.11	−0.26
Bulk density	0.52	0.55	0.47	0.54	0.51	0.53	0.53
Dispersibility	−0.54	0.16	−0.58	−0.49	0.59	−0.25	−0.43
Peak viscosity	0.12	0.09	0.21	0.11	−0.64	−0.34	−0.13
Trough viscosity	0.05	−0.12	0.17	0.04	−0.84*	−0.30	−0.12
Breakdown viscosity	0.21	0.53	0.18	0.20	0.13	−0.25	−0.08
Final viscosity	0.57	−0.32	0.50	0.48	−0.24	0.27	0.46
Setback viscosity	0.27	−0.05	0.10	0.23	0.76	0.48	0.40
Peak time	0.35	0.07	0.18	0.26	0.38	−0.09	0.10
Pasting temperature	0.45	0.48	0.37	0.45	0.55	0.44	0.44

*$p < .05$.

yam flour has a positive but not significant correlation ($p > .05$) with the texture (r = 0.59 and $r = .27$), stretchability ($r = .59$ and $r = .28$), moldability ($r = .68$ and $r = .29$), mouthfeel ($r = .43$ and $r = .68$), and overall acceptability ($r = .54$ and $r = .54$), respectively (Tables 3 and 4). The solubility index (SI), moreover, is related to the extent of leaching of amylose out of starch granules during swelling, and it is affected by intermolecular forces (Awuchi, Igwe, & Echeta, 2019; Moorthy, 2002).

The SI reduced from 17.70% (zero weeks) to 13.67% (20 weeks) in the PPS packaged yam flour, and to 12.32% (16 weeks) in the PVC packaged yam flour, although there was an initial sharp increase in the SI at the 8 weeks of storage period in the PPS (19.10%) and PVC (19.42%) packaged yam flour (Table 2). This implied that the leaching of amylose out of the starch granules during the preparation of *amala* and subsequent retrogradation might be more pronounced as the storage periods increased for both packaging materials (Moorthy, 2002; Yeh, Chan, & Chuang, 2009). The SI values (5.88–9.59) reported by Tortoe et al. (2017) for *D. rotundata* were lower compared to that of this study, and which may be ascribed to the effect of storage periods. The SI of the PPS packaged yam flour had a positive but not significant correlation ($p > .05$) with the texture ($r = .059$), stretchability ($r = .49$), moldability ($r = .59$), mouthfeel ($r = .20$), and overall acceptability ($r = .62$) of the *amala* (Table 3). The correlation between the SI and these sensory attributes (texture, stretchability, moldability, mouthfeel, and overall acceptability) for the PVC packaged yam flour was negative ($p > .05$) (Table 4). This inferred that the type of packaging materials used for the storage of yam flour might affect the SI.

The bulk density (BD) is very critical to evaluate floury products regarding its weight, handling requirement, and the type of packaging materials suitable for storage and transportation of the food materials (Ohizua et al., 2017; Oppong, Arthur, Kwadwo, Badu, & Sakyi, 2015). The BD of the yam flour before storage was 86% (zero weeks), which significantly reduced to 75% (16 weeks) in PPS packaged yam flour and 70% (20 weeks) in PVC packaged yam flour (Table 2). The values of the BD of this study were higher than the values (64%–76%) reported for different varieties of water yam flour by Udensi, Oselebe, and Iweala (2008) and Ogunlakin et al. (2013). Fagbemi (1999) and Adepeju, Gbadamosi, Adeniran, and Omobuwajo (2011) reported that high BD is desirable because it offers greater packaging advantage, as more quantity may be packed within a constant volume. This shows that proper packaging of yam flour in PPS and storing for 20 weeks will be more economical in terms of reduction in transportation cost compared to packaging in PVC. The BD of the PVC packaged yam flour had a positive but not significant ($p > .05$) correlation with all the sensory attributes (texture, color, stretchability, moldability, flavor, mouthfeel, and overall acceptability) of the *amala* (Table 4). The correlation was the same for that of the PPS packaged yam flour except for the stretchability and mouthfeel of the *amala* that was negatively correlated with the BD (Table 3). Besides, the BD of the PPS packaged yam flour had a significant positive correlation ($r = .88$, $p < .05$) with the flavor of the *amala* (Table 3).

