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Functional and Pasting Properties of *Gari* Produced from White-fleshed Cassava Roots as Affected by Packaging Materials and Storage Periods, and Sensory Attributes of the Cooked *Gari* Dough (*eba*)

Wasiu Awoyale[a, b], Hakeem Oyedele[b], and Busie Maziya-Dixon[a*]

[a] International Institute of Tropical Agriculture, PMB 5320 Oyo Road, Ibadan, Oyo State, Nigeria
[b] Department of Food Science & Technology, Kwara State University Malete, PMB 1530, Ilorin Kwara State, Nigeria
[*]Corresponding author
b.maziya-dixon@cgiar.org
Tel.: +2348039784451

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Abstract

Gari (roasted fermented cassava grits) is the most popular product consumed in West Africa and an important food product in the diet of millions of people in developing countries. The study investigated the effect of packaging materials (PM) and storage periods on the functional and pasting properties of *Gari* produced from white-fleshed cassava roots and sensory attributes of the cooked *Gari* dough (*eba*).*Gari* was produced using the standard method and packaged in a polypropylene woven sack (PP) and polyvinyl chloride container (PVC). *Gari* was stored for 24 weeks at room temperature and sampled at four-week intervals for functional and pasting properties, and sensory evaluation of the *eba* , using standard methods. The results showed that the storage periods significantly affected all the functional (except swelling power) and pasting properties of the *Gari*, and PM had no significant ($p>0.05$) effect on the functional (except bulk density) and pasting properties. Also, the PM had no significant effect on the sensory attributes of the *eba* except for the mouldability ($p<0.05$). The setback viscosity of the *Gari* packaged in PVC had a significant ($p<0.05$, $r= -0.58$) negative correlation with the texture of the *eba*. The panellists preferred all the sensory attributes of the *eba* made from the *Gari* stored in PP compared to that made from *Gari* stored in PVC. Therefore, packaging *Gari* in PP may keep most of the properties preferred by consumers when stored for up to 5 months.

Keywords: *Gari*; Packaging materials; Storage period; Sensory evaluation; *eba*

1 Introduction

Cassava (*Manihot esculenta*) is the third-largest source of carbohydrates in the tropics, after rice and maize (Fauquet & Fargette, 1990). Cassava root is a primary staple food in the developing world, providing an essential diet for over half a billion people (FAO, 1995). Nigeria is the largest producer of cassava root in the world, whilst Thailand is the largest exporter of cassava products. At present, cassava is undergoing a transition from a mere subsistence crop found in the fields of peasants to a commercial plant grown in plantations. This expansion is attributed to its discovery as a major source of food carbohydrate that could be processed into different forms of human delicacies and animal feeds (Simonyan et al., 2014).

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Cassava has been a source of raw materials for many industrial products such as starch, flour, and ethanol. Cassava production is relatively easy as it is tolerant of the biotic and edaphic factors that hamper the production of other crops. Cassava roots are used to store energy, unlike the roots of sweet potato and yam tuber that are reproductive organs. Despite their agronomic advantages, root crops are far more perishable than other staple food crops. Westby (2002) reported that cassava has a shelf life that is generally accepted to be of the order of 24 to 48 h after harvest.

Cassava utilization patterns vary considerably in different parts of the world, and in Nigeria, the majority of the cassava produced (90%) is used for human food. Thus, cassava, in its processed form, is a reliable and convenient source of food for ten million rural and urban dwellers in Nigeria (IITA, 2010). However, fresh cassava has a limited storage life because of its high moisture content, and its processing into relatively shelf-stable intermediate and final products for various food applications is therefore necessary (Quaye, Gayin, Yawson & Plahar, 2009). Cassava can be transformed into different products such as *Gari, fufu, lafun,* and many other West African traditional dishes (Afoakwa, Kongor, Annor & Adjonu, 2010).

Gari is a roasted, fermented cassava meal, and the most important food product in the diet of millions of Nigerians and Ghanaians (Afoakwa et al., 2010). *Gari* is a staple food that used to be within the purchasing power of many people in the society irrespective of their income and status (Sanni, Adebowale, Awoyale & Fetuga, 2008). *Gari* is produced by grating fresh roots into a mash, fermenting, de-watering, granulating, sifting, and roasting into gelatinized particles (James et al., 2012). However, there is a need to package the *Gari* before marketing and subsequent storage.

The storage stability of food systems depends on the storage conditions, packaging materials, and the water activity of the food material (Ilouno, Ndimele, Adikwu & Obiekezie, 2016; Okigbo, 2003). The deterioration of floury products is usually attributed to the type of packaging materials and spoilage organisms, such as bacteria and fungi. Various studies have examined the effect of different packaging materials (high and low-density polyethylene bags, polypropylene woven sacks and containers) and storage conditions on the quality attributes of *Gari* (Adebowale et al., 2017; Adejumo & Raji, 2012; FAO, 1999; Ogiehor & Ikenebomeh, 2006). However, at the time of this study, to the best of our knowledge, no work has been reported on the sensory acceptability of cooked paste (*eba*) from *Gari* as it relates to the effect of different packaging materials and storage conditions. Hence, this study aims to evaluate the impact of packaging materials and storage periods on the functional and pasting properties of *Gari* produced from white-fleshed cassava roots, and sensory attributes of the cooked paste (*eba*).

2 Materials and Methods

2.1 Materials

Freshly harvested cassava roots [tropical Manioc esculenta 419 (TME419)] were obtained from the farms of IITA Ibadan. One hundred and fifty kilograms (150 kg) of the cassava roots were then processed into *Gari.* The packaging materials (PVC and PP) were obtained from a local market (Aleshinolye) in Ibadan, Oyo State, Nigeria.

