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Retention of Pro-vitamin A Carotenoids in *Ogi* Powder as Affected by Packaging Materials and Storage Conditions

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Abstract The effect of different packages and storage conditions on the retention of pro-vitamin A carotenoids (pVAC) in *ogi* powder produced from yellow-seeded maize was investigated to study its storage stability on micronutrient retention. The o*gi* powder produced was packaged in a high-density polyethylene bag (HDPE), a polypropylene woven sack (PP), and a polyvinyl chloride container (PVC), and stored in different conditions for 12 weeks with sampling done at three-week intervals for pVACanalysis. At the end of the storage period, *ogi* powder packaged in HDPE stored outside the storage box had the highest percentage retention (31.32%) of *trans*-β-carotene and that packaged in PVC container stored in the lighted compartment had the least (21.57%). Therefore, HDPE could be a good package for the retention of *trans*-β-carotene (which is the most bioactive) in *ogi* powder when stored at a temperature of 27°C and relative humidity of 73%.

Keywords: *packaging materials, storage conditions, ogi powder, pro-vitamin A carotenoids*

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1. Introduction

Vitamin A deficiency (VAD) is a major global public health problem that affects approximately 127 million pre-schoolchildren concerning impaired vision and more than 7.2 million pregnant women. Apart from these consequences, VAD increased infectious morbidity and mortality, growth retardation, and anemia [1]. Maize was chosen as one of the six key staple food crops to combat micronutrient malnutrition especially VAD in developing countries through biofortification [2].

Yellow-seeded maize varieties with high pro-vitamin A content are being biofortified to produce kernels that have enhanced contents of β-carotene and other pro-vitamin A carotenoids (pVAC) [3]. Consequently, the yellow seeded maize will serve as a cost-efficient and renewable resource to alleviate VAD, given the large daily maize consumption by entire families, including children and women who are most vulnerable to this disease [2].

Maize is as roasted fresh green maize, maize flour for *tuwo*, boiled fresh maize and fermented meal for *ogi* among others in Nigeria [4]. *Ogi* is a starchy fermented paste traditionally made from maize, sorghum or millet [5]. It is the most important weaning food for infants in West Africa, although older children and adults also consume it [6]. Therefore, the use of yellow-seeded maize in the production of *ogi* might add to its pro-vitamin A carotenoids content if properly processed, packaged and stored.

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 and relative humidity that could contribute to the degradation of nutrients [7], especially the pVAC. Retention of pVAC during storage of processed foods is by low storage temperature, protection from light, exclusion of oxygen by vacuum or hot-filling, modified atmosphere packaging, or oxygen-impermeable packaging and the presence of a natural or added antioxidant [8].

Detailed knowledge of the retention of pVAC during traditional processing steps is a prerequisite for predicting the efficacy of biofortification in combating VAD. Such knowledge also provides a basis for strategies to enhance carotenoid retention, thereby increasing the pro-vitamin A value of the processed maize [3]. Padula and Rodriguez-Amaya [9] observed that the β-carotene content of bottled guava juice remained practically unchanged during 10 months storage at room temperature. Godoy and Rodriguez-Amaya [10] added that mango slices in epoxy/plain tinplate stored at room temperature lead to 50% reduction in its β-carotene content after 14 months and 84% reduction after 24 months, regardless of the container used. Also, Godoy and Rodriguez-Amaya [10], reported that the β-cryptoxanthin content of bottled papaya puree decreased by 27% after 14 months of storage. Furthermore, the α-carotene, β-carotene and β-cryptoxanthin content of Spanish orange puree reduced by 50, 11 and 30% after 27 months storage at 21°C respectively [11]. Li *et al.[3]* also reported small but significant losses of α-carotene, β-carotene and β-cryptoxanthin in wet milled flour during the initial soaking and milling of yellow maize. However, there is presently no information on the effect of packaging materials and storage conditions on the retention of pVAC in *Ogi* powder.

