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Research Article

Evaluating the Effect of Different Packaging Materials on the Shelf-Life Stability of Ground Melon Seed (*Citrullus colocynthis lanatus*)

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Abstract

Background and Objective: Ground melon seed (GMS) was stored for 4 weeks on the shelf at room temperature ($26 \pm 2^\circ\text{C}$) using different packaging materials, this study aimed to ascertain the best packaging material for the long shelf life of the GMS. **Materials and Methods:** The samples were packaged under atmospheric pressure in laminated high-density polyethylene (LHPE) (7×8 cm), transparent high-density polyethylene (THPE) (7×8 cm) and amber coloured plastic bottle (APB) (33 cl) and were evaluated weekly for their physicochemical, microbial and sensory properties. **Results:** The samples stored in LHPE showed the least changes in physicochemical properties: Free fatty acid ($0.90\text{--}2.18$ mg KOH/g), peroxide value ($2.40\text{--}4.20$ mEq kg^{-1}) and water activity ($0.31\text{--}0.49$), compared to samples packaged in THPE and APB. Soup made from samples packaged in LHPE was most preferred throughout the 4 weeks in all parameters tested with values of $8.0\text{--}8.7$ in overall acceptability. **Conclusion:** LHPE offered the best protection to GMS in all the quality characteristics evaluated for 4 weeks and it is noted to be the most suitable packaging material for shelf-life stability of GMS for 4 weeks.

Key words: Melon seed, Egusi, packaging, storage, shelf-life, physicochemical, sensory properties

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Melon (*Citrullus*) is a genus of 4-5 species that belongs to the family Cucurbitaceae and the tribe Benicaseae, found in Africa¹. *Citrullus colocynthis lanatus*, a species of *Citrullus* is an important crop plant and vegetable in West Africa widely cultivated for its edible nutrient-rich seeds popularly called "Egusi"². "Egusi" is rich in oil and protein comprising 50% oil and 35% protein of which the oil is unsaturated and include linoleic, oleic, palmitic and stearic acids^{3,4}. Its protein contains good quantities of isoleucine, leucine and phenylalanine which are essential amino acids as well as arginine, glutamic acid and aspartic acid⁵ which are non-essential amino acids. In West Africa where soups are an integral aspect of dietary life, the melon seed is used to make Egusi-soup, a delicacy preferred by many Africans among other local soups. The melon seed must first be peeled (hand or machine peeled) and ground before use. Grinding the melon seed during purchase is dependent on the availability of the seller, time-consuming and energy-sapping which calls for the need to make a readily available ground melon seed for easy Egusi soup preparation. Grinding and packaging ground melon seed (GMS) for convenience as a ready-to-use product could lead to its deterioration due to exposure of a large surface area of the highly unsaturated fatty acid and amino acid groups of the seed to environmental factors. The water activity of the GMS may also make it highly susceptible to mould growth and hydrolytic rancidity if not reduced which will reduce its shelf-life. Reducing the water activity of the seeds and preventing the exposure of the GMS to air and light which are catalysts of oxidation by packaging in moisture, air and light-impermeable material could ensure stability and long shelf-life of the ground melon seed.

Food packaging is an essential technique for preserving food quality and thus minimizing food wastage. The package purposely protects the product from environmental hazards throughout its shelf-life. Preservation without packaging is an incomplete process and packaging materials can be used alone or as a combination and they vary⁶. Melon seed when coarsely ground can be used as a thickener in soup and in Nigeria, when boiled, soaked, fermented and wrapped in leaves, they form a food condiment called 'Ogiri'⁷.

The objective of this study was to evaluate the physicochemical and microbial properties of the stored GMS and sensory evaluation of the soup cooked from the samples stored in laminated high-density polyethylene, transparent high-density polyethylene and plastic amber bottles weekly for 4 weeks. This will help to determine the most suitable packaging material that will ensure stability and long shelf-life of the stored GMS and subsequently increase its economic value.

MATERIALS AND METHODS

Study area: This study was carried out in May-August, 2019 at the Food processing laboratory of the Department of Food Science and Technology, University of Nigeria, Nsukka, Nigeria.