2.2 Processing of Cassava roots into *Gari*

Gari was produced using the method described by Abass, Dziedzoave, Alenkhe and James (2013). Healthy cassava roots were peeled, washed, and grated. The resulting mash was packed in a polypropylene (PP) woven sack, which was then put in a fermenter. The grated cassava mash was allowed to ferment for 72 h under ambient temperature. The fermented mash was dewatered and sieved to remove fibrous materials and then roasted. The *Gari* was allowed to cool and packed in polyethylene bags for further study

2.3 Storage studies of *Gari* samples

Five hundred grams of the *Gari* produced were weighed and packaged in a PP woven sack, sealed, and placed in a PVC container and covered with a close-fitting lid. This was stored at room temperature (28 - 30 ^oC) for 24 weeks inside a cupboard. The PP packaging material had a thickness of 0.75 μm, oxygen permeability of 160 mm/100 cm^2 in 24 h and 25 ^oC) and water vapour permeability of 0.27 g/100 cm^2 in 24h at 37.8 ^oC and relative humidity of 90%. The PVC packaging material had a thickness of 0.45 μm, oxygen permeability of 80 mm/100 cm^2 in 24 h and 25 ^oC) and water vapour permeability of 8 g/100 cm^2 in 24h, 37.8^oC and relative humidity of 90%, as reported by Awoyale, Maziya-Dixon and Menkir (2016). The functional and pasting properties of the *Gari* and sensory attributes of the cooked paste (*eba*) were determined every 4 weeks of the 24 weeks storage periods as described by Abiodun, Adegbite and Oladipo (2010).

2.4 Determination of functional properties of *Gari* samples

Bulk Density

Bulk density was determined using the methods described by Ashraf, Anjum, Nadeem and Riaz (2012). *Gari* 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 millilitre.

Determination of swelling power and solubility index

For the determination of swelling power and solubility index, aqueous starch 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^oC for 30 min. (Afoakwa & Nyirenda, 2012). The samples 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, after which a hot air oven (Memmert GmbH+Co.KG: D-91126, Germany) was used to evaporate the supernatant at 105 ^oC, and the residue weighed. The swelling power (SWP), and solubility index (SI) were then calculated as shown in equation 1 and 2:

$$\mathrm{SWP} = \frac{\text{Wt of precipitated paste}}{\text{Wt of sample}} - \text{Wt of residue in the supernatant} \tag{1}$$

$$\mathrm{SI} = \frac{\text{Wt of residue in the supernatant}}{\text{Wt of sample}} \times 100 \tag{2}$$

Water absorption capacity

The water absorption capacity (WAC) of *Gari* was determined as described by Oyeyinka et al. (2013) with a few modifications. *A 1g* sample of *Gari* was weighed into a clean pre-weighed dried centrifuge tube and mixed thoroughly 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.

Oil absorption capacity

A sample of *Gari* (1 g) was suspended in 5 ml of vegetable oil in a centrifuge tube, after which the slurry was shaken on a platform tube rocker for 1 min at ambient temperature and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) 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) (Awoyale et al., 2020).

$$Dispersibility(\%) = \frac{(50 - volumeofthesettleparticule)}{50} \times 100 \tag{3}$$

Dispersibility

The pasting properties of the *Gari* samples were measured using a Rapid Visco Analyser

(Model RVA 4500, Perten Instruments, Australia) equipped with a 1000 cmg sensitivity cartridge. *Gari* (3.5 g) was weighed into a dried empty canister, after which 25 ml of distilled water was added to the sample. The mixture was stirred as prescribed, and the canister fitted into the RVA as recommended. The mixture was then heated from 50 to 95 ^{o}C at a rate of 1.5 ^{o}C/min, over a period of 15 min inside the Visco Analyzer, and cooled to 50 ^{o}C. The viscosity profile indices that were 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 (Falade & Olugbuyi, 2010).

2.5 Preparation of *eba* for sensory evaluation

The *Gari* was cooked into a dough (*eba*) using the modified method described by Udoro, Kehinde, Olasunkanmi, Charles et al. (2014). The *eba* was prepared by adding about 100 g of *Gari* to 195 ml of boiling water (100 ^{o}C) and continuously stirred to form a smooth thick paste. The sensory evaluation was carried out using twelve trained panellists from the staff and graduate students of the International Institute of Tropical Agriculture (IITA), Ibadan who consume *eba* regularly, on the attibutes colour/appearance, texture, stretchability, mouldability, flavour, mouthfeel, and overall acceptability. The sensory acceptability of the *eba* produced from *Gari* before and after each of the storage periods (4 weeks) for 24 weeks was evaluated using a 9-point hedonic scale as reported by Iwe (2002). The authors of this study declare that, the sensory evaluation followed the tenets of the Declaration of Helsinki promulgated in 1964 and was approved by the institutional ethical review committee. In addition, verbal consent was obtained from the participants.

2.6 Statistical analysis

Analysis of variance (ANOVA), separation of the mean values (using Duncan's Multiple Range Test at $P < 0.05$) and the Pearson correlation were calculated using the Statistical Package for Social Scientists (SPSS) software (SPSS Inc., Chicago, IL version 21.0) (Awoyale, Sanni, Shittu & Adegunwa, 2015; Awoyale et al., 2020).