Therefore, the objective of our study is to investigate the effect of different packaging materials and storage conditions on the retention of pVAC in *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 [12]. The water was decanted, and the fermented grains were washed with clean water and wet milled using an attrition mill. The wet bran was removed with a muslin cloth and the sievate was allowed to settle for 24 h to form the starchy sediment *ogi* slurry as described by Osungbaro [13]. 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.* [14] (Figure 1).

2.3. Storage Study

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 Awoyale *et al.* [14] with slight modifications in the size of the storage box and the fluorescent tube. The storage box (2.6 feet length, breadth and width) consisted of two compartments (upper and lower). A 2 feet 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 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. The pro-vitamin A carotenoids analysis of the samples were determined every 3 week until the end of the twelve-week storage period. All analyses were done in triplicate.

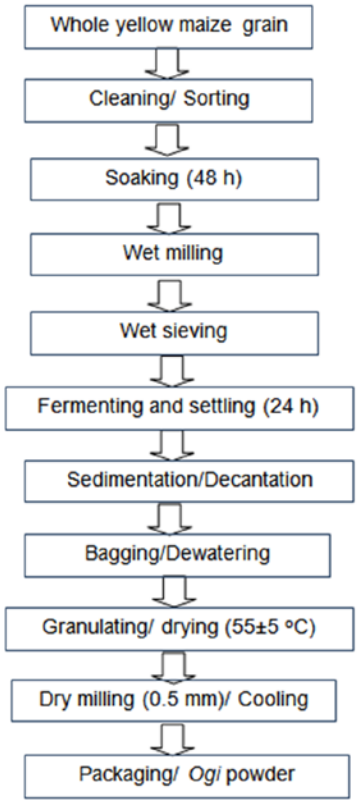

Figure 1. Flow chart for the production of yellow maize *ogi* powder

2.4. Provitamin A Carotenoids Analysis

To determine the provitamin A carotenoid, approximately 15 g of each sample, plus 3 g of Celite 454 (Tedia, Ohio, USA), were weighed. Successive additions of 25 ml of acetone were performed to obtain a paste, which was transferred to a sintered funnel (5 µm) coupled to a 250 ml Buchner flask and filtered under vacuum. This procedure was repeated three times until the sample became colourless, and the extract was transferred to a 500 ml separation funnel containing 40 ml of petroleum ether. The acetone was removed through the slow addition of ultrapure water (Millipore) to prevent emulsion formation. The aqueous phase was discarded, and this procedure was repeated four times until no residual solvent remained. The extract was then transferred through a funnel containing 15 g of anhydrous sodium sulphate and made up a volume of 50 ml with petroleum ether [15]. Additionally, for the identification and quantification of the provitamin A carotenoid, 2 ml was removed from the extract and dried in an amber flask under nitrogen flow. The sample was diluted in 100 µl of acetone under shaking in a vortex mixer (Genie 2-Scientific Industries) and transferred to a 2-ml amber flask for high-performance liquid chromatography (HPLC) analysis. The concentration of the provitamin A carotenoid was determined using the equation reported by Carvalho *et al.* [15].

$$C(\mu g/g) = \frac{A_X * C_S(\mu g/ml) * V(ml)}{A_S * P(g)}$$

Where *Ax* = carotenoid peak area, *Cs* = standard concentration, *As* = standard area, *V*= total extract volume, and *P* = sample weight.

2.5 True Retention of Provitamin A Carotenoids

The pVAC retention of the samples were calculated as reported by *Li et al*. [3] and shown below:

$$\frac{\begin{pmatrix}\text{pVAC content per g of processed food}\\ \text{x g of food after processing}\end{pmatrix}}{\begin{pmatrix}\text{pVAC content per g of raw food}\\ \text{x g of food before processing}\end{pmatrix}} \text{x100}$$

Note: The raw food was taken as the unprocessed yellow seeded maize. The pro-vitamin A carotenoids content (µg/g) of the maize as analyzed using the above method were; β-cryptoxanthin (2.21), α-carotene (0.34), *trans*-β-carotene (0.77), 13-*cis*- β-carotene (0.17) and 9-*cis*-β-carotene (0.35).