Raw materials: Hand peeled melon seed (*Citrullus colocynthis*) (1500 g) was purchased from Ogige Market in Nsukka Local Government area Enugu-North, Enugu State, Nigeria. The packaging materials used in this study were laminated high-density polyethylene (7×8 cm), plastic amber bottles (33 cl) and transparent high-density polyethylene (7×8 cm). The soup ingredients used were palm oil, onion, bouillon cubes (Maggi, Nigeria), pepper (fresh red pepper), iodized salt (Dangote, Nigeria), crayfish (10.33% moisture) and spinach (84.47% moisture) which all were purchased from a specific retailer in the same market in Nsukka.

Methods

Preparation of ground melon seed: Hand peeled matured melon seeds were sorted, cleaned and oven-dried (VWR 1310 Scientific Company, 20 to 200°C) at 60°C for 1 hr at an air velocity of 1.2 m sec⁻¹. The oven-dried seeds were ground to a particle size of 150 µm using a local manual attrition mill (Corona corn hand mill model no. 8541954760, USA). Two hundred grams (200 g) of the ground melon seed (GMS) were used for preliminary studies (physicochemical, microbial analysis and sensory evaluation of soup prepared from the ground Egusi) before storage. The ground melon seed was thereafter, packed under atmospheric pressure in an axenic environment into laminated high-density polyethylene (LHPE) (7×8 cm), transparent high-density polyethylene (THPE) (7×8 cm) and amber coloured plastic bottles (APB) (33 cl) in four replicates (100 g each), sealed using a sealing machine and stored at room temperature (26±2°C) for 4 weeks. The samples were evaluated weekly for their physicochemical and microbial properties to ascertain their stability. The soup was prepared from each sample weekly for sensory evaluation.

Preparation of Egusi soup: The Egusi soup was prepared according to the method and recipe of Akusu and Kiin-Kabari⁸ with slight modifications. Five hundred millilitres of water was added to a pot and heated to boiling point. Thirty millilitres of palm oil was added and boiled (100°C) by conduction and convection heating method using a cooking gas cylinder (local fabricated camp-gas Nigeria) for 2 min then

3.5 g bouillon cubes (maggi), dangote salt (5 g), red pepper (1.5 g), crayfish (15 g) and chopped onions (15 g) were added and allowed to heat for 2 min. The GMS (100 g) was then added and allowed to boil (100°C) for 15 min before shredded spinach (2 g) was added. The soup was allowed to simmer for 2 min before the heat source was turned off.

Storage studies

Storage temperature: The temperature of the storage environment of the samples was monitored during storage by taking a record from a digital thermometer (-20-150°C Polyscience, USA) twice a day throughout storage.

Storage: The packaged GMS were stored for thirty-one days at room temperature (26±2°C) to study its characteristics for this length of days. During the period of storage, analysis was carried out weekly for 4 weeks to determine peroxide value, free fatty acids, total titratable acidity, water activity, water absorption capacity, oil absorption capacity, mould count, total viable count and sensory evaluation.

Physicochemical properties determination of melon seed (*Citrullus colocynthis*)

Determination of free fatty acid: Five grams of the GMS sample was weighed into the 250 mL of Erlenmeyer flask. About 100 mL ethanol and 2 mL phenolphthalein indicator were added to the Erlenmeyer flask. The mixture was shaken to dissolve completely after which it was titrated against a standard base (NaOH) by shaking vigorously until the endpoint reached⁹. A pink colour that persisted for 30 sec indicated the endpoint. The volume and weight of the samples used were recorded.