The measure of the reconstitution of flour in water is known as the dispersibility, and the more the dispersibility, the better the samples reconstitute in water (Adebowale, Sanni, & Onitilo, 2008; Kulkarni & Ingle, 1991). The dispersibility reduced from 74% (zero weeks) to 71.50% (8 weeks) in PPS packaged yam flour, and to 71.50% in PVC packaged yam flour (20 weeks). There was a sharp increase in the dispersibility of the yam flour at 12 weeks of storage in PPS (76%) and PVC (75.5%) packaging materials (Table 2). This implied that yam flour packaged in PPS and PVC might reconstitute properly in hot water without lumps formation in the preparation of *amala*, when stored for 12 weeks (Adebowale et al., 2008), although there was no significant difference ($p > .05$) in the dispersibility of the yam flour stored at zero weeks and 12 weeks for the two packaging materials (Table 2). A negative but not significant ($p > .05$) correlation exists between the dispersibility of the PPS and PVC packaged yam flour and the texture ($r = -.23$ and $r = -.54$), stretchability ($r = -.13$ and $r = -.58$), moldability ($r = -.10$ and $r = -.49$), and overall acceptability ($r = -.33$ and $r = -.43$) of the *amala*, respectively. However, the correlation between the dispersibility and the mouthfeel was positive ($r = 0.01$, $p > .05$) for the PPS packaged yam flour and negative ($r = -0.25$, $p > .05$) for the PVC packaged yam flour (Tables 3 and 4).

3.3 | Effect of storage periods and packaging materials on the pasting properties of yam flour

The pasting properties of flours are used in assessing the suitability of its application as a functional ingredient in food and other industrial products (Oluwalana, Oluwamukomi, Fagbemi, & Oluwafemi, 2011), and it also affects the sensory acceptability of the cooked starchy products (Adebayo-Oyetoro, Ogundipe, & Nojeemdeen, 2016). Gelatinization and pasting of starch are of importance to the food industry because they affect the texture, stability, and digestibility of starchy foods and, thus, control the application and use of flour in different products (Dosunmu & Bassey, 2003; Oke, Awonorin, & Workneh, 2013). The results of the pasting properties of yam flour as affected by storage periods and packaging materials revealed that the storage periods significantly ($p < .05$) affected the pasting properties, while the packaging materials have no significant effect on the pasting properties (Table 5). The combined interaction between storage periods and packaging materials had no significant ($p > .05$) effect on the pasting properties of the stored yam flour except for peak and trough viscosities (Table 5).

The peak viscosity indicates the water binding capacity of the starch, which is often related to the final product quality and indicates the viscous load likely to be encountered during mixing (Maziya-Dixon, Dixon, & Adebowale, 2007). The peak viscosity decreased from 472.71 RVU (zero weeks) to 318.25 RVU (12 weeks) in PPS packaged yam flour, and to 351.42 RVU (8 weeks) in PVC packaged yam flour (Table 5). An increase in peak viscosity was observed at 20 weeks of storage in PPS packaged yam flour (510.83 RVU) and at 16 weeks of storage in PVC packaged yam flour, though there was no significant difference ($p > .05$) in the peak viscosity of the yam flour stored for 16 and 20 weeks for both packaging materials (Table 5). The inconsistency observed in peak viscosity of this study is similar to the observation reported by Akinwande, Adeyemi, Maziya-Dixon, and Asiedu (2007) for starch extracted from different cultivars of *D. rotundata* stored for 4-months, and that of Adebowale et al. (2017). High peak viscosity had been reported to influence the water binding capacity of starch granules and also increases the strength of paste formed during processing (Adebowale et al., 2017; Adebowale, Sanni, & Awonorin, 2005). Thus, yam flour packaged in PPS and PVC and stored for 16 weeks and 20 weeks may be suitable for products requiring high gel strength and elasticity. The peak viscosity of the PPS packaged yam flour had a significant negative correlation with the texture ($r = -.89$, $p < .05$), stretchability ($r = -.87$, $p < .05$), moldability ($r = -.90$, $p < .05$), and overall acceptability ($r = -.90$, $p < .05$) of the *amala*. The correlation between the peak viscosity of the PPS packaged yam flour, and the mouthfeel of the *amala* was also negative but not significant ($r = -.71$, $p > .05$) (Table 3). The PVC packaged yam flour peak viscosity was positively correlated ($p > .05$) with all the sensory attributes of the *amala* except the flavor, mouthfeel, and overall acceptability, which were negatively correlated (Table 4). These variations may be attributed to the difference in the properties of the packaging materials used.

