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Effect of Packaging Materials and Storage Conditions on the Degradation of Xanthophylls in Yellow-Maize Ogi Powder

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Abstract The need to evaluate the effects of packaging materials and storage conditions on the degradation of xanthophylls in yellow maize *ogi* powder is important due to its health implication. *Ogi* powder was packaged in high-density polyethylene bag (HDPE), polypropylene woven sack (PP), and polyvinyl chloride container (PVC). The samples were stored under different conditions for 12 weeks and sampled at three-week intervals for analysis using High Performance Liquid Chromatography. The result showed that the total xanthophyll content of the *ogi* powder was 10.39 µg/g before storage with of zeaxanthin having the highest value (6.73 µg/g) and lutein (3.66 µg/g) the least. The reduction ~~in~~ lutein and zeaxanthin contents was significant in the *ogi* powder packaged in HDPE stored at 35°C and 50% relative humidity (RH). Therefore, PVC is recommended at 34°C and RH of 54% for up to 6 weeks while HDPE may be used at 28°C and 68% RH for 9 weeks, and that of PP might be 35°C and 50% RH if the storage period is extended to 12 weeks.

Keywords: *packaging materials, storage conditions, ogi powder, xanthophyll*

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1. Introduction

The xanthophylls; lutein and zeaxanthin are plant pigments that selectively accumulate in the macula of the retina of the eye where they are thought to protect the eye against the development of age-related macular degeneration [1,2]. Xanthophylls may possess antimutagenic and anticarcinogenic properties and play a role in the health of body tissues other than the eye as suggested by research studies related to carcinogenesis and the risk for cancer [3]. Studies have also shown that dietary intakes of lutein and zeaxanthin can reduce the risks of cataracts, which is the leading cause of blindness among the elderly and visual impairment in children [4,5,6,7,8]. They are the only carotenoids reported to be present in eye lens, where they filter harmful shortwave blue light, and act as antioxidants [9]. Though the blue light filtering efficacy of lutein is reported to be higher than that of zeaxanthin [10]. However, the presence of lutein and zeaxanthin in human blood and tissues is entirely due to the ingestion of food sources containing these xanthophylls [2].

Maize contains significant amounts of lutein, zeaxanthin, and other carotenoids [11]. Maize is widely consumed in Nigeria as roasted/boiled fresh green maize, maize flour for *tuwo* or fermented meal for *ogi* (gruel) among others [12,13]. *Ogi* is a fermented starchy paste traditionally made from maize, sorghum or millet [14]. It is considered the most important weaning food for infants in West Africa, although it is also consumed by older children and adults [15]. Though, the processing of maize is used to increase its shelf life but a significant loss of nutrients may occur via heat degradation or leaching. Kean *et al.* [16] reported that yellow-seeded maize milled fractions contain about 70% total carotenoid of which lutein and zeaxanthin are the major carotenoid.

Processed foods can be well-kept on shelf by a combination of aseptic packaging to exclude microbes and oxygen as well as to maintain a moderate temperature and relative humidity that could contribute to the degradation of nutrients [17], especially the xanthophylls. The presence of the polienic chain in xanthophylls increases their light absorption properties, and gives the molecule a high susceptibility to oxidative degradation and/ or geometrical isomerization caused by light, heat or acids [18]. Thus, the strong antioxidant power of xanthophylls is responsible for their easy degradation by temperature, light or oxygen [19,20,21]. Retention of xanthophylls during storage of processed foods is favoured by low storage temperature, the presence of a natural or added antioxidant, protection from light, exclusion of oxygen-by vacuum or hot-filling, modified atmosphere packaging and/ or oxygen-impermeable packaging [22].