Free fatty acid (FFA) value was calculated as shown in Eq. 1:

$$\text{FFA (mg KOH/g)} = \frac{V \times N \times 292}{W} \quad (1)$$

Where:

FFA (%) = Percentage of free fatty acid (g/100 g) expressed as oleic acid

V = Volume of NaOH (mL)

N = Normality of NaOH titrant (mol 100 mL⁻¹)

283 = Molecular weight of oleic acid (g mol⁻¹)

W = Sample mass (g)

Peroxide value: The peroxide value was determined using the extracted oil from the crude fat (ether extract) by the method described by Nagre *et al.*¹⁰. Five gram of the oil extracted

was added to a test tube to which 1 g of powdered potassium iodide and 200 mL of solvent mixture (two volumes of glacial acetic acid plus one volume of chloroform) were added to the oil in the test tube. The mixture was boiled for 30 sec in a water bath and transferred into a 300 mL conical flask to which 200 mL of an aqueous solution of potassium iodide was washed twice with water and the washings were poured into a conical flask. The solution was then titrated with Sodium thiosulphate (0.002 N) solution using a freshly prepared 1% starch indicator. A blank titration under the same conditions with 0.5 mL of sodium thiosulfate solution was conducted. Calculation of peroxide value was done using Eq. 2:

$$\text{PV (mEq kg}^{-1}\text{)} = \frac{V_1 - V_0 \times C \times 1000 \times T}{M} \quad (2)$$

Where:

PV = Peroxide value expressed (mEq kg⁻¹)

V₁ = Consumption of sodium thiosulfate solution in the main test (mL)

V₀ = Consumption of sodium thiosulfate solution in the blank test (mL)

C = Molar concentration (molarity) of the sodium thiosulfate solution (mol L⁻¹)

T = Titre of the thiosulfate solution

M = Weighed portion of substance (g)

Determination of pH: A pH meter (model 20 pH conductivity meter, Denver Instrument, United Nations Inventory Database) was used and the pH of the GMS sample was taken¹¹.

Determination of total titratable acidity: The titratable acidity was determined by the method of AOAC as described by Fabro *et al.*¹¹. Percentage TTA was calculated using Eq. 3:

$$\text{Titrable acidity (\%)} = \frac{\text{mL (NaOH)} \times N (\text{NaOH}) \times (\text{milliequivalent factor})}{\text{Grams of the sample}} \times 100 \quad (3)$$

Determination of water activity: The water activity meter (LabStart-a_w) was used to determine the water activity of the sample. The meter was allowed a certain time for the sensor to heat up for 20 min. The sample cup was filled with the GMS sample and put in the measurement chamber. The chamber was closed by pushing the upper part of the instrument down until it clicked. Then the actual value in a_w/ % RH was read on display.

Water absorption capacity determination (WAC): The method described by Ohizua *et al.*¹² was used. The centrifuge employed was (Lab-Aids Total Solutions). The volume of free water was read directly from the centrifuge tube and the percentage WAC was calculated as shown in Eq. 4:

$$\text{WAC}(\%) = \frac{\text{Amount of water} - \text{free water}}{\text{Weight of sample}} \times \text{Density of water} \times 100 \quad (4)$$

Oil absorption capacity determination (OAC): The method of Ohizua *et al.*¹² was used. Percentage OAC was calculated as shown in Eq. 5:

$$\text{OAC}(\%) = \frac{\text{Amount of oil added} - \text{free oil}}{\text{Weight of sample}} \times \text{density of corn oil} \times 100 \quad (5)$$

Microbial analysis of Egusi

Determination of total viable count (TVC): The total viable count test was carried out using the method described by Mbaeyi-Nwaoha and Okorie¹³. After incubation, the number of colonies was counted and represented as colony-forming unit per millilitre (CFU mL⁻¹).

$$\text{CFU mL}^{-1} = \text{Average count} \times \text{dilution factor}$$

Determination of mould count: The mould count test was carried out using the method described by Mbaeyi-Nwaoha and Okorie¹³. After incubation, the number of colonies was counted and represented as colony-forming unit per millilitre (CFU mL⁻¹).

$$\text{CFU mL}^{-1} = \text{Average count} \times \text{dilution factor}$$

Sensory evaluation: A semi-trained 10-man panel of students of the Department of Food Science and Technology, University of Nigeria, Nsukka were used to evaluate the sensory properties of the GMS (Egusi) soup prepared weekly for 4 weeks. The panellists were selected based on their familiarity with the sensory qualities of Egusi soup. A 9-point hedonic scale was used to evaluate the colour, flavour, taste, aroma, mouthfeel and overall acceptability of the soup, where 1 and 9 represent disliked extremely and liked extremely, respectively as described by Azuka *et al.*¹⁴. Water was provided to rinse the mouth between evaluations.