2.6. Statistical Analysis

All analyses were done in triplicate and data generated were subjected to an analysis of variance (ANOVA) using Statistical Analysis System [16] package (version 9.1, SAS Institute, Inc., Cary, NC). The Fischer's protected Least Significant Difference (LSD) test was used for mean separation.

3. Results and Discussions

The term pro-vitamin A carotenoids (pVAC) is as a generic descriptor for all carotenoids exhibiting qualitatively the biological activity of vitamin A [17]. Yellow-seeded maize consists of pVAC such as α-carotene, β-carotene and β-cryptoxanthin [3]. As *ogi* is the major food product made from maize; considered as the most important food for infants and as well consumed by older children and adults in West Africa [6], detailed knowledge of the retention of these pVAC during ogi powder production and subsequent storage is a prerequisite for predicting the efficacy yellow-seeded maize in combating vitamin A deficiency (VAD) [3], among these population groups. This work revealed that the storage periods significantly affected all the pVAC contents of the *ogi* powder, while the packaging materials had a significant effect on the α-carotene ($p \leq 0.01$), and the 13-*cis* ($p \leq 0.01$) and 9-*cis* ($p \leq 0.05$) β-carotene contents. Besides, the interactions between the storage period and packaging materials had a significant effect ($p \leq 0.01$) on only the α-carotene content of the *ogi* powder (Table 1). The result showed that α-carotene was the most unstable out of all the pVAC evaluated in the *Ogi* powder, concerning the storage periods and packaging materials.

Table 1. Effect of storage periods on the pro-vitamin A contentsof *Ogi* powder

Pro-vitamin A	Before storage (µg/g)	Storage period (µg/g)	Mean values (µg/g)	Range (µg/g)	CV (%)	P Storage period	P Packages	P Storage period X Packages
β-Cryptoxanthin		3.00	0.90	0.68 - 1.19	18.30	*	NS	NS
		6.00	0.81	0.61 - 0.97	7.94	*	NS	NS
	1.38	9.00	0.80	0.64 - 1.00	9.75	*	NS	NS
		12.00	0.74	0.45 - 0.98	24.70	*	NS	NS
α-carotene		3.00	0.11	0.09 - 0.15	24.30	***	**	**
		6.00	0.09	0.06 - 0.12	9.00	***	**	**
	0.16	9.00	0.08	0.06 - 0.10	13.20	***	**	**
		12.00	0.05	0.03 - 0.08	15.30	***	**	**
Trans-β-carotene		3.00	0.30	0.21 - 0.42	19.70	***	NS	NS
		6.00	0.25	0.20 - 0.27	8.69	***	NS	NS
	0.41	9.00	0.24	0.20 - 0.29	8.42	***	NS	NS
		12.00	0.24	0.19 - 0.29	17.3	***	NS	NS
13-*cis*-β-carotene		3.00	0.09	0.06 - 0.11	20.10	***	**	NS
		6.00	0.08	0.06 - 0.10	13.60	***	**	NS
	0.13	9.00	0.07	0.06 - 0.10	16.50	***	**	NS
		12.00	0.06	0.06 - 0.08	6.46	***	**	NS
9-*cis*-β-carotene		3.00	0.17	0.12 - 0.21	19.00	***	*	NS
		6.00	0.14	0.12 - 0.16	8.45	***	*	NS
	0.21	9.00	0.13	0.11 - 0.15	5.88	***	*	NS
		12.00	0.13	0.11 - 0.15	10.50	***	*	NS
Total β-carotene		3.00	0.56	0.42 - 0.73	16.90	***	*	NS
		6.00	0.47	0.39 - 0.56	8.37	***	*	NS
	0.75	9.00	0.45	0.38 - 0.52	6.50	***	*	NS
		12.00	0.43	0.36 - 0.50	12.50	***	*	NS