Packaging materials used for the household storage of floury foods such as *ogi* powder include high density polyethylene (HDPE), polypropylene (PP) woven sacks and polyvinyl chloride container [23]. These packages 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 [24]. Allahvaisi [25] reported that the oxygen transmission (mm/100 cm^2 in 24 h and 25°C) of polyethylene, polypropylene and polyvinyl chloride are 500, 160 and between 8 to 160, respectively. The percentage water absorption of these packaging materials is rated polypropylene > polyethylene > polyvinyl chloride. The sunlight resistance is moderate-good for polyethylene, moderate for polypropylene and good for polyvinyl chloride. This researcher added that the water vapour transmission (g/100 cm^2 in 24h) of polyethylene is between 1-1.5, polypropylene 0.25 and polyvinyl chloride 4-10. Adetuyi *et al.* [26] 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. Consequently, it will be important to study the effect of different packaging materials and storage conditions on the degradation of the xanthophyll content of yellow maize *ogi* powder.

Therefore the aim of this study was to investigate the effect of packaging materials and storage conditions on the degradation of the xanthophyll content of yellow-maize *ogi* powder.

2. Materials and Methods

2.1. Materials

Yellow maize grain (DMR-LSRY) was obtained from the Maize Improvement Programme; International Institute of Tropical Agriculture, Ibadan, Nigeria. High-density polyethylene nylon bags (HDPE), polypropylene woven sacks (PP), and polyvinyl plastic containers (PVC) were obtained from a local market in Ibadan, Nigeria. The HDPE packaging material has a thickness of 1.3µm, the oxygen permeability of 500 mm/100 cm^2 in 24 h and 25°C) and water vapour permeability of 1.4 g/100 cm^2 in 24h, 37.8°C and relative humidity of 90%. The PP packaging material has a thickness of 0.75 µm, the oxygen permeability of 160 mm/100 cm^2 in 24 h and 25°C) and water vapour permeability of 0.27 g/100 cm^2 in 24h at 37.8°C and relative humidity of 90%. The PVC packaging material has a thickness of 0.45 µm, the oxygen permeability of 80 mm/100 cm^2 in 24 h and 25°C) and water vapour permeability of 8 g/100 cm^2 in 24h, 37.8°C and relative humidity of 90%. These were the specifications given by Afriplast Industries Ltd, Sw7/8, Obafemi Awolowo Way, Oke-Bola, Ibadan, Nigeria; where they packaging materials were produced.

2.2. 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 [27]. The water was decanted, and the fermented grains were washed with clean water and wet milled using an attrition mill. The bran was removed wet with a muslin cloth and the filtrate was allowed to settle for 24 h to form yellow starchy sediment, which is *ogi* slurry as [28]. 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 dryer (55±5°C), and dry milled to pass a mesh sieve of 0.5 mm, as reported by Awoyale *et al.* [27] (Figure 1).

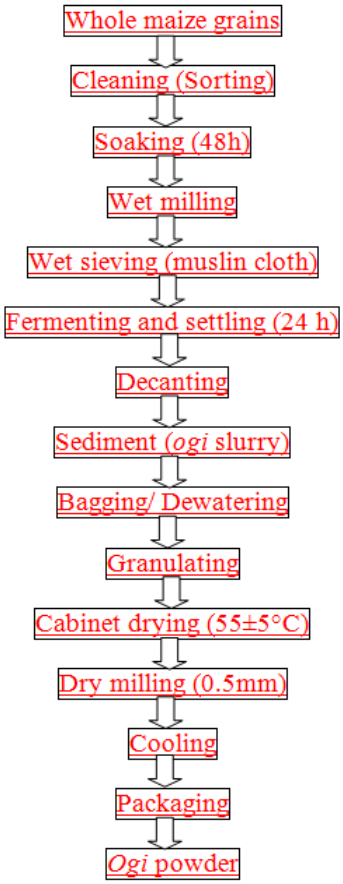

Figure 1. Flow chart for the production of *ogi* powder

2.3. Experimental Design

The yellow *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 as reported by Awoyale *et al.* [29]. 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 aluminium foil to increase light intensity. The lower compartment was painted with gloss black paint to maintain a dark enclosure for the samples. The doors of the two compartments were separated for ease of sample collection. Samples packaged in the materials were stored in both the lighted and dark compartments, in order to mimic the different storage environment for commercially sold *ogi* powder in the Nigeria market. 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-hygrometer at three-week intervals before sample

