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Effect of packaging materials and storage conditions on the physicochemical and chemical properties of *ogi* powder

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Abstract

The effects of packages, storage conditions and the length of storage on the physicochemical and chemical properties of *ogi* powder produced from yellow maize grain were investigated. *Ogi* was produced using the traditional method, dried at 55°C to a powder in a cabinet drier, milled, cooled and packed in high-density polyethylene bag (HDPE), a polypropylene woven sack (PP), and a polyvinyl chloride container (PVC). The samples were stored under different conditions for 12 weeks and sampled at three-week intervals for analysis. Significant differences were observed for all the physicochemical and chemical properties of the *ogi* powder investigated except for the water absorption capacity and the ash content. At the end of the storage period, PVC-packed *ogi* powder stored in the dark compartment of the storage box had the highest degree of yellowness (2632.33) and HDPE bag-packed *ogi* powder stored in the lighted compartment had the least one (2424.33). *Ogi* powder packed in PVC stored in the dark compartment had the highest final viscosity (193 RVU) and that packed in PP woven sack stored in the dark compartment had the lowest one (185 RVU). *Ogi* powder packed in PP woven sack stored in the lighted compartment had the highest setback (89 RVU) while that packed in PP woven sack and stored in the dark compartment had the lowest one (82 RVU). The overall mean of the sugar content at the end of the 12 weeks of storage was 1.14%; PP woven sack (2%) and PVC (0.59%) packed *ogi* powder stored in the lighted compartment of the storage box had the highest and lowest value, respectively. The overall mean of the starch content at the end of the 12 weeks storage period was 53.81%; *ogi* powder packed in PP woven sack and stored in the lighted compartment had the highest (66.1%) and *ogi* powder packed in PP woven sack stored in the dark compartment had the least (42.86%) value. After 12-weeks of storage, moisture content increased from 5.5% before storage to 10.23% in *ogi* powder packed in PP woven sacks and stored in the dark compartment. Therefore, HDPE bag could be used to store *ogi* powder at a temperature of 26.10-27.90°C and relative humidity range of 63-75% and *ogi* powder packed in PVC can be stored at a temperature and relative humidity range of 27.20-30°C and 58-66%, respectively, for good product quality.

Key words: Packaging materials, storage conditions, *ogi* powder, physicochemical properties.

Introduction

Maize is widely consumed in Nigeria as roasted fresh green maize, fermented meal for *ogi* (gruel), maize flour for *tuwo* or boiled fresh maize among others in Nigeria ¹. *Ogi/akamu/pap* is a fermented starchy paste traditionally made from maize, sorghum or millet ². It is considered the most important weaning food for infants in West Africa, although it is also consumed by older children and adults ³.

The physical and biochemical qualities of *ogi* are influenced by the cereal grain type, milling method, or fermentation ⁴. Nutrient losses occur during the processing of cereal grains to *ogi*, these include fiber, protein, calcium, iron, phosphorus and vitamins such as thiamine, riboflavin, niacin, folic and panthotenic acids ⁵. These losses are inevitable as most of the protein in cereal grains is located in the testa and germ, which are usually sifted off during processing ⁵.

Packaging is an integral part of food processing. It provides the proper environmental conditions for long shelf life. It protects the products against microbiological, chemical or physical deterioration ⁶. Processed foods can be preserved for extended periods by a combination of aseptic packaging to exclude microbes and oxygen as well as to maintain a moderate temperature ⁷. During

storage, one or more food characteristics can reach an undesirable state and consequently the consumer may reject the product or the product can be detrimental to the health of the consumer. At this moment, the food has reached the end of its shelf life. Packaging materials used for the household storage of flours such as those for pounded-yam, *fufu*, *lafun* and *ogi* include high density polyethylene (HDPE) and polypropylene (PP) woven sacks and plastic bags ⁸. These materials are clear, glossy films with good optical properties and high tensile strength. They are heat sealable as well as having low permeability to moisture, gases and odours, and are not affected by changes in humidity ⁹. Polypropylene and high density polyethylene packages have been reported to possess 5.5 and 6.8 g m⁻² per 24 h of water vapour transmission rate, respectively. Gas permeability (g m⁻² per 24 h) in polypropylene and high density polyethylene packaging materials were also reported to be 4.4 and 3 (N₂), 92 and 45 (CO₂) and 28 and 10 (O₂), respectively ⁹. Adetuyi *et al.* ¹⁰ reported that the optimum moisture content for the storage of a floury food product must be in relation to the length of storage envisaged and to the prevailing ambient temperature and relative humidity. Because of hygroscopicity, flour

will gain or lose moisture to the surrounding atmosphere unless packed in hermetically sealed containers. Polyethylene and plastic containers were found to have no significant effect on the functional and physicochemical properties of malted and unmalted maize blends at the end of a twelve-week storage period ¹⁰. Adeniji ¹¹ also reported that plantain and banana chips stored with transparent polyethylene bags in an unlighted box had good shelf life.

The choice of packaging materials depends on the nature of the product, the storage method, and handling conditions (temperature, humidity, risk of physical deterioration) among other factors ¹². Ekwu and Ikegwu ¹³ packed cocoyam flour in closed and open plastic bowls, polyethylene bags, and jute bags and stored these for 5 months in a rodent-proof cage. The authors reported that the packaging material had a significant effect on the functional properties of the flours, the best packaging material was the polyethylene bag ¹³. Fadamiro and Odeyemi ¹⁴ also reported that polythene-in-polythene bags were better than polythene-in-hessian and polythene-in-paper containers for the storage of cocoa powder at 15, 25, and 40°C over a period of 3 months. The authors also reported that weight loss increased with the increase in storage temperature ¹⁴.

Ogi in the form currently available to the consumers cannot be stored at home for any length of time without spoilage; therefore, there is a need to extend its shelf life. This will ensure its availability as a weaning food and breakfast cereal and allow effective distribution to all consumers. The objective of our study is to investigate the effect of packaging materials, storage conditions, and length of storage on the physicochemical and chemical properties of *ogi* powder produced from yellow maize grain.

Materials and Methods

Materials: Yellow maize grain (DMR-LSRY) was obtained from the Maize Improvement Programme; International Institute of Tropical Agriculture, Ibadan, Nigeria. Polyethylene nylon bags, polypropylene woven sacks, and polyvinyl plastic containers were obtained from a local market in Ibadan, Nigeria.