*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$, NS-not significant ($p > 0.05$)
All analyses were in triplicate

The β-cryptoxanthin content in the *Ogi* powder reduced from 1.38 µg/g before storage to 0.74 µg/g at the end of storage (Table 1). HDPE packaged *ogi* powder stored outside the storage box retained the highest β-cryptoxanthin content (35.65%) and that packaged in PVC stored in the lightened compartment retained the least (24.46%) (Table 2). The high temperature of the lighted compartment of the storage box (35°C) (Table 4) might be responsible for the low retention of β-cryptoxanthin in the PVC packaged *ogi* powder [18]. However, the β-cryptoxanthin percentage retention level in the *Ogi* powder was significantly affected ($p \leq 0.01$, $p \leq 0.001$) by the storage compartment, packaging materials and storage periods (Table 3).

Table 2. Effect of packages and storage conditions on the provitamin A retention (%) level of *ogi* powder

Parameters	Storage weeks	O	OON	OOS	OOC	OLS
β-Cryptoxanthin	3	59.80±4.60^{a}	35.70±0.74^{d-f}	29.70±1.37^{g}	33.80±0.32^{e-g}	39.90±2.20^{b-d}
	6	59.80±4.60^{a}	38.50±0.66^{b}	31.20±0.89d^{e}	38.90±1.46^{b}	28.50±0.06^{e}
	9	59.80±4.60^{a}	37.50±3.26^{b-d}	33.40±2.58^{de}	36.00±0.37^{cd}	29.00±2.19^{ef}
	12	59.80±4.50^{a}	35.70±1.25^{b}	34.70±0.84^{bc}	32.20±0.01^{b-d}	31.60±0.30^{c-e}
α-carotene	3	48.50±4.23^{a}	34.00±0.87^{bc}	26.80±1.18^{d}	30.60±0.05^{b-d}	32.90±2.13^{bc}
	6	48.50±4.23^{a}	29.70±0.32^{bc}	23.00±0.19^{de}	33.00±1.90^{b}	21.30±0.84^{e}
	9	48.50±4.23^{a}	27.20±1.90^{b}	22.90±2.80^{b-d}	25.10±2.89^{bc}	16.60±1.80^{e}
	12	48.50±4.23^{a}	22.10±1.75^{b}	22.60±1.60^{b}	14.90±1.51^{c}	15.00±1.04^{c}
Trans-β-carotene	3	50.20±3.10^{a}	34.40±2.76^{c}	33.70±0.19^{c}	34.40±2.98^{c}	37.60±0.06^{bc}
	6	50. 20±3.10^{a}	33.10±0.98^{b}	26.80±0.37^{ef}	31.80±0.77^{bc}	24.50±2.78^{f}
	9	50. 20±3.10^{a}	29.40±0.32^{c}	27.80±1.34^{cd}	28.60±0.81^{c}	24.90±1.29^{d}
	12	50.20±3.10^{a}	31.30±1.27^{b}	30.30±0.47^{bc}	28.00±0.23^{c-e}	27.40±1.34^{d-f}
13-*cis*-β-carotene	3	75.10±4.15^{a}	66.10±4.55^{b}	47.30±1.51^{e}	60.10±2.39^{cd}	34.10±0.39^{f}
	6	75. 10±4.15^{a}	43.90±2.04^{d}	34.00±0.49^{e}	60.00±0.76^{b}	34.80±0.68^{e}
	9	75. 10±4.14^{a}	52.60±8.16^{b}	34.60±0.01^{d}	48.40±1.46^{bc}	34.30±0.37^{d}
	12	75. 10±4.15^{a}	45.90±1.02^{b}	33.70±1.24^{c}	34.30±0.40^{c}	34.30±0.36^{c}
9-*cis*-β-carotene	3	61.80±6.03^{a}	44.90±0.45^{bc}	43.00±3.42^{c}	46.30±1.32^{bc}	46.80±1.54^{bc}
	6	61. 80±6.02^{a}	44.20±2.52^{b}	38.40±0.39^{b-e}	43.90±2.06^{bc}	33.40±2.98^{e}
	9	61. 80±6.03^{a}	40.60±2.39^{bc}	36.10±1.26^{cd}	35.80±0.93^{cd}	35.40±1.22^{cd}
	12	61. 80±6.03^{a}	40.40±0.24^{bc}	42.10±2.84^{b}	39.80±0.71^{b-d}	31.80±2.51^{ef}
Total β-carotene	3	55.90±3.27^{a}	44.60±2.30^{b}	39.50±3.24^{cd}	40.90±0.72^{b-d}	40.40±1.48^{b-d}
	6	55.90±3.27^{a}	37.80±0.03^{b}	29.70±0.64^{e}	38.10±0.44^{b}	32.80±0.23^{c-e}
	9	55.90±3.27^{a}	36.10±2.50^{bc}	31.90±2.86^{de}	33.20±0.20^{cd}	28.60±0.75^{e}
	12	55.90±3.27^{a}	35.30±1.16^{b}	34.30±0.34^{b}	32.00±1.24^{bc}	28.10±2.13^{de}