collection. The packaging of the samples was done in such a way that the total number of each packaging materials tellers with number of time samples will be collected for analyses (that is, 4 collections at 3 storage conditions, making 12 packaging materials each) (Table 3). Hence, collection of samples for analyses was made easy by removing each packaging materials containing the samples from the storage conditions. The xanthophyll carotenoids analyses of the samples were determined every 3 week until the end of the twelve-week storage period. All analyses were done in triplicate.

2.4. Xanthophyll Analysis

The method of Howe and Tanumihardjo [30] was employed to assess the samples for carotenoid composition and content. The extraction of carotenoid from the *ogi* samples (0.6 g) was done by adding ethanol (10 mL) containing 0.1% butylated hydroxyl toluene (BHT), using a vortex, mixer, and a 5 min ethanol precipitation in 85°C water bath. Potassium hydroxide (500 µL, 80% w/v) was added to the mixture to saponify the interfering oil. Samples were vortexed and placed in a water bath (85°C) for 5 min. It was vortexed again and returned to the water bath for an additional 5 min. Upon removal they were immediately placed in an ice bath where 3 mL of cold deionized water was added. Carotenoids were separated three times with addition of 3 mL of hexane, vortexed, and then centrifuged (1200 g) for 5 min. The combined hexane fractions were washed with deionized water three times, vortexed, and centrifuged for 5 min at 1200 g. The hexane fractions were dried down using TurboVap LIV concentrator under nitrogen gas. The dried extract was reconstituted in methanol/dichloromethane (1 mL, 50:50 v/v) and 100 µL aliquot were injected into the HPLC system for analyses of the xanthophylls (lutein and zeaxanthin). Waters HPLC system (Water Corporation, Milford, MA) consisting of a guard column, C30 YMC Carotenoid column (4.6 9 250 mm, 3 µm), Waters 626 binary HPLC pump, 717 auto-sampler and a 2996 photodiode array detector (PDA) was used for carotenoids quantification. The system operated with Empower 1 software (Waters Corporation). Solvent A consisted of methanol: water (92:8 v/v) with 10 mmol/L ammonium acetate and solvent B consisted of 100% methyl tertiary-butyl ether. Gradient elution was performed at 1 mL/min with the following condition: 29 min linear gradient from 83% to 59% A, 6 min linear gradient from 59% to 30% A, 1 min hold at 30% A, 4 min linear gradient from 30% to 83% A and a 4 min hold 83%. β-carotene eluted at ~25 min. Chromatograms were generated at 450 nm and identification of lutein and zeaxanthin were determined using external standard method based on the calibration curve from pure standards and verification of absorption spectrum and co-elution with available authentic standards. Standards of lutein and zeaxanthin were purchased from CaroteNature, GmbH (Lupsingen, Switzerland). Solvents were HPLC grade.

3. Statistical Analysis

Data were subjected to an analysis of variance (ANOVA) using Statistical Analysis System [31] package (version 9.1, SAS Institute, Inc., Cary, NC). The Fischer's protected Least Significant Difference (LSD) test was used for mean separation.