Processing of maize grains to *ogi* powder: The yellow maize grains were sorted, cleaned, and steeped in clean water at room temperature for 48 h ¹⁵. The water was decanted and the fermented grains were washed with clean water and wet milled using an attrition mill. The bran was removed by wet sieving with a muslin cloth and the sieveate was allowed to settle for 24 h to form the starchy sediment *ogi* slurry as described by Osungbaro ¹⁶. The sediment was dewatered in a jute sack using a hydraulic jack. The dewatered mash was pulverized in a granulating machine, dried in a cabinet drier (55±5°C), and dry milled to pass a mesh sieve of 0.5 mm (Fig. 1).

Storage studies: *Ogi* powder (200 g) was packed as follows: in HDPE bags (23 cm height × 16 cm breadth) sealed with an electric sealer, PP sack (25 cm height × 13 cm breadth) sealed with a stitching machine and polyvinyl chloride containers (PVC) (6 cm height × 13 cm breadth), covered with a lid. They were stored in a specially constructed wooden cupboard as reported by Adeniji ¹¹ with slight modifications in the size of the storage box and the fluorescent tube. The storage box (2.6 ft length, breadth and width) consisted of two compartments (upper and lower). A 2 ft fluorescent tube was fitted in the inner part of the upper compartment that was lined with

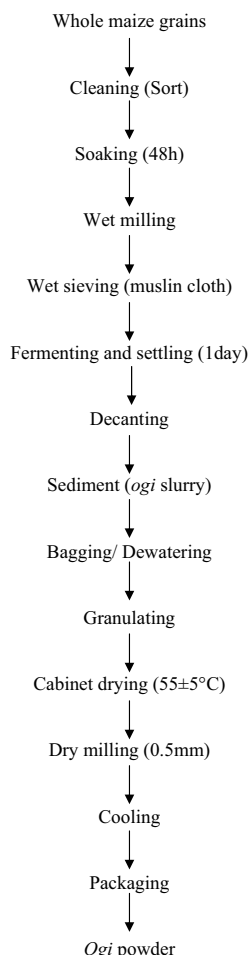


Figure 1. Flow chart for the production of *ogi* powder.

aluminium foil to increase light intensity. The lower compartment was painted with black gloss paint to maintain a dark enclosure for the samples. The doors of the two compartments were separate for ease of sample collection. Samples packaged in the materials were stored in both the lighted and dark compartments. Samples that served as controls were stored outside the storage box. All samples were stored for 12 weeks. The temperature and relative humidity of each of the storage conditions were measured with Max-Min thermo-hygrometre at three-week intervals before sample collection. Physicochemical and chemical analysis of the samples were determined every 3 week until the end of the twelve-week storage period. All analyses were done in duplicate.

Determination of physicochemical properties

Water absorption capacity: The water absorption capacity (WAC) was determined using the method described by Beuchat ¹⁷. Exactly 1 g of each sample was mixed with 10 ml of distilled water and blended for 30 s. The samples were allowed to

stand for 30 min and centrifuged at 1303 g for 30 min at room temperature. The supernatant was decanted. The weight of water absorbed by the samples was calculated and expressed as the percentage WAC.

Pasting properties: Pasting characteristics was determined using a Rapid Visco Analyzer (Model RVA-4C, Newport Scientific, Warriewood, Australia) interfaced with a personal computer equipped with the Thermocline software supplied by same manufacturer ¹⁸. A sample of 3 g (moisture content less than 12%) was weighed into a canister and made into slurry by adding 25ml of distilled water. The canister (covered with a stirrer) was inserted into the RVA. The slurry was held at 50°C for 1 min, heated to 95°C within 3 min, and then held at 95°C for 2 min, cooled to 50°C within 3 min and then held at 50°C for 2 min, while maintaining a rotation speed of 160 rpm. The viscosity is expressed as Rapid Viscosity Units (RVU). Records were taken of peak viscosity (the maximum viscosity during pasting), breakdown viscosity (the difference between the peak viscosity and the minimum viscosity during pasting), setback viscosity (the difference between the maximum viscosity during cooling and the minimum viscosity during pasting), final viscosity (the viscosity at the end of the RVA run), pasting temperature (°C) (the temperature at which there is a sharp increase in the viscosity of the flour suspension after the commencement of heating) and peak time (min) (time taken for the paste to reach the peak viscosity).

Colour measurement: Colour was determined using a hand-held ColourTec PCM/PSM^{TM1} colour meter as described by Adeniji *et al.*¹⁹, using a white tile as the reference and recording the values of yellowness (b*). The degree of yellowness (b*) was included as the *ogi* powder was made from yellow maize grain. Colour analysis was done in duplicate and the values for each parameter were recorded from three different points.

Determination of chemical composition: Moisture, ash, pH, and fat contents were determined using standard laboratory procedures²⁰. Protein content was determined using the Kjeldahl method (KjeltecTM model 2300 protein analyser²¹). A conversion factor of 6.25 was used to convert total nitrogen to percentage crude protein.

Total sugars and starch content analysis: Total sugars and starch content were analysed according to the method described by Dubois *et al.*²²

Statistical analysis: Data were subjected to analysis of variance (ANOVA) using Statistical Analysis System²³ package (version 9.1, SAS Institute, Inc., Cary, NC). The Fischer's protected Least Significant Difference (LSD) test was used for mean separation.

Results and Discussion

Physicochemical properties: There were no significant differences in the WAC of the *ogi* samples viz-a-viz the packaging materials and storage conditions ($p > 0.05$) (Table 1). However, there was an increase in the mean WAC of the *ogi* powder from the three-week (203.33%) to the twelve-week (213.33%) of storage. The WAC of the *ogi* powder before storage was 203% (Table 2). The mean WAC at 9 weeks of storage was 205% with a range of 197 to 213%; the mean at 12 weeks was 213% with a range of 199 to 254% (Table 1). At the end of the storage period, *ogi* powder packed in PP sacks and stored in the dark

compartment had the lowest WAC and that packed in a PVC container had the highest (Table 2). High WAC is attributed to the loose structure of the starch polymers while a low values indicate the compactness of the molecular structure²⁴. This implies that *ogi* powder packed in PVC and stored in the dark compartment of the storage box had a loose starch polymer structure, while *ogi* powder packed in a PP woven sack stored in the dark compartment had the starch polymer packed in a compact molecular structure. This might probably be due to the different oxygen permeability of the packages⁹.