Parameters	Storage weeks	OLN	OLC	ODN	ODS	ODC
β-Cryptoxanthin	3	30.30±1.80^{fg}	45.10±4.+04^{b}	42.60±0.155^{bc}	42.40±2.85^{bc}	38.70±1.67^{c-e}
	6	29.30±1.82^{e}	33.40±0.27^{cd}	37.10±0.17^{bc}	36.30±0.24^{bc}	33.70±1.82^{cd}
	9	27.50±1.78^{f}	30.80±1.65^{ef}	42.20±0.41^{b}	33.20±2.24^{de}	40.00±0.53^{bc}
	12	28.00±0.19^{ef}	24.50±0.43^{f}	34.00±2.06^{bc}	28.90±0.67^{de}	32.00±0.39^{b-d}
α-carotene	3	17.80±2.55^{e}	31.00±1.12^{b-d}	35.10±2.80^{b}	32.10±2.22^{bc}	29.20±1.55^{cd}
	6	21.90±2.26^{e}	26.70±0.98^{cd}	24.40±2.19^{de}	26.30±1.44^{cd}	31.10±0.32^{b}
	9	20.80±0.01^{c-e}	18.30±0.11^{de}	26.00±0.88^{b}	24.00±0.64^{bc}	23.50±3.15^{bc}
	12	8.50±0.83^{e}	15.40±1.24^{c}	13.10±2.03^{cd}	9.11±0.56^{de}	14.60±1.57^{c}
Trans-β-carotene	3	25.70±0.07^{d}	38.40±2.76^{bc}	40.30±3.12^{b}	37.00±2.03^{bc}	33.40±1.84^{c}
	6	27.90±0.85^{d-f}	30.10±1.30^{b-e}	32.00±1.45^{bc}	30.90±1.81^{b-d}	28.80±0.12^{c-e}
	9	25.10±0.34^{d}	28.00±0.03^{cd}	35.30±0.56^{b}	28.40±1.86^{c}	33.60±1.77^{b}
	12	23.90±0.72^{gh}	21.60±0.30^{h}	29.50±0.84^{b-d}	24.80±0.56^{fg}	26.60±0.82^{e-g}
13-*cis*-β-carotene	3	48.80±1.47^{e}	56.60±1.71^{d}	60.40±3.49^{cd}	62.00±0.36^{b-d}	63.20±1.31^{bc}
	6	35.40±2.39^{e}	49.20±1.00^{c}	48.30±1.94^{c}	47.30±1.73^{cd}	35.40±1.27^{e}
	9	34.30±0.48^{d}	34.30±0.44^{d}	45.90±0.93^{c}	34.30±0.42^{d}	46.70±1.49^{bc}
	12	34.30±0.45^{c}	34.30±0.45^{c}	34.40±0.43^{c}	34.20±0.43^{c}	34.30±0.55^{c}
9-*cis*-β-carotene	3	35.70±0.29^{d}	45.00±0.03^{bc}	49.60±0.35^{b}	45.70±2.34^{bc}	44.00±2.71^{bc}
	6	34.90±1.88^{de}	41.10±2.62^{bc}	39.70±0.56^{b-d}	38.30±1.15^{de}	39.90±1.41^{b-d}
	9	35.20±2.48^{d}	35.40±0.09^{cd}	43.20±1.31^{b}	35.70±0.59^{cd}	41.60±0.83^{b}
	12	31.90±2.14^{ef}	34.90±0.86^{d-f}	38.70±1.64^{b-d}	30.90±0.60^{f}	36.40±0.05^{c-e}
Total β-carotene	3	31.00±0.55^{e}	41.60±0.19^{b-d}	42.20±0.84^{b-d}	43.00±3.38^{bc}	38.10±0.42^{d}
	6	31.20±2.04^{de}	35.10±1.14^{bc}	35.90±2.85^{bc}	34.60±1.01^{b-d}	34.00±0.73^{cd}
	9	28.70±0.52^{e}	30.50±0.35^{de}	38.40±0.37^{b}	31.90±2.53^{de}	36.70±0.99^{bc}
	12	27.10±0.69^{e}	27.20±1.83^{de}	32.20±0.47^{bc}	27.40±0.48^{de}	30.60±1.12^{cd}