3 Results and Discussion

3.1 Effect of storage periods and packaging materials on the functional properties of stored *Gari* samples

The functional properties of a material determine its application and end-use (Adeleke, Odedeji et al., 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 effects of storage periods and packaging materials on the functional properties of the *Gari* are presented in Table 1. The WAC represents the ability of a product to associate with water under conditions where water is limited, and it was observed to be significantly ($p<0.001$) affected by storage periods. WAC of the *Gari* sample ranged from 445.54% to 524.95% in PP, and 445.54% to 533.76% in PVC, which were within the range reported by Awoyale et al. (2016) and Olanrewaju and Idowu (2017), this variation may be attributed to different storage periods and differences in the granule structure, and degrees of availability of the water binding sites among the samples (Xian, Shariffa & Azwan, 2020). No combined interactive effects ($p>0.05$) (Table 1) of storage periods and packaging materials were observed on the functional properties except for bulk density (BD) and solubility index (SI) ($p<0.001$). However, a significant and positive correlation ($p<0.01$; $r = 0.56$) existed between the WAC for stored *Gari* samples and the overall acceptability of panellists for *eba*, and the same result was observed for mouldability ($p<0.05$; $r = 0.51$) and mouthfeel ($p<0.01$; $r = 0.46$), respectively (Table 1).
The OAC is a measure of the ability of food material to absorb oil, which acts as a flavour retainer and improves the mouthfeel of foods generally (Awuchi, Igwe & Echeta, 2019). A sig-

Table 1: Effect of storage period and packaging materials on the functional properties of *gari*

Parameters	Storage wks	*Gari* stored in PP		*Gari* stored in PVC		p value	p value of Storage	p value of Storage
		Mean	Range	Mean	Range	of Package	periods	period x Package
WAC (%)	0	445.54±3.25^{a}	443.24 – 448.84	445.54±3.25^{a}	443.24 – 447.84			
	4	456.75±0.57^{a}	456.35 – 457.15	533.76±4.59^{c}	499.40 – 568.12	NS	***	NS
	8	524.95±2.14^{b}	523.43 – 526.46	509.57±3.22^{bc}	507.29 – 511.84	NS	***	NS
	12	495.58±3.12^{b}	493.37 – 497.78	514.87±9.98^{bc}	507.81 – 521.93	NS	***	NS
	16	442.53±2.93^{a}	440.28 – 444.60	452.78±8.03^{a}	447.11 - 458.45	NS	***	NS
	20	500.71±3.14^{b}	477.28 – 524.14	476.88±14.50^{ab}	466.63 – 568.12	NS	***	NS
OAC (%)	0	140.10±6.57^{a}	135.45 – 144.74	140.10±6.57^{cd}	135.45 – 144.74			
	4	126.'17±1.45^{a}	118.08 – 134.27	115.91±7.05^{a}	110.64 – 120.62	NS	***	NS
	8	139.61±6.51^{a}	135.00 – 144.21	152.91±1.44^{d}	151.90 – 153.93	NS	***	NS
	12	135.77±7.40^{a}	130.54 – 141.00	136.40±8.13^{c}	130.65 – 142.15	NS	***	NS
	16	141.68±4.63^{a}	138.40 – 144.96	132.81±4.50^{bc}	129.63 – 135.99	NS	***	NS
	20	121.70±1.93^{a}	110.43 – 132.96	121.07±2.61^{ab}	119.23 – 122.91	NS	***	NS
SP (%)	0	11.54±0.26^{a}	11.36 – 11.72	11.54±0.26^{a}	11.36 – 11.72			
	4	11.77±0.05^{a}	11.73 – 11.80	12.15±0.40^{a}	11.86 – 12.43	NS	NS	NS
	8	12.31±0.79^{a}	11.76 – 12.87	12.06±1.71^{a}	10.85 – 13.27	NS	NS	NS
	12	10.74±0.53^{a}	10.36 – 11.11	11.26±0.60^{a}	10.83 – 11.69	NS	NS	NS
	16	14.84±1.13^{a}	14.04 – 15.64	13.32±1.20^{a}	12.47 – 14.17	NS	NS	NS
	20	11.70±0.01^{a}	11.69 – 11.71	12.19±0.88^{a}	10.83 – 14.17	NS	NS	NS
SI (%)	0	37.98±1.06^{b}	37.23 – 38.73	37.98±1.06^{bc}	37.23 – 38.73			
	4	37.38±7.04^{b}	32.41 – 42.36	35.14±2.56^{b}	33.32 – 36.96	NS	***	NS
	8	38.06±3.15^{b}	35.83 – 40.28	39.12±1.21^{bc}	38.26 – 39.95	NS	***	NS
	12	45.82±2.92^{b}	43.75 – 47.88	44.32±4.2^{c}	41.34 – 47.30	NS	***	NS
	16	14.00±5.59^{a}	10.05 – 17.96	15.12±3.52^{a}	12.63 – 17.61	NS	***	NS
	20	39.41±7.80^{b}	11.69 - 15.64	43.10±4.91^{bc}	39.62 – 46.57	NS	***	NS
BD (g/ml)	0	0.57±0.01^{b}	0.57 – 0.58	0.57±0.01^{bc}	0.57 – 0.58			
	4	0.57±0.00^{b}	0.57 – 0.57	0.61±0.11^{c}	0.60 – 0.62	***	***	***
	8	0.59±0.03^{b}	0.57 – 0.62	0.55±0.03^{ab}	0.53 – 0.57	***	***	***
	12	0.55±0.03^{b}	0.53 – 0.57	0.51±0.02^{a}	0.50 – 0.53	***	***	***
	16	0.56±0.01^{b}	0.56 – 0.57	0.57±0.02^{bc}	0.56 – 0.59	***	***	***
	20	0.50±0.00^{a}	0.50 – 0.50	0.57±0.00^{bc}	0.57 – 0.57	***	***	***
Dispersibility (%)	0	45.50±0.71^{a}	45.00 – 46.00	45.50±0.71^{a}	45.00 – 46.00			
	4	46.25±0.35^{a}	46.00 – 46.50	45.75±0.35^{a}	45.50 – 46.00	NS	***	***
	8	59.00±0.00^{c}	59.00 – 59.00	53.00±0.00^{b}	53.00 – 53.00	NS	***	***
	12	44.00±0.00^{a}	44.00 – 44.00	56.00±0.00^{c}	56.00 – 56.00	NS	***	***
	16	44.50±0.71^{a}	44.00 – 45.00	47.00±1.41^{a}	46.00 – 48.00	NS	***	***
	20	49.50±2.12^{b}	48.00 – 51.00	51.00±1.41^{b}	50.00 – 52.00	NS	***	***