Statistical analysis: The study adopted a completely randomised design. The data generated were subjected to

One-Way-ANOVA using SPSS version 20.0 at a 5% level of significance. Means were separated using Duncan's New Multiple Range Test (DNMRT).

RESULTS AND DISCUSSION

Room temperature and relative humidity of the storage

room: The average relative humidity of the storage environment was 84.5%. This high relative humidity was attributed to the wet season (June to November) in which the experiment was carried out. The average room temperature was 26.0°C which was moderate and typical of the peak of the wet season in Nigeria.

Effect of packaging material and storage time on selected physicochemical properties of ground melon seed:

The physicochemical properties of the differently packaged ground melon seed (*Citrullus colocynthis* L.) stored for four weeks are presented in Fig. 1, 2 and Table 1.

Free fatty acid: The free fatty acid value obtained for GMS as presented in Fig. 1 was 0.90 mg KOH/g before storage which is less than the 6.6 mg KOH/g oleic (max.) value recommended for unrefined (virgin) oil¹⁵. Igwenyi *et al.*¹⁶ reported a higher free fatty acid value of 2.15% for *Citrullus colocynthis* dried seed oils. For stored samples packaged in LHPE, there was a 58.72% significant ($p < 0.05$) increase in the free fatty acid from 0.90-2.18 mg KOH/g during the 4 weeks storage period, for THPE samples there was a 65.12% increase (0.90-2.58 mg KOH/g), while for APB samples there was a 73.68 % increase (0.90-3.42 mg KOH/g). All samples were within an acceptable range after 4 weeks of storage despite the minimal increase. Free fatty acid content increases in foods containing lipids due to autoxidation of unsaturated fatty acids leading to rancidity and serving as quality criteria. Rancid oils are marked with off-flavour or off-odour due to the breakdown products (aldehydes, ketones, alcohols and organic acids) of oxidation. There was no off-flavour observed among samples despite the increase in free fatty acid. The APB stored samples exhibited the highest change in free fatty acids while LHPE samples exhibited the least change. The reason for higher FFA in APB compared to THPE stored samples is obscured and require further studies which is because the THPE has poor UV rays resistance while the LHPE and APB packaging materials have total and UV rays barrier effect which if absent, could trigger lipid oxidation catalyzed by light. All the samples were within the permissible range for free fatty acid of non-rancid oils after 4 weeks of storage which is 10.0 mg KOH/g in Codex Alimentarius Standards according to Nina *et al.*¹⁵.

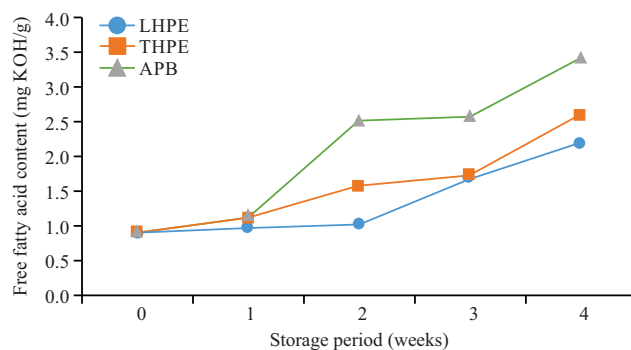
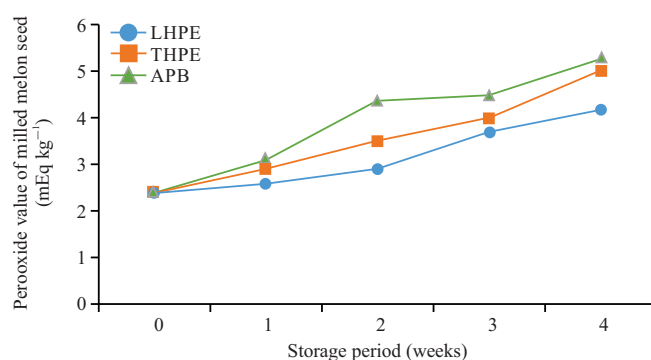