There was a significant difference ($p \leq 0.0001$) in the colour (yellowness) of the *ogi* powder before and after the storage periods (Table 1). The yellowness (b*) decreased from 2610 before storage to 2037 in the *ogi* powder packed in HDPE bag and stored in the lighted compartment of the box at the three-week storage period and later increased to 2632.33 in PVC packed *ogi* powder stored in the dark compartment of the storage box at the twelve-week of storage (Table 2). At the end of the total storage period, the overall mean of the degree of yellowness was 2533.22; PVC packed *ogi* powder stored in the dark compartment of the box had the highest value (2632.33) and HDPE packed *ogi* powder stored in the lighted compartment of the box had the least (2424.33) (Table 2). Colour is a major component of visual appearance of produce/products; it is therefore an important indicator of quality²⁵. The decrease in the yellowness of HDPE packed *ogi* powder stored in the lighted compartment of the storage box might be due to the effect of high light intensity and temperature on the pigment present²⁶.

Pasting properties: The effects of packaging materials and storage conditions on the pasting properties of *ogi* powder are presented in Table 3. There was significant difference ($p \leq 0.0001$) in all the pasting properties evaluated throughout the storage period irrespective of the packaging materials (Table 1). Mean peak viscosity of the *ogi* powder before storage was 179 RVU, breakdown viscosity was 64 RVU, final viscosity was 204 RVU

Table 1. Effect of packaging materials and storage periods on the level of significance in the physicochemical and pasting properties of *ogi* powder.

Parameters	Storage period (weeks)	Mean	Range	P of package	P of storage	P of package $\times$ storage
WAC (%)	3	203.33	196.00-209.00	ns	ns	ns
	6	207.44	200.00-222.00			
	9	205.44	197.00-213.00			
	12	213.33	199.00-254.00			
b*	3	2403.07	2037.00-2537.33	***	***	***
	6	2420.48	2207.67-2537.00			
	9	2554.48	2486.67-2618.67			
	12	2533.22	2424.33-2632.33			
Peak (RVU)	3	174.40	159.38-183.75	***	***	***
	6	182.73	166.04-192.88			
	9	179.08	165.54-188.42			
	12	178.74	164.78-183.78			
Breakdown (RVU)	3	69.45	57.58-75.59	***	***	***
	6	78.00	63.05-86.55			
	9	79.86	58.13-88.67			
	12	75.77	62.02-82.32			
Final visc (RVU)	3	187.93	176.50-193.17	***	***	***
	6	192.67	185.25-199.67			
	9	188.10	183.25-192.58			
	12	189.56	185.28-193.81			
Setback (RVU)	3	82.97	74.71-85.96	***	***	*
	6	87.94	82.25-91.92			
	9	88.88	83.38-93.63			
	12	86.59	82.51-89.29			

ns-not significant at $p \leq 0.05$, ***- $p = 0.0001$, **- $p = 0.001$, *- $p = 0.01$.

Table 2. Effect of packaging materials and storage conditions on the physicochemical properties of *ogi* powder.

Parameters	Storage weeks	Initial <i>ogi</i> value	OON	OOS	OOC	OLS	OLN	OLC	ODN	ODS	ODC
WAC (%)	3	203 ^{abc}	206.00 ^{abc}	198.00 ^{bc}	209.00 ^a	199.00 ^{abc}	208.00 ^{ab}	209.00 ^a	205.00 ^{abc}	196.00 ^c	200.00 ^{abc}
	6	203 ^{ab}	205.00 ^{ab}	214.00 ^{ab}	207.00 ^{ab}	206.00 ^{ab}	222.00 ^a	208.00 ^b	200.00 ^{ab}	201.00 ^{ab}	204.00 ^{ab}
	9	203 ^{cde}	204.00 ^{bcde}	197.00 ^c	204.00 ^{bcde}	210.00 ^{ab}	206.00 ^{abc}	213.00 ^a	208.00 ^{abc}	199.00 ^{de}	208.00 ^{abc}
	12	203 ^{ab}	208.00 ^{ab}	218.00 ^{ab}	210.00 ^{ab}	209.00 ^{ab}	210.00 ^{ab}	212.00 ^{ab}	200.00 ^{ab}	199.00 ^b	254.00 ^a
b*	3	2610 ^a	2502.33 ^{bc}	2537.33 ^b	2417.00 ^{de}	2450.67 ^{cd}	2037.00 ^f	2472.67 ^c	2368.33 ^e	2368.33 ^e	2474.00 ^c
	6	2610 ^a	2207.67 ^f	2443.00 ^{de}	2537.00 ^b	2423.33 ^{de}	2436.33 ^{de}	2377.33 ^c	2462.00 ^{cd}	2524.00 ^{bc}	2373.67 ^c
	9	2610 ^{ab}	2526.00 ^e	2486.67 ^f	2590.33 ^{abc}	2543.33 ^{de}	2545.00 ^{de}	2547.67 ^{de}	2572.00 ^{bcd}	2560.67 ^{cde}	2618.67 ^a
	12	2610 ^a	2581.33 ^{ab}	2477.00 ^c	2611.33 ^a	2454.33 ^{cd}	2424.33 ^d	2534.67 ^b	2478.33 ^c	2605.33 ^a	2632.33 ^a

OON: *ogi* powder outside packed in polyethylene bag; OOS: *ogi* powder outside packed in polypropylene sack; OOC: *ogi* powder outside packed in PVC containers; OLS: *ogi* powder in light compartment packed in polypropylene sack; OLN: *ogi* powder in light compartment packed in polyethylene bag; OLC: *ogi* powder in light compartment packed in PVC containers; ODN: *ogi* powder in dark compartment packed in polyethylene bag; ODS: *ogi* powder in dark compartment packed in polypropylene sack; ODC: *ogi* powder in dark compartment packed in PVC containers. Means with different superscript along the same column are significantly different at $p \leq 0.05$.

Table 3. Effect of packaging materials and storage conditions on the pasting properties of *ogi* powder.