WAC: Water absorption index, OAC: Oil absorption capacity, SP: solubility power, SI: Solubility index, BD: Bulk density, PP: 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 ($p>0.05$)

Table 2: Effect of storage period and packaging materials on the pasting properties of *gari*

Parameters	Storage wks	*Gari* stored in PP Mean	*Gari* stored in PP Range	*Gari* stored in PVC Mean	*Gari* stored in PVC Range	p value of Package	p value of Storage periods	p value of Storage period x Package
Peak viscosity (RVU)	0	653.63±34.71^{d}	629.08-678.17	653.63±34.71^{d}	629.08-678.17			
	4	494.96±22.80^{c}	478.83-511.08	415.84±8.25^{c}	410.00-421.67	NS	***	*
	8	372.46±18.33^{b}	359.50-385.42	347.75±4.95^{ab}	344.25-351.25	NS	***	*
	12	352.75±2.23^{b}	351.17-354.33	353.96±15.73^{b}	342.83-365.08	NS	***	*
	16	276.75±24.40^{a}	259.50-294.00	326.13±14.91^{ab}	315.58-336.67	NS	***	*
	20	276.46±8.90^{a}	270.17-282.75	308.83±6.01^{a}	304.58-313.08	NS	***	*
	0	383.83±17.32^{c}	371.58-396.08	383.83±17.32^{d}	371.58-396.08			
	4	354.92±13.31^{c}	3.50-364.33	317.63±5.37^{c}	313.83-321.42	NS	***	**
	8	280.21±9.84^{b}	273.25-287.17	267.29±4.65^{b}	264.00-270.58	NS	***	**
	12	272.75±11.78^{b}	264.42-281.08	261.13±35.18^{ab}	236.25-286.00	NS	***	**
	16	245.2±34.83^{ab}	220.58-269.83	286.80±16.79^{bc}	274.92-298.67	NS	***	**
	20	210.50±7.54^{a}	205.17.215.83	221.21±3.13^{a}	219.00-223.42	NS	***	**
Breakdown viscosity (RVU)	0	269.79±17.38^{d}	257.17-282.08	269.79±17.38^{c}	257.50-282.08			
	4	140.04±9.49^{c}	133.33-146.75	98.21±13.61^{b}	88.58-107.83	NS	***	NS
	8	92.25±8.49^{b}	86.25-98.25	80.46±0.30^{b}	80.25-80.67	NS	***	NS
	12	80.00±9.55^{b}	73.25-86.75	92.83±19.45^{b}	79.08-106.58	NS	***	NS
	16	31.55±10.43^{a}	24.17-38.92	39.34±1.89^{a}	38.00-40.67	NS	***	NS
	20	65.96±1.36^{b}	65.00-66.92	87.63±2.89^{b}	85.58-89.67	NS	***	NS
	0	568.96c±9.37^{c}	562.33-575.58	568.96±9.37^{d}	179.50-190.75			
	4	503.38±15.49^{b}	492.42-514.33	456.84±2.60^{c}	137.25-141.17	NS	**	NS
	8	405.75±4.13^{a}	402.83-408.67	400.13±5.95^{a}	131.92-133.75	NS	**	NS
	12	423.84±10.73^{a}	416.25-431.42	424.34±3.77^{b}	135.67-190.75	NS	**	NS
	16	415.04±3.24^{a}	412.75-417.33	434.29±10.66^{b}	143.17-151.83	NS	**	NS
	20	401.46±2.06^{a}	400.00-402.92	415.84±13.91^{ab}	187.00-202.25	NS	**	NS
Setback viscosity (RVU)	0	185.13±7.96^{b}	179.50-190.75	185.13±5.63bc	5.00-5.20			
	4	148.46±2.18^{ab}	146.92-150.00	139.21±1.96^{a}	5.20-5.27	NS	*	NS
	8	125.54±5.71^{a}	121.50-129.58	132.84±0.91^{a}	5.40-5.53	NS	*	NS
	12	151.09±22.51^{ab}	135.17-167.00	163.21±27.54^{abc}	5.33-5.87	NS	*	NS
	16	169.84±31.59^{b}	147.50-192.17	147.50±6.12^{ab}	5.93-6.07	NS	*	NS
	20	190.96±26.57^{b}	187.08-194.83	194.63±27.09^{c}	5.20-5.47	NS	*	NS
Peak time (Min)	0	5.10±0.14^{a}	5.00-5.20	5.10±0.10^{a}	5.00-5.20			
	4	5.17±0.05^{ab}	5.13-5.20	5.24±0.04^{a}	5.20-5.27	NS	***	NS
	8	5.34±0.09^{ab}	5.27-5.40	5.47±0.07^{a}	5.40-5.53	NS	***	NS
	12	5.60±0.00^{ab}	5.60-5.60	5.60±0.27^{ab}	5.33-5.87	NS	***	NS
	16	6.23±0.42^{c}	5.93-6.53	6.00±0.07^{b}	5.93-6.07	NS	***	NS
	20	5.37±0.05^{bc}	5.33-5.40	5.34±0.14^{a}	5.20-5.47	NS	***	NS
Pasting temperature (^{o}C)	0	80.70±0.07^{a}	80.65-80.75	80.70±0.05a	80.65-80.75			
	4	80.73±0.04^{a}	80.70-80.75	81.50±0.05^{a}	81.45-81.55	NS	***	NS
	8	82.35±1.06^{ab}	81.60-83.10	83.28±0.03^{ab}	83.25-83.30	NS	***	NS
	12	83.13±0.04^{ab}	83.10-83.15	83.18±0.03^{ab}	83.15-83.20	NS	***	NS
	16	91.55±5.09^{c}	87.95-95.15	87.23±3.23^{b}	84.00-90.45	NS	***	NS
	20	87.13±1.10^{bc}	86.35-87.90	83.23±0.08^{ab}	83.15-83.30	NS	***	NS

PP: 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 ($p>0.05$))

nificant difference ($p<0.05$) was observed in the OAC of *Gari* stored in PVC, with no significant difference ($p>0.05$) for that stored in PP. The OAC obtained for this study ranged between 121.70% to 141.68% in PP and 115.91 to 152.91% in PVC, which were similar to the values reported by Awoyale, Sanni, Shittu, Adebowale and Adegunwa (2019) (Table 1).