4. Results

The result showed that the total xanthophyll content of the yellow maize *ogi* powder before storage was 10.39 µg/g on dry weight basis; zeaxanthin had the highest value (6.73 µg/g) and lutein the least (3.66 µg/g). However, the xanthophylls contents of *ogi* powder significantly ($p<0.05$) decreased with increase in storage period using different packaging materials. The lutein content of the *ogi* powder reduced to 1.54 µg/g and zeaxanthin to 3.50 µg/g at the end of storage (Table 1). This implied that there was a 57% reduction in lutein and 48% reduction in zeaxanthin at the end of the 12 weeks of storage (Table 3). The storage periods ($p< 0.001$) and packaging materials ($p<0.05$) had significant effect on the lutein and zeaxanthin contents of the stored *ogi* powder, while the interactions between the storage period and packaging materials had significant effect ($p<0.01$) only on the zeaxanthin content of the *ogi* powder (Table 1). However, the interaction of the packaging materials and the storage period had no significant statistical effect ($p>0.05$) on the degradation of lutein content of *ogi* powder during storage.

Table 1. Effect of storage period on the xanthophylls content of stored yellow-seeded maize *ogi* powder

Parameters	Storage weeks	Mean	Range	P of Storage period	P of Package	P of Storage period X Package
lutein (µg/g)	0	3.66				
	3	2.20	1.56 - 3.04	***	*	NS
	6	1.93	1.44 - 2.45	***	*	NS
	9	1.75	1.38 - 2.10	***	*	NS
	12	1.54	1.15 - 1.95	***	*	NS
zeaxanthin (µg/g)	0	6.73				
	3	4.19	2.92 - 5.52	***	*	*
	6	3.50	2.52 - 4.39	***	*	*
	9	3.46	2.61 - 4.40	***	*	*
	12	3.50	2.62 - 4.78	***	*	*
Total Xanthophylls (µg/g)	0	10.39				
	3	6.38	4.48 - 8.55	***	*	NS
	6	5.43	3.96 - 6.83	***	*	NS
	9	5.21	4.01 - 6.48	***	*	NS
	12	5.04	3.77 - 6.72	***	*	NS

*p<0.05, **p<0.01, ***p<0.001, NS=not significant (p>0.05), All analyses were in triplicate.

At 3 weeks of storage, *ogi* powder packaged in PVC stored at 34°C and 54% RH (Table 3) had the highest lutein content with just a 17% degradation but the one packaged in HDPE stored at the same temperature and RH had the least degradation with a 57% reduction (Table 2). However, the zeaxanthin content of the *ogi* powder packaged in PVC and stored at 34°C and 54% RH had 18% degradation while the zeaxanthin content of that packaged in HDPE stored at the same condition had 57% reduction (Table 2).

Table 2. Effect of packaging materials and storage conditions on the xanthophylls content of stored yellow-seeded maize *ogi* powder

Parameters	Storage weeks	Initial *ogi* value	OON	OOS	OOC	OLS	Initial *ogi* value
Lutein	3	3.66±0.12^{a}	2.04±0.10^{bc}	2.48±1.13^{bc}	1.96±0.18^{c}	1.90±0.41^{c}	3.66±0.12^{a}
(µg/g)	6	3.66±0.12^{a}	2.19±0.05^{bc}	1.74±0.09^{dcf}	2.45±0.19^{b}	1.44±0.20^{f}	3.66±0.12^{a}
	9	3.66±0.12^{a}	2.10±0.26^{b}	1.82±0.11^{bc}	2.08±0.62^{b}	1.38±0.06^{c}	3.66±0.12^{a}
	12	3.66±0.12^{a}	1.78±0.16^{bcd}	1.84±0.16^{bc}	1.42±0.07^{bcd}	1.95±0.76^{b}	3.66±0.12^{a}
zeaxanthin)	3	6.73±0.33^{a}	3.83±0.17^{bc}	4.57±1.99^{bc}	3.70±0.33^{bc}	3.79±0.34^{bc}	6.73±0.33^{a}
(µg/g)	6	6.73±0.33^{a}	3.92±0.14^{b}	3.21±0.03^{cde}	4.39±0.41^{b}	2.52±0.43^{f}	6.73±0.33^{a}
	9	6.73±0.33^{a}	3.68±0.46^{bcd}	3.42±0.28^{cde}	4.03±0.83^{bc}	2.83±0.17^{de}	6.73±0.33^{a}
	12	6.73±0.33^{a}	3.60±0.32^{bc}	3.47±0.06^{bc}	3.22±0.16^{bc}	4.78±1.93^{b}	6.73±0.33^{a}
Total Xanthophylls	3	10.39±0.45^{a}	5.87±0.27^{bc}	7.05±3.12^{bc}	5.67±0.51^{c}	5.70±0.75^{bc}	10.39±0.45^{a}
(µg/g)	6	10.39±0.45^{a}	6.11±0.19^{de}	4.95±0.12^{b}	6.83±0.60^{b}	3.96±0.63^{e}	10.39±0.45^{a}
	9	10.39±0.45^{a}	5.78±0.72^{bc}	5.24±0.39^{b-e}	6.11±1.46^{b}	4.21±0.23^{de}	10.39±0.45^{a}
	12	10.39±0.45^{a}	5.38±0.48^{bc}	5.31±0.10^{bc}	4.64±0.23^{bc}	6.72±2.69^{b}	10.39±0.45^{a}