Parameters	Storage weeks	Initial <i>ogi</i> value	OON	OOS	OOC	OLS	OLN	OLC	ODN	ODS	ODC
Peak (RVU)	3	179.25 ^b	176.46 ^b	159.38 ^d	177.83 ^b	183.75 ^a	177.21 ^b	177.63 ^b	176.63 ^b	162.75 ^c	178.00 ^b
	6	179.25 ^{de}	183.59 ^{bcd}	174.42 ^c	192.88 ^a	183.21 ^{cd}	184.67 ^{bc}	188.63 ^{ab}	183.50 ^{bcd}	166.04 ^f	187.67 ^{bc}
	9	179.25 ^{bc}	179.71 ^{bc}	170.13 ^d	188.42 ^a	178.63 ^{bc}	184.25 ^{ab}	185.09 ^{ab}	176.58 ^c	165.54 ^d	183.34 ^{ab}
	12	179.25 ^c	183.47 ^{ab}	176.72 ^{cd}	174.07 ^d	180.17 ^{bc}	183.74 ^a	183.78 ^a	178.90 ^c	164.78 ^e	183.00 ^{ab}
Breakdown (RVU)	3	63.75 ^d	72.29 ^{ab}	57.58 ^e	71.04 ^{abc}	75.59 ^a	72.71 ^{ab}	73.17 ^{ab}	69.00 ^{bcd}	64.88 ^{cd}	68.75 ^{bcd}
	6	63.75 ^e	77.84 ^{bc}	71.42 ^d	82.21 ^{ab}	84.25 ^{ab}	82.75 ^{ab}	86.55 ^a	74.96 ^{cd}	63.05 ^c	79.00 ^{bc}
	9	63.75 ^e	86.05 ^{ab}	71.13 ^d	88.67 ^a	83.63 ^{ab}	84.92 ^{ab}	87.25 ^{ab}	77.17 ^c	58.13 ^f	81.75 ^{bc}
	12	63.75 ^e	79.76 ^b	73.75 ^d	72.56 ^d	79.69 ^b	81.59 ^{ab}	82.32 ^a	73.71 ^d	62.02 ^e	76.50 ^e
Final visc (RVU)	3	204.30 ^a	189.21 ^b	176.50 ^c	192.75 ^b	191.38 ^b	189.09 ^b	188.00 ^b	191.46 ^b	179.79 ^c	193.17 ^b
	6	204.30 ^a	192.84 ^d	192.42 ^d	199.67 ^b	190.88 ^d	191.54 ^d	190.54 ^d	193.38 ^{cd}	185.25 ^e	197.50 ^{bc}
	9	204.30 ^a	183.63 ^d	187.38 ^{bcd}	192.58 ^b	188.63 ^{bcd}	190.34 ^{cd}	183.25 ^d	185.54 ^{cd}	190.80 ^{bc}	190.75 ^{bc}
	12	204.30 ^a	192.01 ^b	189.81 ^{ab}	187.17 ^{bc}	189.75 ^{ab}	190.86 ^{ab}	187.26 ^{bc}	190.13 ^{ab}	185.28 ^d	193.81 ^b
Setback (RVU)	3	88.84 ^a	85.04 ^{ab}	74.71 ^c	85.96 ^{ab}	83.21 ^{ab}	84.59 ^{ab}	83.54 ^{ab}	83.83 ^{ab}	81.92 ^b	83.92 ^{ab}
	6	88.84 ^{ab}	87.09 ^{abc}	89.42 ^{ab}	89.00 ^{ab}	91.92 ^a	89.63 ^{ab}	88.46 ^{ab}	84.83 ^{bc}	82.25 ^c	88.83 ^{ab}
	9	88.84 ^{abc}	89.96 ^{ab}	88.38 ^{abc}	92.84 ^a	93.63 ^a	91.00 ^{ab}	85.42 ^{bc}	86.13 ^{bc}	83.38 ^c	89.17 ^{abc}
	12	88.84 ^a	88.30 ^a	86.83 ^{ab}	85.65 ^b	89.29 ^a	88.71 ^a	85.80 ^b	84.93 ^b	82.51 ^c	87.31 ^{ab}

OON: *ogi* powder outside packed in polyethylene bag; OOS: *ogi* powder outside packed in polypropylene sack; OOC: *ogi* powder outside packed in PVC containers; OLS: *ogi* powder in light compartment packed in polypropylene sack; OLN: *ogi* powder in light compartment packed in polyethylene bag; OLC: *ogi* powder in light compartment packed in PVC containers; ODN: *ogi* powder in dark compartment packed in polyethylene bag; ODS: *ogi* powder in dark compartment packed in polypropylene sack; ODC: *ogi* powder in dark compartment packed in PVC containers. Means with different superscript along the same column are significantly different at $p \leq 0.05$.

and setback viscosity was 89 RVU (Table 3). At the end of the storage period, mean peak viscosity was 179 RVU with a range of 165 to 184 RVU; breakdown viscosity ranged from 62 to 82 RVU with a mean of 76 RVU; final viscosity ranged from 185 to 194 RVU with a mean of 190 RVU and mean setback was 86.59 and ranged from 82.51 to 89.29 RVU (Table 3).

Pasting is the phenomenon following gelatinisation in the dissolution of starch. Pasting involves granular swelling, exudation of molecular components from starch granules and eventually total disruption of the granules ²⁷. *Ogi* is usually consumed after being cooked into paste; hence, its pasting properties are important in predicting the behaviour of the cooked paste. There was a general slight decrease in the peak viscosity after 3 weeks of storage. The peak viscosity decreased from 179 RVU before storage to 159 RVU in *ogi* powder packed in PP woven sacks and stored outside the storage box. At the end of the storage period, the overall mean for the peak viscosity was 179 RVU; *ogi* powder packed in PVC containers stored in the lighted compartment had the highest peak viscosity (184 RVU) while that packed in PP woven sacks stored in the dark compartment had the lowest (165 RVU) (Table 3). The differences observed in the peak viscosities of the *ogi* powders may be attributed to different rates of water absorption and swelling of starch granules during heating ²⁸.

Breakdown viscosity of *ogi* powder before storage was 64 RVU. After 3 weeks of storage, mean breakdown viscosity was 69 RVU with a range of 57 to 75 RVU. At the end of the twelve-week storage, mean breakdown viscosity was 75 RVU and ranged from

62 to 82 RVU (Table 1). The breakdown viscosity is regarded as a measure of the degree of disintegration of starch granules or paste stability during heating ²⁹. The implication of this observation is that *ogi* powder packed in PP woven sack and stored in the dark compartment with the lowest breakdown value was more resistant to heat and shear force during heating and that there was less rupture of starch granules, which could therefore guarantee a more stable cooked paste ³⁰.