Swelling power (SP) of starchy foods reveals the extent of associative forces within the granules; thus, the higher the SP, the lower the associative forces (Sanni, 2005). Good quality *Gari* is one that can swell up to at least 3 times its original size (Awoyale et al., 2020). The results showed that *Gari* stored in PP with higher SP (14.84%) had granules with lower associative forces when compared with *Gari* stored in PVC with lower SP (13.32%) (Table 1). This study showed no significant difference ($p > 0.05$) in the SP of the *Gari* during storage periods. Similarly, there was no significant ($p>0.05$) effect of the packaging materials and the interactions between the storage period and the packaging material on the stored *Gari*. The Solubility index (SI), which 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 (Awoyale et al., 2020) of the stored *Gari* ranged from 14.00% to 45.82%. A significant difference ($p<0.05$) existed in the SI during the storage periods. The SI of *Gari* packaged in PP had a significant positive correlation ($p<0.05$, $r = 0.61$) with the overall acceptability of the *eba*, and a negative ($p<0.05$) correlation with peak time ($r = -0.62$) and pasting temperature ($r = -0.63$) (Table 3). Similar correlations were observed with *Gari* packaged in PVC, but this was not significant ($p>0.05$) (Table 4).

The bulk density (BD) is critical to evaluate floury products with respect to the weight, handling requirements and the type of packaging materials suitable for storage and transportation of food materials, (David, Arthur, Kwadwo, Badu & Sakyi, 2015). Similarly, the BD of a product is an essential parameter in determining suitable packaging materials and materials handling during food processing (Adebowale, Adegoke, Sanni, Adegunwa & Fetuga, 2012). Here, the BD of the *Gari* varied from 0.50 - 0.61 g/ml which was desirable and fell within an acceptable range of 0.50 g/ml to 0.91 g/ml as reported by Adindu and Aprioku (2006), and also agreed with the values 0.52 - 0.62 g/ml indicated by Nwancho, Ekwu, Mgbebu, Njoku and Okoro (2014), and Awoyale et al. (2016) (0.57 g/ml for white *Gari* and 0.56 g/ml for yellow *Gari*). Either loose or packed BD is influenced by factors such as dryness and particle size distribution of samples; thus the values obtained in this study were comparable to those reported by Udoro et al. (2014) (0.50 - 0.65g/cm^3). Komolafe and Arawande (2010) reported that the lower the BD value, the higher the amount of *Gari* that could be packaged in each volume of the container, which decreases the space occupied, the packaging, and transportation costs. However, *Gari* samples stored in PVC were observed to have higher BD, which was attributed to the packaging material. The storage and packaging materials had a significant ($p<0.001$) effect on the BD of *Gari*. A similar, significant ($p<0.01$) trend was observed for the combined interactive effect of the storage period and packaging materials of the *Gari*. The BD of the *Gari* packaged in PP was positively correlated ($p<0.05$, $r = 0.58$) with the mouldability while a positive and non-significant correlation existed with the trough viscosity ($p>0.05$, $r= 0.54$). However, a negative and significant correlation existed between the BD of the *Gari* packaged in PVC ($p<0.01$, $r = -0.81$) and the dispersibility of the *Gari* (Table 4).

Dispersibility is a measure of the reconstitution of flour starch in water, the higher the dispersibility, the better samples reconstitute in water as reported by Adebowale, Sanni and Fadaunsi (2008) and Awoyale et al. (2020). Dispersibility varied from 44.00% to 59.00% in PP and 45.50% to 56.00% in PVC, which agreed with an earlier study reported by Awoyale, Abass, Ndavi, Maziya-Dixon and Sulyok (2017) (43.22) on *Gari* (Table 2). Similarly, *Gari* stored (59.00%) in PP showed a significantly higher dispersibility value than *Gari* stored in PVC. This should be easily reconstituted in water without lump formation due to high dispersibility, whilst lump formation may likely occur in the *Gari* stored in PVC (56.00%) when soaked in water because of its low dispersibility Awoyale et al. (2020). The packaging materials had no significant effect ($p>0.05$)

on the dispersibility of the stored *Gari*. The storage periods and the interaction between the packaging materials and the storage periods had a significant impact ($p<0.01$) on the stored *Gari*. However, the dispersibility of the *Gari* packaged in PP had no significant correlation ($p>0.05$) on the functional, pasting and sensory properties of the *eba*.The *Gari* packaged in PVC had a negative correlation ($p<0.05$) with the trough viscosity ($r = -0.64$), and the final viscosity ($r = -0.63$) (Table 4).

3.2 Effect of storage periods and packaging materials on the pasting properties of *Gari*

Table 2 shows the effect of storage periods and packaging materials on the pasting properties of *Gari*. The pasting properties of flour products are used in assessing the suitability of its application as a functional ingredient in food products (Oluwalana, Oluwamukomi et al., 2011). Thus, the pasting properties of food products are essential in predicting their behaviour during and after cooking. The results of this study showed that the packaging materials had no significant ($p>0.05$) effect on the pasting properties of the *Gari*, but the storage periods had a significant impact ($p<0.05$) on the pasting properties (Table 2).