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TABLE 5 Effect of storage periods and packaging materials on the pasting properties of yam flour

Parameters	Storage weeks	Yam stored in PP	Yam stored in PVC	Package	Storage periods	Storage period x Package
Peak viscosity (RVU)	0	472.71 ± 19.15d	472.71 ± 19.15b			
	4	408.41 ± 6.01c	422.13 ± 16.91b	NS	***	*
	8	358.80 ± 25.63b	351.42 ± 0.00a	NS	***	*
	12	318.25 ± 5.19a	355.25 ± 47.84a	NS	***	*
	16	508.38 ± 1.12e	535.25 ± 4.13c	NS	***	*
	20	510.83 ± 1.41e	535.00 ± 15.32c	NS	***	*
Trough viscosity (RVU)	0	175.75 ± 3.78c	175.75 ± 3.78c			
	4	140.30 ± 8.66b	134.09 ± 6.60b	NS	***	**
	8	139.38 ± 18.09b	132.42 ± 0.00b	NS	***	**
	12	108.50 ± 2.23a	114.21 ± 6.89a	NS	***	**
	16	254.29 ± 4.65d	258.25 ± 2.83d	NS	***	**
	20	260.42 ± 2.95d	270.96 ± 3.13e	NS	***	**
Breakdown viscosity (RVU)	0	296.96 ± 22.92b	296.96 ± 22.92b			
	4	268.64 ± 2.65b	288.04 ± 10.31bc	NS	***	NS
	8	219.42 ± 43.72c	219.00 ± 0.00a	NS	***	NS
	12	209.75 ± 2.94a	241.04 ± 54.74ab	NS	***	NS
	16	254.09 ± 5.78ab	277.00 ± 1.30ab	NS	***	NS
	20	250.42 ± 4.36ab	264.05 ± 12.20ab	NS	***	NS
Final viscosity (RVU)	0	404.42 ± 163.34a	404.42 ± 163.34a			
	4	433.21 ± 5.48a	442.92 ± 21.21a	NS	*	NS
	8	421.96 ± 23.28a	432.08 ± 0.00a	NS	*	NS
	12	336.17 ± 0.23a	345.13 ± 2.54a	NS	*	NS
	16	423.63 ± 2.54a	418.34 ± 3.06a	NS	*	NS
	20	416.92 ± 23.69a	436.96 ± 7.25a	NS	*	NS
Setback viscosity (RVU)	0	228.67 ± 167.11a	228.67 ± 167.11a			
	4	292.92 ± 3.18a	308.84 ± 14.62a	NS	*	NS
	8	282.58 ± 41.37a	299.67 ± 0.00a	NS	*	NS
	12	227.67 ± 2.47a	230.92 ± 9.43a	NS	*	NS
	16	169.34 ± 7.19a	160.09 ± 0.23a	NS	*	NS
	20	156.50 ± 26.63a	166.00 ± 4.13a	NS	*	NS
Peak time (Min)	0	4.90 ± 0.04b	4.90 ± 0.04b			
	4	4.83 ± 0.14b	4.90 ± 0.04b	NS	***	NS
	8	4.74 ± 0.09b	4.60 ± 0.00ab	NS	***	NS
	12	4.40 ± 0.38a	4.37 ± 0.33a	NS	***	NS
	16	4.64 ± 0.05ab	4.60 ± 0.00ab	NS	***	NS
	20	4.64 ± 0.05ab	4.64 ± 0.05ab	NS	***	NS
Pasting temperature (°C)	0	83.35 ± 0.14a	83.35 ± 0.14a			
	4	83.35 ± 0.07a	83.70 ± 0.57a	NS	***	NS
	8	83.30 ± 0.07a	83.30 ± 0.00a	NS	***	NS
	12	83.30 ± 0.07a	83.28 ± 0.04a	NS	***	NS
	16	83.30 ± 0.00a	83.23 ± 0.04a	NS	***	NS
	20	83.35 ± 0.07a	83.25 ± 0.00a	NS	***	NS

Note: Means with different letters within the same column are significantly different ($p < .05$).

Abbreviations: NS, not significant; PPS, polypropylene woven sack; PVC, polyvinyl chloride container; RVU, rapid visco unit.

*$p < .05$; **$p < .01$; ***$p < .001$.