There was a significant decrease ($p < 0.0001$) in the final viscosity of *ogi* powder. After 3 weeks of storage and irrespective of the packaging materials and storage conditions, the mean final viscosity was 187 RVU and ranged from 176 to 193 RVU. At the end of the storage period (12 weeks), mean final viscosity was 189 RVU and ranged from 185 to 193 RVU (Table 3); *ogi* powder packed in PVC stored in the dark compartment have the highest (193 RVU) and *ogi* powder packed in PP woven sack stored in the dark compartment had the lowest (185 RVU) (Table 3). The higher value of final viscosity has been attributed to the aggregation of the amylose molecules in the paste ³¹. Therefore, the low final viscosity value of *ogi* powder packed in PP woven sack stored in the dark compartment may be due to a seeming enzymatic activity that might have occurred during the grit soaking stage ³², thus reducing the aggregation of its amylose molecules.

The overall mean of the setback viscosity at the end of the twelve-week storage period was 86 RVU and ranged from 82 to 89 RVU. *Ogi* powder packed in PP woven sack stored in the lighted compartment had the highest (89 RVU). That packed in PP woven

sack and stored in the dark compartment had the lowest (82 RVU) (Table 3). The lowest setback observed in *ogi* powder packed in PP woven sack stored in the dark compartment may be attributed to a partial dextrinisation of the starch molecules. Akingbala *et*

*al.*¹⁵ observed that the enzymes stimulated in the soaking grains are capable of causing partial hydrolysis of the starch molecules, thereby reducing the amount of starch to be gelatinised, thus lowering the setback viscosity. The setback viscosity can be used to predict the storage life of a food product prepared from the flour³³. Therefore, the implication of this observation is that the product prepared from *ogi* powder packed in PP woven sacks and stored in the dark compartment is most likely to exhibit a lower retrogradation tendency and a higher cohesiveness than that of others, due to the lower setback viscosity³⁴.

Table 4. Effect of packaging materials and storage periods on the level of significance in the chemical properties of *ogi* powder.

Parameters	Storage weeks	Mean	Range	P of package	P of storage	P of package × storage
Protein (%)	3	7.45	7.28-7.73			
	6	7.56	7.28-7.78	***	***	***
	9	7.60	7.38-7.71			
	12	7.46	7.19-7.77			
Moisture (%)	3	6.55	5.07-9.11			
	6	6.59	5.32-8.29	***	***	***
	9	7.29	5.27-9.83			
	12	7.86	6.25-10.38			
Ash (%)	3	0.47	0.40-0.53			
	6	0.45	0.41-0.48	ns	ns	ns
	9	0.49	0.44-0.53			
	12	0.46	0.42-0.48			
Fat (%)	3	5.24	4.90-5.69			
	6	5.16	3.81-6.22	***	**	***
	9	4.90	3.59-5.46			
	12	5.37	4.75-6.00			
Sugar (%)	3	0.33	0.10-0.80			
	6	0.48	0.18-0.83	***	***	***
	9	0.56	0.34-1.01			
	12	1.14	0.59-2.00			
Starch (%)	3	74.74	65.95-81.11			
	6	72.02	63.44-83.81	***	***	***
	9	70.45	58.73-81.39			
	12	53.81	42.86-66.10			
pH	3	4.15	4.03-4.30			
	6	4.13	4.02-4.27	***	***	***
	9	4.15	4.05-4.28			
	12	4.14	4.06-4.27			

ns-not significant at $p \geq 0.05$, ***- $p = 0.0001$, **- $p = 0.001$, *- $p = 0.01$.

Table 5. Effect of packaging materials and storage conditions on the chemical properties of *ogi* powder.