Parameters	Storage weeks	OLN	OLC	ODN	ODS	ODC
Lutein	3	1.56±0.12^{c}	3.04±0.67^{b}	2.24±0.34^{bc}	2.48±0.35^{bc}	2.05±0.41^{bc}
(µg/g)	6	1.61±0.01^{ef}	1.87±0.07^{c-f}	1.96±0.32^{cde}	1.93±0.30^{cde}	2.16±0.31^{bcd}
	9	1.41±0.26^{c}	1.47±0.14^{c}	2.07±0.08^{b}	1.59±0.01^{bc}	1.80±0.31^{bc}
	12	1.15±0.03^{d}	1.37±0.34^{bcd}	1.50±0.03^{bcd}	1.28±0.00^{cd}	1.53±0.29^{bcd}
zeaxanthin)	3	2.92±0.02^{c}	5.52±1.36^{ab}	4.53±0.15^{bc}	4.78±0.57^{b}	4.03±0.35^{bc}
(µg/g)	6	2.80±0.02^{ef}	3.15±0.01^{def}	3.88±0.29^{bc}	3.80±0.19^{bcd}	3.82±0.58^{bcd}
	9	2.61±0.17^{e}	2.88±0.31^{de}	4.40±0.11^{b}	3.52±0.06^{bcd}	3.80±0.62^{bc}
	12	2.62±0.10^{c}	3.21±0.84^{bc}	3.58±0.03b^{c}	3.16±0.12^{c}	3.86±0.73^{bc}
Total Xanthophylls	3	4.48±0.09^{c}	8.55±2.04^{ab}	6.76±0.49^{bc}	7.26±0.92^{bc}	6.09±0.76^{bc}
(µg/g)	6	4.41±0.01^{e}	5.02±0.08^{cde}	5.84±0.61^{bcd}	5.73±0.49^{cd}	5.98±0.89^{bcd}
	9	4.01±0.43^{e}	4.34±0.45^{cde}	6.48±0.19^{b}	5.11±0.08^{b-e}	5.60±0.93^{bcd}
	12	3.77±0.13^{c}	4.59±1.18^{bc}	5.08±0.05^{bc}	4.44±0.13^{c}	5.39±1.02^{bc}

OON-*ogi* powder outside packed in polyethylene nylon; OOS- *ogi* powder outside packed in polypropylene sack; OOC- *ogi* powder outside packed in PVC can; OLS- *ogi* powder in light compartment packed in polypropylene sack; OLN- *ogi* powder in light compartment packed in polyethylene nylon; OLC- *ogi* powder in light compartment packed in PVC can; ODN- *ogi* powder in dark compartment packed in polyethylene nylon; ODS- *ogi* powder in dark compartment packed in polypropylene sack; ODC- *ogi* powder in dark compartment packed in PVC can. ± Standard deviation. Means with different superscript along the same row are significantly different at $p \leq 0.05$. All analyses were in triplicate.