The trough viscosity measures the ability of the starch paste to withstand breakdown during cooling. Thus, the trough viscosity is very important in describing the quality of the starch gel (Adebowale et al., 2008; Adegunwa, Omolaja, Adebowale, & Bakare, 2016; Madsen & Christensen, 1996; Mubaiwa, Fogliano, Chidewe, & Linnemann, 2018). The trough viscosity increased from 175.75 RVU (zero weeks) to 260.42 RVU (20 weeks) in PPS packaged yam flour, and to 270.96 RVU (20 weeks) in PVC packaged yam flour, but there was a significant ($p < .05$) reduction in the trough viscosity of the PPS (108.50 RVU) and PVC (114.21 RVU) packaged yam flour at 12 weeks of storage (Table 5). The higher trough viscosity of the yam flour at the 20 weeks of storage may indicate greater ability to withstand shear at high temperatures and higher cooked paste stability when the yam flour is reconstituted in boiled water to *amala* (Farhat, Oguntona, & Neale, 1999; Rasper, 1969). The texture ($r = -.90$, $p < .05$), stretchability ($r = -.83$, $p < .05$), moldability ($r = -.83$, $p < .05$), and overall acceptability of the PPS packaged yam flour *amala* have a significant negative correlation with the trough viscosity of the yam flour. The other sensory attributes of the *amala* (color, flavor, and mouthfeel) were negatively correlated with the trough viscosity of the PPS packaged yam flour, though not significant (Table 3). The trough viscosity of the PVC packaged yam flour, moreover, had a positive but not significant ($p > .0\%$) correlation with the texture ($r = .05$), stretchability ($r = .17$), and moldability ($r = .04$) of the *amala*, while the correlation with the color ($r = -.12$, $p > .05$), flavor ($r = -.84$, $p < .05$), mouthfeel ($r = -.30$, $p > .05$), and overall acceptability ($r = -0.12$, $p > .05$) of the *amala* was negative and not significant except for the flavor, which was significant (Table 4).

The breakdown viscosity significantly ($p < .05$) reduced from 296.96 RVU (zero weeks) to 209.75 RVU (12 weeks) in PPS packaged yam flour, and to 219 RVU (8 weeks) in PVC packaged yam flour (Table 5). There was no significant difference ($p > .05$) in the breakdown viscosity of the PPS packaged yam flour stored for 12 weeks, and the PVC packaged yam flour stored for 8 weeks with that of the 20 weeks of storage (Table 5). Breakdown viscosity describes the ability of the floury product to withstand heating and shear stress during cooking, and high breakdown viscosity is associated with a decreased ability of starch to withstand heating and shear tress (Adebowale et al., 2008, 2017; Ohizua et al., 2017). This means that the storage of yam flour in PPS for 12 weeks and PVC for 8 weeks may increase the ability of the starch to withstand heating and shear stress during reconstitution to *amala*, due to the low breakdown viscosities (Adebowale et al., 2008; Falade & Christopher, 2015).

The final viscosity is the most commonly used parameter to determine the ability of starch-based materials to form a viscous paste or gel after cooking and subsequent cooling as well as the resistance of the paste to shear force during stirring (Adebowale et al., 2005; Maziya-Dixon et al., 2007; Sanni et al., 2015). An increase in the final viscosity was observed in the PPS packaged yam flour from 404.42 RVU (zero weeks) to 433.21 RVU (4 weeks) and a subsequent reduction to 416.92 RVU at the end of the storage period of 20 weeks. Similarly, the final viscosity of the PVC packaged yam flour increased from 404.42 RVU (zero weeks) to 442.92 RVU (4 weeks) and later reduced to 436.96 RVU at the end of the storage period (20 weeks) (Table 5), although the final viscosity was not significantly different for all the storage periods. This implied that yam flour packaged in PVC and stored for up to 20 weeks has the tendency of higher final viscosity and may form a viscous paste when prepared into *amala* compared to that packaged in PPS (Adebowale et al., 2005). The final viscosity of the yam flour in this study falls within the range of values (157.11–649.58) reported by Wahab et al. (2016) for *D. rotundata*. All the sensory attributes of the PPS packaged yam flour *amala* were negatively correlated ($p > .05$) with the final viscosity of the yam flour (Table 3). The final viscosity of the PVC packaged yam flour had a positive but not significant ($p > .05$) correlation with the texture ($r = .57$), stretchability ($r = .50$), moldability ($r = .48$), mouthfeel ($r = .27$), and the overall acceptability ($r = .46$) of the *amala* (Table 4).