Parameters	Storage weeks	Initial <i>ogi</i> value	OON	OOS	OOC	OLS	OLN	OLC	ODN	ODS	ODC
Protein (%)	3	7.54 ^b	7.73 ^a	7.49 ^{bc}	7.55 ^{bc}	7.32 ^d	7.29 ^d	7.47 ^{bc}	7.28 ^d	7.45 ^c	7.45 ^c
	6	7.54 ^c	7.69 ^{ab}	7.58 ^a	7.28 ^d	7.49 ^c	7.71 ^{ab}	7.49 ^c	7.51 ^c	7.54 ^c	7.78 ^a
	9	7.54 ^c	7.63 ^b	7.67 ^{bc}	7.59 ^c	7.54 ^c	7.71 ^a	7.61 ^{ab}	7.64 ^d	7.67 ^{ab}	7.38 ^d
	12	7.54 ^c	7.48 ^{cd}	7.37 ^{ab}	7.49 ^{cd}	7.22 ^f	7.77 ^a	7.70 ^b	7.19 ^f	7.45 ^d	7.44 ^d
Moisture (%)	3	5.50 ^d	6.57 ^c	9.11 ^a	5.52 ^d	6.55 ^c	5.76 ^d	5.07 ^c	6.50 ^c	8.12 ^b	5.71 ^d
	6	5.50 ^a	7.08 ^b	8.29 ^a	6.14 ^{cd}	6.40 ^c	6.41 ^c	5.32 ^c	7.23 ^b	6.47 ^c	6.00 ^d
	9	5.50 ^f	6.96 ^d	8.68 ^b	6.48 ^c	6.58 ^{de}	6.84 ^{de}	5.27 ^f	8.19 ^c	9.83 ^a	6.75 ^{de}
	12	5.50 ^h	8.12 ^c	8.11 ^c	6.84 ^f	7.56 ^e	7.87 ^d	6.25 ^g	8.86 ^b	10.38 ^a	6.75 ^f
Ash (%)	3	0.47 ^{ab}	0.40 ^b	0.46 ^{ab}	0.48 ^{ab}	0.49 ^{ab}	0.50 ^{ab}	0.53 ^a	0.40 ^b	0.45 ^{ab}	0.48 ^{ab}
	6	0.47 ^a	0.43 ^a	0.45 ^a	0.45 ^a	0.41 ^a	0.45 ^a	0.48 ^a	0.48 ^a	0.43 ^a	0.45 ^a
	9	0.47 ^{bc}	0.48 ^{abc}	0.44 ^c	0.49 ^{abc}	0.48 ^{abc}	0.53 ^a	0.49 ^{abc}	0.48 ^{abc}	0.49 ^{abc}	0.50 ^{ab}
	12	0.47 ^a	0.46 ^a	0.45 ^a	0.43 ^a	0.46 ^a	0.45 ^a	0.47 ^a	0.48 ^a	0.42 ^a	0.48 ^a
Fat (%)	3	5.33 ^{abc}	5.69 ^a	4.90 ^c	5.02 ^{bc}	4.92 ^c	5.51 ^{ab}	5.55 ^{ab}	5.06 ^{bc}	5.12 ^{bc}	5.41 ^{abc}
	6	5.33 ^b	5.18 ^b	5.12 ^b	6.22 ^a	5.94 ^a	4.03 ^c	3.81 ^c	5.30 ^b	4.86 ^b	5.94 ^a
	9	5.33 ^a	5.14 ^a	5.08 ^a	5.46 ^a	4.45 ^{ab}	3.59 ^b	5.34 ^a	5.09 ^a	4.80 ^a	5.11 ^a
	12	5.33 ^{ab}	5.23 ^{ab}	5.77 ^{ab}	5.25 ^{ab}	6.00 ^a	4.75 ^b	4.90 ^{ab}	5.48 ^{ab}	5.26 ^{ab}	5.69 ^{ab}
Sugar (%)	3	0.66 ^{ab}	0.12 ^{cd}	0.10 ^{cd}	0.10 ^d	0.80 ^a	0.69 ^{ab}	0.27 ^c	0.14 ^{cd}	0.61 ^b	0.15 ^{cd}
	6	0.66 ^b	0.54 ^c	0.70 ^b	0.37 ^d	0.18 ^c	0.35 ^d	0.22 ^c	0.40 ^d	0.83 ^a	0.72 ^b
	9	0.66 ^c	0.36 ^{de}	0.34 ^c	0.34 ^c	0.91 ^{ab}	1.01 ^a	0.51 ^d	0.37 ^{de}	0.85 ^b	0.39 ^{de}
	12	0.66 ^g	1.97 ^a	0.86 ^c	1.26 ^b	2.00 ^a	0.73 ^f	0.59 ^h	1.19 ^c	0.94 ^d	0.74 ^f
Starch (%)	3	60.03 ^d	74.25 ^{abc}	77.91 ^{ab}	79.46 ^b	73.60 ^{abc}	68.85 ^{bed}	65.95 ^{cd}	80.13 ^a	81.11 ^a	71.40 ^{abc}
	6	60.03 ^f	65.39 ^{de}	75.06 ^b	73.88 ^{bc}	82.89 ^a	83.81 ^a	68.97 ^d	67.78 ^{de}	70.00 ^{cd}	63.44 ^{ef}
	9	60.03 ^d	66.75 ^c	71.77 ^b	74.25 ^b	73.07 ^b	81.39 ^a	67.47 ^c	75.05 ^b	65.61 ^c	58.73 ^d
	12	60.03 ^b	56.27 ^c	53.03 ^d	56.82 ^c	66.10 ^a	52.71 ^d	53.05 ^d	57.45 ^c	42.86 ^f	46.01 ^c
pH	3	4.27 ^b	4.30 ^a	4.27 ^b	4.24 ^c	4.13 ^c	4.16 ^d	4.12 ^c	4.04 ^f	4.05 ^f	4.03 ^f
	6	4.27 ^a	4.27 ^a	4.26 ^a	4.26 ^a	4.09 ^c	4.12 ^b	4.09 ^{bc}	4.02 ^d	4.02 ^d	4.03 ^d
	9	4.27 ^a	4.28 ^a	4.27 ^a	4.25 ^b	4.07 ^{ef}	4.06 ^f	4.05 ^f	4.14 ^c	4.11 ^d	4.09 ^c
	12	4.27 ^a	4.27 ^a	4.26 ^a	4.25 ^a	4.09 ^b	4.07 ^{ab}	4.07 ^{ab}	4.08 ^{ab}	4.07 ^{ab}	4.06 ^c

OON: *ogi* powder outside packed in polyethylene bag; OOS: *ogi* powder outside packed in polypropylene sack; OOC: *ogi* powder outside packed in PVC containers; OLS: *ogi* powder in light compartment packed in polypropylene sack; OLN: *ogi* powder in light compartment packed in polyethylene bag; OLC: *ogi* powder in light compartment packed in PVC containers; ODN: *ogi* powder in dark compartment packed in polyethylene bag; ODS: *ogi* powder in dark compartment packed in polypropylene sack; ODC: *ogi* powder in dark compartment packed in PVC containers, ns-not. Means with different superscript along the same column are significantly different at $p \leq 0.05$.

Table 6. Temperature (°C) and relative humidity (R.H) (%) of each of the storage conditions.

Conditions	1 st		2 nd		3 rd		4 th	
	Temp.	R.H	Temp.	R.H.	Temp.	R.H.	Temp.	R.H.
Light	33.70	54.00	33.80	50.00	34.20	52.00	35.20	50.00
Dark	27.40	66.00	27.20	58.00	28.00	63.00	30.00	58.00
Outside box	26.60	75.00	26.10	63.00	27.50	68.00	27.90	73.00

period was 7.46%. When packed in HDPE bag, *ogi* powder stored in the lighted compartment had the highest (7.77%) and that stored in the dark compartment had the least (7.19%) (Table 5). This decrease might be caused by the high proteolytic activities from the increased relative humidity of the compartment (Table 6)³⁶.

Ogi powder before storage had a moisture content of 5.5%. This decreased to 5.07% in *ogi* powder packed in PVC containers and stored in the lighted compartment of the storage box. After twelve-week of storage, moisture content increased to 10.23% in *ogi* powder packed in PP woven sacks and stored in the dark compartment (Table 5). This increase in moisture content to 10.23% is still below the recommended safe level (12-13%) for storage of flour³⁷. The high water vapour transmission rate of the PP woven sacks⁹ and the increase in the relative humidity of the dark compartment (Table 6) might be responsible for the increase in moisture content. The low water vapour transmission rate of PVC⁹ and the decrease in the relative humidity of the lighted compartment (Table 6) might be responsible for the decrease in moisture content. The increase in the percentage moisture content of the stored *ogi* powder can be attributed to its hygroscopic properties³⁶ and might be due to the fact that at a high humidity (mean relative humidity 76.5±3%), the vapour pressure may have increased which aids water absorption into the samples. The ash content decreased from 0.47% before storage to 0.4% in HDPE bag packed *ogi* powder (stored outside and in the dark compartment of the storage box) at three-week of storage. It later increased to 0.53% in *ogi* powder packed in PVC can (three-week storage) and in HDPE (nine-week storage) and stored in the lighted compartment of the storage box (Table 5). At the end of the storage period of 12 weeks, the overall mean of the ash content was 0.46%; *ogi* powder packed in HDPE bag and PVC and stored in the dark compartment had the highest (0.48%). *Ogi* powder packed in PP woven sack and stored in the dark compartment of the storage box had the lowest (0.42%) (Table 5); however, there was no statistical difference in the ash content irrespective of the packaging materials and storage conditions.