The peak viscosity (PV) is the maximum viscosity developed during or soon after the heating of the floury product (Adebowale et al., 2008) and here it ranged from 276.46 RVU to 653.63 RVU, similar to the values reported by Nwancho et al. (2014) (322.67 RVU) for *Gari* produced from dried cassava chips. On the other hand, values obtained for this study were higher than values recorded by Awoyale et al. (2017), Awoyale et al. (2019) (241.30 RVU; 183 RVU). However, PV is often related to the final product quality, as it indicates the viscous load faced during mixing (Maziya-Dixon, Dixon & Adebowale, 2007). The PV of the *Gari* packaged in PP had a significant positive correlation with the trough viscosity ($p<0.01$, $r = 0.96$), breakdown viscosity ($p<0.01$, $r = 0.97$), final viscosity ($p<0.01$, $r = 0.96$) while a significant negative correlation was observed with peak time ($p<0.05$, $r = -0.61$) and pasting temperature ($p<0.05$, $r = -0.69$) of the *eba* (Table 3). Similar correlations were observed in the *Gari* packaged in PVC (Table 4).

Trough viscosity (TV) is the minimum viscosity that occurs after the initiation of product cooling; thus, it measures the ability of the paste to withstand breakdown during cooling. TV values ranged between 210.50 RVU and 383.83 RVU (PP) and 221.21 RVU and 383.83RVU (PVC), which agreed with the value recorded by Sanni et al. (2009) (269.75 RVU). Similarly, the trough viscosity reduced with an increase in the storage periods. The PV of the *Gari* packaged in PP had a significant positive correlation with the trough ($p<0.01$, $r = 0.86$), breakdown viscosity ($p<0.01$, $r = 0.92$), while significant negative correlation was observed with pasting temperature ($p<0.05$, $r = -0.65$) (Table 3). Similar correlations were observed in the *Gari* packaged in PVC (Table 4).

Breakdown viscosity (BDV), which reflected the ability of the sample to withstand shear stress and heating during cooking for this study, was observed to be significantly different ($p<0.05$) during storage and the storage periods had a significant ($p<0.001$) effect on the stored *Gari*. The BDV of this study ranged from 31.55 to 269.79 RVU (PP), and 39.34 to 269.79 RVU for *Gari* packaged in PVC. The highest value BDV was recorded for zero storage, and the value was noticed to decrease with storage periods up to the fourth month of storage; afterwards, the value was higher in the sixth month. The BDV of the *Gari* packaged in PP had a significant positive correlation ($p<0.01$, $r = 0.94$), with a significant negative correlation of the pasting time ($p<0.05$, $r = -0.67$), and pasting temperature ($p<0.05$, $r = -0.69$) of the *eba* (Table 3).

Final viscosity (FV) is the ability of the flour to form starch and viscous paste or gel after cooking and cooling (Maziya-Dixon et al., 2007). The FV ranged from 401.46 to 568.96 RVU (PP) and 400.13 to 568.96 RVU (PVC). There was a significant ($p<0.05$) difference in the FV of *Gari* stored in PVC though, the highest value 503.38 RVU of FV was observed in the second month in the *Gari* stored in PP after zero storage, and this may be ascribed to the packaging materials used (Table 2).

Setback viscosity (SBV) gives an idea about the

Table 3: Pearson correlation of the functional, pasting and sensory properties of *gari* packaged in a polypropylene bag and stored for 20 weeks

	SI	BD	Disp	PV	TV	BDV	FV	SBV	Ptime	Ptemp	Text	Col	Stretch	Mould	Flav	Mouthf	OA
SI	1.00																
BD	−0.11	1.00															
Disp	0.20	0.25	1.00														
PV	0.29	0.43	−0.16	1.00													
TV	0.23	0.54	−0.17	0.96**	1.00												
BDV	0.32	0.31	−0.14	0.97**	0.86**	1.00											
FV	0.14	0.33	−0.37	0.96**	0.92**	0.94**	1.00										
SBV	−0.20	−0.50	−0.49	0.05	−0.17	0.22	0.24	1.00									
Ptime	−0.62*	−0.06	−0.26	−0.61*	−0.48	−0.67*	−0.52	−0.09	1.00								
Ptemp	−0.63*	−0.31	−0.17	−0.69*	−0.65*	−0.69*	−0.56	0.18	0.87**	1.00							
Text	−0.34	0.39	−0.30	−0.03	0.09	−0.12	0.00	−0.21	0.45	0.16	1.00						
Col	0.43	−0.18	0.07	0.03	0.02	0.03	−0.10	−0.28	0.00	−0.05	0.20	1.00					
Stretch	0.24	0.19	−0.18	0.26	0.33	0.19	0.20	−0.30	0.13	−0.14	0.66*	0.53	1.00				
Mould	0.05	0.58*	0.08	0.24	0.34	0.15	0.14	−0.47	0.21	−0.24	0.58*	0.12	0.63*	1.00			
Flav	0.47	−0.29	0.02	−0.03	−0.11	0.03	−0.08	0.07	−0.28	−0.20	0.31	0.54	0.46	−0.04	1.00		
Mouthf	0.56	−0.11	0.21	0.30	0.22	0.35	0.22	0.05	−0.53	−0.63*	−0.09	0.09	0.21	0.37	0.45	1.00	
OA	0.61*	−0.13	0.20	−0.10	−0.16	−0.05	−0.21	−0.14	−0.21	−0.29	0.21	0.50	0.33	0.29	0.78**	0.67*	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 4: Pearson correlation of the functional, pasting and sensory properties of *gari* packaged in polyvinyl chloride container and stored for 20 weeks