The setback viscosity gives an idea of the retrogradation tendency of starch in the flour sample after 50°C (Adebowale et al., 2008; Ohizua et al., 2017). The setback viscosity of the PPS packaged yam flour initially increased from 228.67 RVU (zero weeks) to 292.92 RVU (4 weeks) and later decreased to 156.50 RVU at the end of storage (20 weeks). Also, the PVC packaged yam flour originally increased from 228.67 RVU (zero weeks) to 308.84 RVU (4 weeks), and then reduced to 160.09 RVU (16 weeks) (Table 5). High setback viscosity is reported to be associated with syneresis or weeping during freeze/thaw cycles (Adebowale et al., 2005; Wahab et al., 2016), while low setback during the cooling of paste or a starch-based food indicates greater resistance to retrogradation (Sanni, Kosoko, Adebowale, & Adeoye, 2004; Wahab et al., 2016). This implied that the *amala* produced from the zero week yam flour might weep easily compared to that packaged in both PPS and PVC and stored for 20 weeks (Adebowale et al., 2005). The setback viscosities of the PPS and PVC (except color) packaged yam flour were positively correlated with all the sensory attributes ($p > .05$) (Tables 3 and 4).

The temperature at which the first detectable increase in viscosity is measured and which is an index characterized by the first change due to swelling of starch is called the pasting temperature (Chinma et al., 2013; Julanti, Rusmarilin, & Ridwansyah, 2015; Ohizua et al., 2017). The pasting temperature of the yam flour packaged in PPS and PVC remains statistically the same throughout the storage periods (approximately 83°C). The peak time, which is a measure of the cooking time of the flour (Adebowale et al., 2008; Ohizua et al., 2017), was approximately 5min for all the yam flour packaged in PPS and PVC and stored for 20 weeks (Table 5). However, there was a significant ($p < .05$) reduction in the peak time from 4.90 min (zero weeks) to 4.40 min (12 weeks) in PPS packaged yam flour, and to 4.37 min (12 weeks) in PVC packaged yam flour (Table 5). This implied that all the yam flour might be prepared into *amala* in approximately 5 min and less than the boiling point of water (83°C), thus, reducing the cost of energy consumption (Awoyale et al., 2016). The peak time of the PPS packaged yam flour was negatively correlated with all the sensory attributes of the *amala* ($p > .05$) except the flavor, which was positive and also not significant ($p > .05$) (Table 3). In contrast, the peak time of the PVC packaged yam flour had a positive but not significant correlation with all the sensory attributes of the *amala* except for the mouthfeel, which was negative ($p > .05$) (Table 4). All the sensory attributes of the *amala* (except color and flavor) produced from the PPS packaged yam flour have a negative correlation with the pasting temperature of the yam flour ($p > .05$) (Table 3), while the correlation between the pasting temperature of the PVC packaged yam flour and all the sensory attributes were positive ($p > .05$) (Table 4).

4 | CONCLUSIONS

This study revealed that the packaging materials and storage periods had no significant effect ($p > .05$) on the sensory attributes of the *amala* except the moldability, which was significantly affected by the storage periods. All the functional (except swelling power) and pasting properties of the yam flour were also significantly affected ($p < .05$) by the storage periods. The peak and trough viscosities of the yam flour packaged in polypropylene woven sack have a significant negative correlation with the texture, stretchability, moldability, and overall acceptability of the *amala*. The correlation of the peak and trough viscosities of the yam flour packaged in polyvinyl chloride container with the texture, stretchability, and moldability of the *amala* was positive but not significant, while that of the overall acceptability was negative, although the flavor of the *amala* produced from polyvinyl chloride container packaged yam flour was positively correlated with the oil absorption capacity and negative for the trough viscosity. The overall acceptability was higher in the polyvinyl chloride container packaged yam flour amala compared to that packaged in polypropylene woven sack, specifically at the 16 weeks of storage. Therefore, yam flour should be stored in polyvinyl chloride container instead of the polypropylene woven sack, to retain its sensory attributes for 12 weeks.

ACKNOWLEDGMENTS

This research was supported by Roots, Tubers, and Bananas Foods and carried out at the International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State, Nigeria.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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How to cite this article: Awoyale W, Oyedele HA, Maziya-Dixon B. Correlation of the sensory attributes of thick yam paste (*amala*) and the functional and pasting properties of the flour as affected by storage periods and packaging materials. *J Food Process Preserv*. 2020;00:e14732. https://doi.org/10.1111/jfpp.14732