The fat content increased from 5.33% before storage to 6.22% in PVC *ogi* powder stored outside the storage box at 6 weeks of storage and decreased to 3.59% in *ogi* powder packed in HDPE bag and stored in the lighted compartment at 9 weeks of storage (Table 5). The overall mean of the fat content at the end of the twelve-week storage period was 5.37%; *ogi* powder packed in PP woven sack and stored in the lighted compartment had the highest (6%) and powder packed in HDPE bag and stored in the lighted compartment had the least (4.75%) (Table 5). The decrease in fat content in the *ogi* powder packed in HDPE bag and stored in the lighted compartment might be attributed to the lipolytic activity of enzymes (i.e., lipase and lipoxidase) in the package during storage³⁶.

The sugar content decreased from 0.66% before storage to 0.1% in *ogi* powder packed in both PP woven sacks and PVC containers stored outside the storage box at 3 weeks of storage. It later increased to 2% in *ogi* powder packed in PP woven sack stored in

the lighted compartment at the 12 weeks of storage (Table 5). The overall mean of the sugar content at the end of the 12 weeks of storage was 1.14%; PP woven sack (2%) and PVC (0.59%) packed *ogi* powder stored in the lighted compartment of the storage box had the highest and lowest value, respectively (Table 5). The overall mean of each of the storage periods indicates that a direct relationship exist

between the sugar content of *ogi* powder and the length of storage (that is, as the storage period increased; the sugar content increased). Starch content increased from 60.03% before storage to 83.81% in *ogi* powder packed in HDPE bag and stored in the lighted compartment at 6 weeks of storage. It decreased to 42.86% in powder packed in PP woven sacks stored in the dark compartment at 12 weeks of storage (Table 5). The overall mean of the starch content at the end of the twelve-week storage period was 53.81%; *ogi* powder packed in PP woven sack and stored in the lighted compartment had the highest (66.1%) and *ogi* powder packed in PP woven sack stored in the dark compartment had the least value (42.86%) (Table 4). From the overall mean of each of the storage periods it appears that, an inverse relationship exists between the starch content and the length of storage (that is, as the storage period increased, the starch content decreased)(Table 5). The decrease in the starch content of *ogi* powder packed in PP woven stored in the dark compartment could be due to differences in the protective barrier offered by the packaging material. A similar observation was made by Daramola *et al.*³⁸ on the starch content of *pupuru* flour during storage.

The pH of the *ogi* powder slightly increased from 4.27 before storage to 4.30 in *ogi* powder packed in HDPE bag stored outside the storage box at 3 weeks of storage. It decreased to 4.02 in *ogi* powder packed in HDPE bag and PP woven sacks stored in the dark compartment at 6 weeks of storage (Table 5). The overall mean of the pH value at the end of the 12 weeks storage period was 4.14 (Table 5). *Ogi* powder packed in HDPE bag stored outside the storage box had the highest value (4.27) and *ogi* powder packed in container stored in the dark compartment had the lowest (4.06) (Table 5). This implies that the powder packed in HDPE bag stored outside the storage box maintained the original pH value after 12 weeks of storage. It was observed that *ogi* powder stored outside the storage box throughout the storage periods had higher pH values than that stored in the storage compartments (lighted and dark) irrespective of the packaging materials.

Conclusions

Packaging materials and storage conditions significantly affected the physicochemical and chemical properties of *ogi* powder during storage. It can thus, be concluded that for proper packaging and storage of yellow maize *ogi* powder, HDPE bag could be used and stored at a temperature range of 26.10-27.90°C and a relative humidity range of 63-75% (outside the storage box) or packed in PVC and stored at temperature range of 27.20-30°C and relative humidity range of and 58-66% (dark compartment of the storage box) for good product quality.