	SI	BD	Disp	PV	TV	BDV	FV	SBV	Ptime	Ptemp	Text	Col	Stretch	Mold	Flav	Mouthf	OA
SI	1.00																
BD	−0.27	1.00															
Disp	0.52	−0.81**	1.00														
PV	0.13	0.22	−0.53	1.00													
TV	−0.16	0.35	−0.66*	0.91**	1.00												
BDV	0.32	0.10	−0.38	0.96**	0.75**	1.00											
FV	−0.01	0.27	−0.63*	0.97**	0.89**	0.92**	1.00										
SBV	0.30	−0.13	−0.01	0.25	−0.10	0.48	0.38	1.00									
Ptime	−0.54	−0.29	0.24	−0.54	−0.28	−0.66*	−0.47	−0.45	1.00								
Ptemp	−0.65*	−0.27	0.17	−0.54	−0.34	−0.62*	−0.43	−0.24	0.78**	1.00							
Text	−0.032	−0.48	0.58	−0.36	−0.19	−0.44	−0.45	−0.58*	0.35	0.39	1.00						
Col	−0.47	0.14	−0.11	−0.36	−0.19	−0.45	−0.34	−0.35	0.28	0.22	0.30	1.00					
Stretch	−0.19	−0.26	0.27	−0.17	−0.04	−0.24	−0.17	−0.29	0.11	0.12	0.73**	0.37	1.00				
Mould	0.30	−0.21	0.50	−0.26	−0.22	−0.27	−0.29	−0.20	0.05	0.08	0.65*	−0.04	0.54	1.00			
Flav	0.36	−0.22	0.42	−0.11	−0.21	−0.02	−0.140	0.12	−0.20	−0.38	0.35	0.21	0.69*	0.51	1.00		
Mouthf	0.44	−0.18	0.37	−0.06	−0.19	0.03	−0.16	0.04	−0.43	−0.51	0.38	0.35	0.61*	0.39	0.89**	1.00	
OA	−0.12	0.20	−0.06	−0.01	0.08	−0.06	−0.04	−0.25	−0.24	−0.263	0.39	0.43	0.79**	0.32	0.74**	0.75**	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 retrogradation tendency of starch in the flour sample after 50 ^{o}C. The SBV values ranged from 125.54 to 190.96 RVU in PP and 132.84 to 194.63 RVU in PVC, and it was observed to decrease with storage periods up until the third month of storage; afterwards, the value was noticed to increase in the fourth month up to the sixth month. However, the highest value was seen in the *Gari* stored in PVC: high SBV values have been reported to affect dough digestibility (Shittu, Lasekan, Sanni & Oladosu, 2001), whilst lower values, which were recorded for third month of storage, are beneficial as they indicate a lower tendency for retrogradation (Sandhu, Singh & Malhi, 2007). The SBV of the *Gari* packaged in PP was negatively correlated ($p>0.05$, $r = -0.49$) with the mouldability of the *eba* but not significant (Table 3) while that of the *Gari* packaged in PVC had a significant ($p<0.05$, $r= -0.58$) negative correlation with the texture of the *eba* (Table 4).

Peak time is reported by Adebowale, Sanni and Awonorin (2005) to be a measure of the cooking time of the flour. The peak times obtained for this study ranged from 5.10 - 6.23 min (PP), and 5.10 - 6.00 min (PVC), which were in line with the studies of Nwancho et al. (2014) (4.67 - 6.47 min) and Awoyale et al. (2016) (5.65 - 5.90 min). Statistically, the storage periods had a significant effect ($p<0.001$) on the *eba* made from the stored *Gari*, while no significant effect ($p>0.05$) of the packaging materials and no combined interactive effect was observed. The results of the peak time of the *Gari* implied that all the *Gari* might be cooked into a paste in <6 mins.

Pasting temperature (PT) is an index of the minimum energy required to initiate rapid water ingression, swelling, and eventual gelatinization of starch granules (Awoyale et al., 2016). Thus, the PT of the *Gari* samples was observed to fall below 100 ^{o}C. The PT of *Gari* ranged from 80.70 - 91.55 ^{o}C (PP) and 80.70 - 87.23 ^{o}C (PVC), which agreed with Awoyale et al. (2016) (78.36 ^{o}C - 80.40 ^{o}C), Olanrewaju and Idowu (2017) (82.05 ^{o}C - 83.66 ^{o}C), but higher than the values reported by Sanni et al. (2008) (63.40 ^{o}C - 64.65 ^{o}C). Similarly, the storage periods had a significant effect ($p<0.001$) on the pasting temperature while the packaging materials and combined interactive had no significant effect on the pasting temperature. The values obtained for *Gari* stored in PP were higher and this was attributed to packaging materials used. However, the high PT value is an indication for ease of formation of paste as reported by Nwancho et al. (2014) and this implies that *Gari* stored in PP tends to spontaneously form a paste of *eba* in contrast to *Gari* stored in PVC.

3.3 Effect of storage conditions and packaging materials on the sensory attributes of cooked *Gari* dough (*eba*)

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. Table 2 shows the sensory attributes of the cooked *Gari* dough (*eba*) produced from *Gari* stored in different packaging materials; PP and PVC. The storage periods and packaging materials had no significant effect ($p>0.05$) on the sensory attributes of the cooked *Gari* dough (*eba*) except for the mouldability, which was significantly ($p<0.05$) affected. The interactions between the storage periods and packaging materials had no significant effect ($p>0.05$) on the cooked *Gari* dough (*eba*) (Table 5). However, the panellists preferred all the sensory attributes of the *eba* from the *Gari* stored in PP compared to the *eba* made from *Gari* stored in PVC. Thus, the overall acceptability was higher in the *eba* made from *Gari* packaged in PP. Therefore, packaging *Gari* in PP may keep most of the properties preferred by the consumers when stored for up to 5 months.