Table 3. Temperature and Relative humidity of each of the storage compartment

Compartment	3weeks		6weeks		9weeks		12weeks	
	Temp.(°C)	R.H (%)	Temp.(°C)	R.H (%)	Temp.(°C)	R.H (%)	Temp.(°C)	R.H (%)
Light	33.7	54.0	33.8	50.0	34.2	52.0	35.2	50.0
Dark	27.4	66.0	27.2	58.0	28.0	63.0	30.0	58.0
Outside box	26.6	75.0	26.1	63.0	27.5	68.0	27.9	73.0

Temp- Temperature, R.H-Relative humidity.

At 6 weeks of storage, the degradation of lutein was more pronounced (61%) in *Ogi* powder packaged in PP stored at 34°C and 54% RH, and less pronounced (33%) in *ogi* powder packaged in PVC stored at 26°C and RH of 63% (Table 2 & Table 3). The degradation of zeaxanthin at this storage period was more pronounced (63%) in *ogi* powder packaged in PP and stored at 34°C and RH of 50% but less (35%) in *ogi* powder packaged in PVC stored at 26°C and RH of 63%. Though there was non-significant difference ($p>0.05$) in the reduction of the zeaxanthin content of the *ogi* powder packaged in HDPE stored at 26°C and RH of 63% with that of the *ogi* powder packaged in PVC stored at the same temperature and RH (Table 2 & Table 3).

Extending the storage period of the *ogi* powder to 9 weeks further degraded its xanthophyll contents. The degradation in lutein content was higher (62%) with *ogi* powder packaged in PP stored at temperature and RH of 34°C and 52%, respectively, but lower (43%) in *ogi* powder packaged in HDPE stored at 28°C and 68% RH. However, there was non-significant difference ($p>0.05$) in the degradation of the lutein content of *ogi* powder packaged in HDPE stored at 28°C and 68% RH with that packaged in PVC stored at 28°C and 68% RH and HDPE stored at 28°C and 63% RH (Table 2 & Table 3). Conversely, the degradation of the zeaxanthin content of the *ogi* powder was observed to be higher (61%) in *ogi* powder packaged in HDPE stored at 34°C and RH of 52%, and lowers in HDPE stored at 28°C with RH of 63% (Table 2 & Table 3).

Additionally, prolonging the storage period of the *ogi* powder up to 12 weeks resulted in more degradation of the xanthophylls contained in the stored *ogi* powder. *Ogi* powder packaged in HDPE stored at 35°C and 50% RH had more (69%) of the lutein degradation with less (47%) observed in *ogi* powder packaged in PP stored at the same temperature and RH (Table 2 & Table 3). Similarly, the highest degradation of the zeaxanthin contained in the *ogi* powder was noticed in the ogi packaged in HDPE stored at 35°C and 50% RH and the least in PP stored at the same storage condition (Table 3). However, the percentage

degradation of zeaxanthin in the *ogi* powder at this storage period ranged from 29 to 61% (Table 2).

5. Discussion

Considerable research has been done at global level to generate new knowledge to understand the causes, and define steps/processes to slow the onset of cataract and age-related macular degeneration (AMD) through diets. Evidence showed that lutein and zeaxanthin are important dietary carotenoids used in preventing and reducing cataracts and AMD [32]. Consequently, since yellow maize is one of the major sources of these xanthophylls, detailed knowledge of its xanthophyll content after been processed to *ogi* powder, packaged and stored before consumption by young children or adults would be important.

The high value of zeaxanthin in the *ogi* powder before storage confirmed previous work on yellow maize, as yellow maize and its products has been reported to contain more of zeaxanthin than lutein [33,34]. The high level of reduction of lutein in the stored *ogi* powder could be attributed to high susceptibility of lutein to undergo oxidative degradation and geometrical isomerization [21]. However, the degradation in the stored *ogi* powder lutein and zeaxanthin contents could be attributed to increased temperature of the storage compartments [35], thus the reason behind the significant effect of the storage period and packaging materials on the xanthophyll contents of the stored *ogi* powder.