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References

- ¹Omuetti, O. and Ajomale, K. 2005. Chemical and sensory attributes of soy-corn milk types. *African Journal of Biotechnology* **4**(6):847-851
- ²Akingbala, J. O., Rooney, L. M. and Faubion, J. M. 1981. A Laboratory procedure for the preparation of "ogi" a Nigerian fermented food. *Journal of Food Science* **14**:1523-1526.
- ³Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D. and Webb, C. 2003. Cereal-based fermented foods and beverages. *Food Reserves International* **36**:527-543.
- ⁴Hounhouigan, D. J., Nout, M. J., Nago, R., Houben, C. M. and Rombouts, F. M. 1993. Changes in physicochemical properties of maize during natural fermentation of Mawe. *Journal of Cereal Science* **17**:291-300.
- ⁵Amingo, E. R. and Akingbala, J. O. 2004. Nutritive composition of *ogi* fortified with okra seed meal. *Analytical Chemistry* **71**:1017-1024.
- ⁶Komolafe, E. A. 2005. *Food Packaging. A Monograph*. Biotidara Press and Computers, Akure, 81 p.
- ⁷Van Garde, S. J. and Margy, W. 1994. *Food Preservation and Safety: Principles and Practice*. Iowa State University Press, Ames, 272 p.
- ⁸Teniola, O. D. 2003. Role of packaging and product presentation in the acceptability, quality improvement and safety of the traditional African fermented foods. Federal Institute of Industrial Research, Oshodi (FIRO), Lagos, Nigeria, pp. 1-24.
- ⁹Kadam D. M., Samuel, D. V. K., Chandra, P. and Sikarwar, H. S. 2008. Impact of processing treatments and packaging material on some properties of stored dehydrated cauliflower. *International Journal of Food Science and Technology* **43**:1-14.
- ¹⁰Adetuyi, F. O., Badejo, O. F., Ikujuola, A. V. and Omosuli, S. V. 2009. Storage influence on the functional properties of malted and unmalted maize (*Zea mays* L. ssp. *mays*) and soybean (*Glycine max* L. Merrill) flour blends. *African Journal of Food Science*. **3**(2):56-60.
- ¹¹Adeniji, T. A. 2005. The effect of fluorescent light and packaging materials on the shelf life of plantain and banana chips during storage. *African Journal of Applied Zoology Environmental Biology* **7**:19-22.
- ¹²Brown, W. E. 1992. *Plastics in Food Packaging: Properties Design and Fabrication*. Marcel Dekker Inc., 50 p.
- ¹³Ekwu, F. C. and Ikegwu, J. O. 1998. Effect of packaging materials and storage period on the functional and microbial load of cocoyam flour. *Proceeding of the 22nd Annual NIFST Conference*, pp. 266-267.
- ¹⁴Fadamiro, H. Y. and Odeyemi, O. O. 1998. Effect of temperature and packaging materials on storage of cocoa (*Theobroma cacao* L.). *Applied and Tropical Agriculture* **3**(2):99-103.
- ¹⁵Akingbala, J. O., Onochie, E. U., Adeyemi, I. A. and Oguntimehin, G. B. 1987. Steeping of whole dry milled maize kernels in *ogi* preparation. *Journal of Food Processing and Preservation* **11**:1-11.
- ¹⁶Osungbaro, T. O. 2009. Physical and nutritive properties of fermented cereal foods. *African Journal of Food Science* **3**(2):023-027.
- ¹⁷Beuchat, L. R. 1977. Functional and electrophoretic characteristic of succinylated peanut flour. *Agriculture and Food Chemistry* **25**:258-261.
- ¹⁸Deffenbaugh, L. B. and Walker, C. E. 1989. Comparison of starch pasting properties in the brabender Viscoamylograph and the Rapid Visco-Analyzer. *Cereal Chemistry* **66**:493-499.
- ¹⁹Adeniji, T. A., Barimalaa, I. S. and Achinewhu, S. C. 2006. Evaluation of bunch characteristics and flour yield potential in black sigatoka resistant plantain and banana hybrids. *Global Journal of Pure and Applied Sciences* **12**(1):41-43.
- ²⁰AOAC 1990. *Official Methods of Analysis of the Association of Official Analytical Chemists*. 15th edn. Arlington, Virginia, USA, p. 22(113-114), 169(207-208).
- ²¹Foss Analytical AB. 2003. Kjeldahl method of protein determination. *Manual for Kjeltac System 2300 Distilling and Titration Unit*, 36 p.
- ²²Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A. and Smith, F. 1956. Colorimetric method for determination of total sugars and related substances. *Analytical Chemistry* **28**:350-356.
- ²³SAS 2008. *Qualification Tools User's Guide SAS® 9.1*. SAS Institute Inc, Cary, NC, U. S. A.
- ²⁴Sanni, L. O., Adebawale, A. A., Filani, T. A., Oyewole, O. B. and Westby, A. 2006. Quality of flash and rotary dried fufu flour. *Journal of Food, Agriculture and Environment* **4**(3&4):74-78.
- ²⁵Bainbridge, Z., Tomlins, K., Wellings, K. and Westby, A. 1996. *Methods for Assessing Quality Characteristics of Non-grains Starch. Part 3. Laboratory Methods*. Natural Resources Institute, Chatham, UK, pp. 21-40.
- ²⁶Li, S., Tayie, F. A. K., Young, M. F., Rocheford, T. and White, W. S. 2007. Retention of provitamin A carotenoids in high β -carotene maize (*Zea mays*) during traditional African household processing. *Journal of Agriculture and Food Chemistry* **55**:10744-10750.
- ²⁷Sanni, S. A., Adebawale, A. A., Olayiwola I. O. and Maziya-Dixon, B. 2008. Chemical composition and pasting properties of iron-fortified maize flour. *Journal of Food, Agriculture & Environment* **6** (3&4):172-175.
- ²⁸Ragae, S. and Abdel-Aal, E. M. 2006. Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chemistry* **95**:9-18.
- ²⁹Dengate, H. N. 1984. Swelling, pasting, and gelling of wheat starch. In Pomeranz, Y. (ed.). *Advances in Cereal Science and Technology*. AACC, USA, pp. 49-82.
- ³⁰Farhat, I. A., Oguntola, T. and Neale, J. R. 1999. Characterisation of starches from West African yams. *Journal of Science, Food and Agriculture* **79**:2105-2112.
- ³¹Miles, M. J., Morris, V. J., Orford, P. D. and Ring, S. G. 1985. The roles of amylase and amylopectin in the gelation and retrogradation of starch. *Carbohydrate Reserves* **135**:271-281.
- ³²Nche, P. F., Odamtten, G. T., Nout, M. J. R. and Rombouts, F. M. 1996. Soaking of maize determines the quality of aflata for kenkey production. *Journal of Cereal Science* **24**:291-297.
- ³³Zaidul, I. S. M., Yamauchi, H., Kim, S., Hashimoto, N. and Noda, T. 2007. RVA study of mixtures of wheat flour and potato starches with different phosphorus contents. *Food Chemistry* **102**:1105-1111.
- ³⁴Bolade, M. K. 2009. Effect of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a maize-based non fermented food dumpling. *African Journal of Food Science* **3**(10):288-298.
- ³⁵Chandru, R., Ranganna, B., Palanimuthu, V., Munishamanna, K. B., and Subramanyam, S. 2010. Biochemical and microbial changes associated with storage of value added ready to cook finger millet flour. *Mysore Journal of Agricultural Sciences* **44**(2):255-259.
- ³⁶Butt, M. S., Nasir, M., Akhtar, S. and Sharif, K. 2010. Effect of moisture and packaging on the shelf life of wheat flour. *International Journal of Food Safety* **4**:1-6.
- ³⁷FAO 1992. *Maize in Human Nutrition*. FAO Food and Nutrition Series, No. 25 Food and Agriculture Organization, Rome, Italy, 105 p.
- ³⁸Daramola, O. A., Idowu, M. A., Atanda, O. O. and Oguntola, C. R. B. 2010. Effects of packaging material on the quality of "pupuru" flour during storage. *African Journal of Food Science* **4**(5):258-263.