4 Conclusion

The study conducted showed that the packaging materials had no significant effect on the functional properties except for bulk density and all pasting properties of the stored *Gari*, and that the storage periods significantly affected all the functional properties except the swelling power. However, the result of the sensory analysisshowed that during the storage periods only the mouldability and packaging materials had asignificant effect on the sensory acceptability of

Table 5: Effect of storage periods and packaging materials on the sensory acceptability of cooked *gari* paste (*eba*)

Parameters		*Gari* stored in PP		*Gari* stored in PVC		p value of	p value of	p value of Storage
	Storage wks	Mean	Range	Mean	Range	Package	Storage periods	period x Package
Texture	0	7.31±1.97^{a}	2 – 9	7.31±1.97^{a}	2 – 9			
	4	7.54±0.88^{a}	6 – 9	7.69±0.75^{a}	7 – 9	NS	NS	NS
	8	7.62±1.04^{a}	6 – 9	7.23±0.93^{a}	6 – 9	NS	NS	NS
	12	7.54±1.45^{a}	4 – 9	7.46±1.12^{a}	5 – 9	NS	NS	NS
	16	7.69±1.01^{a}	5 – 9	7.77±0.93^{a}	6 – 9	NS	NS	NS
	20	7.54±0.52^{a}	7 – 8	7.54±0.52^{a}	7 – 8	NS	NS	NS
Colour	0	7.69±1.70^{a}	4 – 9	7.69±1.70^{a}	4 – 9			
	4	7.92±0.95^{a}	6 – 9	8.00±0.91^{a}	6 – 9	NS	NS	NS
	8	7.92±0.76^{a}	7 – 9	7.62±0.77^{a}	6 – 9	NS	NS	NS
	12	7.92±0.76^{a}	7 – 9	7.77±0.73^{a}	7 – 9	NS	NS	NS
	16	7.77±0.93^{a}	6 – 9	7.85±0.99^{a}	6 – 9	NS	NS	NS
	20	7.77±0.73^{a}	6 – 9	7.85±0.90^{a}	6 – 9	NS	NS	NS
Stretchability	0	6.31±6.31^{a}	1 – 9	6.31±2.56^{a}	1 – 9			
	4	7.85±0.90^{b}	6 – 9	7.62±1.04^{b}	6 – 9	NS	NS	NS
	8	7.00±1.29^{ab}	4 – 8	7.46±1.27^{b}	5 – 9	NS	NS	NS
	12	7.62±1.61^{b}	3 – 9	7.54±0.88^{b}	6 – 9	NS	NS	NS
	16	7.85±0.90^{b}	6 – 9	7.46±0.97^{b}	6 – 9	NS	NS	NS
	20	7.69±0.85^{b}	6 – 9	7.85±0.69^{b}	7 – 9	NS	NS	NS
Mouldability	0	7.00±2.89^{a}	1 – 9	7.00±2.89^{a}	1 – 9			
	4	7.85±0.80^{a}	6 – 9	7.92±0.95^{a}	6 – 9	NS	*	NS
	8	7.77±1.30^{a}	4 – 9	7.69±1.25^{a}	4 – 9	NS	*	NS
	12	7.85±0.80^{a}	6 – 9	8.00±0.71^{a}	7 – 9	NS	*	NS
	16	8.08±0.86^{a}	7 – 9	7.54±1.12^{a}	5 – 9	NS	*	NS
	20	7.77±1.09^{a}	5 – 9	7.85±0.69^{a}	7 – 9	NS	*	NS
Flavour	0	6.77±1.74^{a}	3 – 9	6.77±1.74^{a}	3 – 9			
	4	7.23±1.01^{a}	6 – 9	7.62±0.77^{ab}	6 – 9	NS	NS	NS
	8	7.38±1.04^{a}	5 – 9	7.46±0.97^{ab}	6 – 9	NS	NS	NS
	12	7.69±0.75^{a}	7 – 9	7.62±0.96^{ab}	6 – 9	NS	NS	NS
	16	7.62±0.96^{a}	6 – 9	7.62±0.87^{ab}	6 – 9	NS	NS	NS
	20	7.62±0.51^{a}	7 – 8	7.77±1.01^{ab}	6 – 9	NS	NS	NS
Mouthfeel	0	6.77±2.00^{a}	1 – 9	6.77±2.00^{a}	1 – 9			
	4	7.00±1.22^{a}	4 – 8	7.46±1.20^{a}	4 – 9	NS	NS	NS
	8	7.23±1.36^{a}	4 – 9	7.38±0.77^{a}	6 – 9	NS	NS	NS
	12	7.85±0.99^{a}	6 – 9	7.62±0.77^{a}	6 – 9	NS	NS	NS
	16	7.31±1.03^{a}	5 – 9	7.38±0.87^{a}	6 – 9	NS	NS	NS
	20	7.31±0.63^{a}	6 – 8	7.46±1.20^{a}	5 – 9	NS	NS	NS
OA	0	7.15±1.82^{a}	3 – 9	7.15±1.82^{a}	3 – 9			
	4	7.77±0.83^{ab}	6 – 9	7.69±0.85^{a}	6 – 9	NS	NS	NS
	8	7.77±0.83^{ab}	7 – 9	7.54±0.78^{a}	6 – 9	NS	NS	NS
	12	7.92±0.64^{ab}	7 – 9	8.00±0.58^{a}	7 – 9	NS	NS	NS
	16	8.08±0.76^{b}	7 – 9	7.85±0.69^{a}	7 – 9	NS	NS	NS
	20	7.77±0.60^{ab}	7 – 9	7.62±0.77^{a}	7 – 9	NS	NS	NS

PP: 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 ($p>0.05$)

the *eba*. Similarly, *eba* stored in a polypropylene woven sack (PP) gave better sensory properties compared to that stored in polyvinyl chloride containers. Hence, the use of polypropylene bags for packaging and storage of *Gari* is encouraged to retain its sensory attributes.

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