The uses of HDPE, PP and PVC packaging materials as well as the lighted and dark compartment of the storage box imitate the different packaging materials and storage conditions used for commercial sale of *ogi* powder or related products in Nigeria market [23]. The storage box is made in such a way that the temperature and RH are altered due to the presence of fluorescent light in the lighted compartment and its absence in the dark compartment. These different packaging materials have varying water vapour and oxygen transmission rate, and sunlight resistance as reported by Allahvaisi [25], which may affect products shelf life. Consequently, *ogi* powder packaged in PVC stored at 34°C and 54% RH (lighted compartment) could retain more of its lutein and zeaxanthin content compared to using PP at the same storage conditions for a storage period of 3 weeks. The high retention of these xanthophylls in the PVC could be attributed to the low oxygen permeability and good light resistance of the package, thus confirming the observations of Rodriguez-Amaya *et al.* [36] and Cardoso *et al.* [22]. These studies reported that the retention of xanthophylls during storage of processed foods is favoured by low storage temperature, the presence of a natural or added antioxidant, protection from light, exclusion of oxygen-by vacuum or hot-filling, modified atmosphere packaging and/ or oxygen-impermeable packaging.

The PVC might still reduce the degradation of lutein and zeaxanthin content of the *ogi* powder if the storage period is extended to 6 weeks with change in temperature and RH to 26°C and 63%, respectively (outside the storage box) [24,25]. The PP may not be a good packaging material for the retention of these xanthophylls in the *ogi* powder at 26°C and 63% RH (outside the storage box) at 6 weeks of storage, due to the high reduction percentage of lutein and zeaxanthin in the package. Additionally, the HDPE could be the best packaging materials for the retention of lutein and zeaxanthin in the *ogi* powder when the storage period is increased to 9 weeks with storage temperature of 28°C and RH 68% (outside the storage box). In the absence of the HDPE for the packaging of the *ogi* powder at this storage period and conditions, PVC could be used for the retention of lutein since there was ~~no~~ insignificant difference in the degradation of lutein in this package and that of the HDPE. However, when the storage temperature is changed to 34°C and the RH to 52% (lighted compartment), HDPE may not be a good packaging material if the intention is to retain more of the zeaxanthin in the *ogi* powder. This is because there was high reduction percentage in zeaxanthin in this package and storage conditions. This observation could be attributed to high temperature of the storage compartment and light sensitivity of the packaging material [22].

The degradation of lutein and zeaxanthin contained in *ogi* powder could be reduced if the *ogi* powder is packaged in PP and stored at 35°C and 50% RH (lighted compartment). This is because more of these xanthophylls were retained in this packaging material and storage conditions. This implied that PP is more sensitive to oxygen but not to temperature and light, thus, the reduction in the degradation of these xanthophylls at 35°C for a period of 12 weeks. However, HDPE may not be a good packaging material at this length of storage and storage conditions, since more of the xanthophylls were lost. This effect of HDPE could be linked to its high oxygen permeability and sensitivity to light [25].

6. Conclusion

The yellow maize *ogi* powder may be used for the reduction of the risk of cancers, cardiovascular disease, age-related macular degeneration, and cataract formation due to the presence of lutein and zeaxanthin. However, if there is need for storage before consumption, which is mostly being practiced by the consumers and for the *ogi* powder to retain its health benefits; PVC packaging material is recommended at 34°C and RH of 54% for up to 6 weeks while HDPE may be used at 28°C and 68% RH for 9 weeks. But, PP may be used at 35°C and 50% RH if the storage period is extended to 12 weeks. However, there is need to study the bioavailability and bio-accessibility of these xanthophylls with regards to their health functions.

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