O-*Ogi* before storage, OON-*ogi* in high density polyethylene nylon stored outside the storage box; OOS- *ogi* in polypropylene woven sack stored outside the storage box ; OOC- *ogi* in polyvinyl chloride can stored outside the storage box; OLS- *ogi* in polypropylene woven sack stored in lighted compartment ; OLN- *ogi* in high density polyethylene nylon stored in the lighted compartment ; OLC- *ogi* in polyvinyl chloride can stored in the lighted compartment ; ODN- *ogi* in high density polyethylene nylon stored in the dark compartment; ODS- - *ogi* in polypropylene woven sack stored in dark compartment; ODC- *ogi* in polyvinyl chloride can stored in the dark compartment . ± Standard deviation

Means with different letters along the same column are significantly different at $p \leq 0.05$

All analyses were in triplicate

The α-carotene content of the *ogi* powder on the other hand, which is the least stable out of all the pVAC as stated earlier, reduced from 0.16 µg/g before storage to 0.05 µg/g at the end of storage (Table 1). *Ogi* powder packaged in PP woven sack stored outside the storage box retained the highest percentage of α-carotene (22.58%) while that in HDPE stored in the lighted compartment retained the least (8.50%) (Table 2). The high retention of α-carotene in PP woven sack packed *ogi* powder stored at the relative humidity of 73% (Table 4) could be to the low water vapour transmission rate of the packaging material [19].

Trans-β-carotene is the natural isomeric form of β-carotene in most foods. It is highly unstable, particularly in dehydrated foods and could be converted to the *cis*-form in the presence of light, oxygen, moisture and high temperature among others [8]. The *trans*-β-carotene content of the *ogi* powder reduced from 0.41µg/g before storage to 0.24 µg/g at the end of 12 weeks of storage (Table 1), with *ogi* powder packaged in HDPE stored outside the storage box having the highest percentage retention (31.32%) and that packed in PVC container stored in the lighted compartment the least (21.57%) (Table 2).Since, *trans*-β-carotene is highly bioactive in terms of its bioconversion to vitamin A [8], HDPE could be a good package when stored at a temperature of 27°C and relative humidity of 73% for the retention of this pVAC in *Ogi* powder. Thus, to reduce vitamin A deficiency disease among young children and adults, *ogi* powder made from yellow seeded maize could be packaged and stored at room temperature and relative humidity of 73% after production. Furthermore, the low retention of *trans*-β-carotene in PVC packaged *ogi* powder stored in the lighted compartment (high temperature) of the storage box is in agreement with the observation made by Rodriguez-Amaya [8]. Also, the low heat transmission rate of PVC may also be a factor in the low retention of *trans*-β-carotene [20]. Moreover, the *trans*-β-carotene percentage retention level of the *ogi* powder was significantly affected by the storage compartment (p≤0.001), packaging materials (p≤0.05), storage periods (p≤0.001) and their interactions (Table 3).

Table 3. Combined effect of storage compartment, packages and storage periods on the pro-vitamin A true retention level of *ogi*powder

Pro-vitamin A	β-Cryptoxanthin	α-carotene	*Trans* β-carotene	13-*cis* β-carotene	9-*cis* β-carotene	Total β-carotene
Mean values (%)	35.00	24.20	30.70	44.50	40.10	35.0
CV (%)	4.93	7.36	4.95	4.70	4.87	4.54
P Compartment	***	***	***	***	***	***
P Package	**	**	*	***	***	**
P Storage period	***	***	***	***	***	***
P Package X Compartment	***	***	***	***	***	***
P Compartment X Storage period	***	***	***	***	***	***
P Package X storage period	***	***	***	***	**	**
P Package X compartment X storage period	***	***	***	***	**	***

**p≤0.01, ***p≤0.001, CV-coefficient of variation
All analyses were in triplicate.

Heat, light, and acids promote isomerization of *trans*-carotenoids, their usual configuration in nature, to the *cis*-form [8]. It was observed that, the 13 and 9-*cis*-β-carotene contents reduced from 0.13 µg/g and 0.21 µg/g before storage to 0.06 µg/g and 0.13 µg/g respectively at the end of storage (Table 1). However, the *ogi* powder percentage retention of 13-*cis*-β-carotene (75.07%) was higher than that of 9-*cis*-β-carotene (61.79%) before storage (Table 2). This implied that the *trans*-β-carotene was converted to more of the 13-*cis*-β-carotene than the 9-*cis*-β-carotene after processing maize into *ogi* powder. This is in accordance with the observation made by Rodriguez-Amaya [8]. However, at the end of the 12 weeks of storage, HDPE packaged *ogi* powder stored outside the storage box had the highest 13-*cis*-β-carotene percentage retention level (45.85%) while that in PP woven sack stored at the same condition had the least retention (33.72%) (Table 2). Contrary to the 13-*cis*-β-carotene retention, the percentage retention of 9-*cis*-β-carotene was highest in *ogi* powder packaged in PP woven sack stored outside the storage box (42.13%) and lowest in that packaged in the same packaging material but stored in the dark compartment of the storage box (30.90%) (Table 2). The high temperature (30°C) of the dark compartment may be responsible for the low retention of 9-*cis*-β-carotene in the PVC packaged *ogi* powder [8]. Nevertheless, the storage compartments, packaging materials and the storage periods had significant effects (p≤0.001) on the *cis*-β-carotene percentage retention level of the *ogi* powder (Table 3).

Table 4. Temperature and Relative humidity of each of the storage compartment

Compartment	3 weeks		6 weeks		9 weeks		12 weeks	
	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.

4. Conclusion

The different packages and storage conditions significantly (p≤0.001) affected the retention of all the pVACin the *Ogi* powder. At the end of the storage period, *ogi* powder packaged in HDPE stored outside the storage box retained more of the β-cryptoxanthin content and that packaged in PVC stored in the lighted compartment retained the least. More of the *ogi* powder α-carotene content was retained in PP stored outside the storage box and less in HDPE stored in the lighted compartment. Additionally, *ogi* powder packaged in HDPE stored outside the storage box had the highest percentage retention of *trans*-β-carotene and that packaged in PVC container stored in the lighted compartment had the least. Therefore, since it has been established that *trans*-β-carotene is the most bioactive out of all the pVAC regarding its bioconversion to vitamin A, HDPE could be a good package for *Ogi* powder in the retention of this β-carotene when stored at a temperature of 27°C and relative humidity of 73%.

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