Fig. 1: Effect of different packaging materials on free fatty acid content of ground melon seed stored for 4 weeks

Fig. 2: Effect of different packaging materials on the peroxide value of milled melon seed stored for 4 weeks at $(26 \pm 2^\circ\text{C})$ Table 1: Effect of different packaging materials on some of the physicochemical properties of milled melon seed stored for 4 weeks at $(26 \pm 2^\circ\text{C})$

Samples	Storage period (weeks)	TTA (%)	WAC (%)	OAC (%)	a_w
LHPE	0	0.10 ± 0.01^a	1.49 ± 0.02^a	1.47 ± 0.01^a	0.31 ± 0.01^a
	1	0.18 ± 0.01^b	1.54 ± 0.01^b	1.50 ± 0.02^{ab}	0.35 ± 0.02^{ab}
	2	0.24 ± 0.01^{cd}	1.60 ± 0.02^{cd}	1.53 ± 0.02^{bc}	0.37 ± 0.02^{ab}
	3	0.51 ± 0.01^e	1.66 ± 0.02^{fg}	1.57 ± 0.01^{de}	0.44 ± 0.01^{de}
	4	0.83 ± 0.01^g	1.71 ± 0.02^i	1.62 ± 0.01^g	0.49 ± 0.02^{fg}
THPE	0	0.10 ± 0.01^a	1.49 ± 0.02^a	1.47 ± 0.01^a	0.31 ± 0.01^a
	1	0.19 ± 0.01^b	1.56 ± 0.01^{bc}	1.52 ± 0.01^{bc}	0.38 ± 0.01^{bc}
	2	0.25 ± 0.01^d	1.62 ± 0.01^{de}	1.56 ± 0.01^{cd}	0.43 ± 0.04^{cd}
	3	0.53 ± 0.01^{ef}	1.67 ± 0.01^{gh}	1.61 ± 0.02^{fg}	0.47 ± 0.02^{ef}
	4	0.85 ± 0.01^g	1.73 ± 0.01^{jk}	1.66 ± 0.02^{hi}	0.51 ± 0.02^{gh}
APB	0	0.10 ± 0.01^a	1.49 ± 0.02^a	1.47 ± 0.01^a	0.31 ± 0.01^a
	1	0.21 ± 0.02^{bc}	1.58 ± 0.01^{bc}	1.54 ± 0.01^{bc}	0.41 ± 0.02^{bc}
	2	0.27 ± 0.01^d	1.64 ± 0.02^{ef}	1.59 ± 0.02^{ef}	0.46 ± 0.02^{ef}
	3	0.55 ± 0.01^f	1.69 ± 0.01^{hi}	1.63 ± 0.01^{gh}	0.51 ± 0.02^{gh}
	4	0.89 ± 0.02^h	1.75 ± 0.02^k	1.70 ± 0.01^i	0.54 ± 0.04^h

a_w : Water activity, WAC: Water absorption capacity, OAC: Oil absorption capacity, TTA: Total titratable acidity, values are Mean $\pm$ Standard Deviation of duplicate readings. Means on the same column with different superscripts are significantly ($p < 0.05$) different, KEY: LPE: Laminated polyethylene packaged Egusi, ABE: Amber bottle packaged Egusi and CLE: Cellophane packaged Egusi

Peroxide value: The peroxide value of the ground melon seed before storage was found to be 2.40 mEq kg^{-1} (Fig. 2) which is lower than the peroxide value of Egusi oils stored at the low temperature of 25°C (4.4 and 6.6 mEq kg^{-1}) under both dark and indoor light conditions respectively as reported by Gurudeeban *et al.*¹⁷. For the GMS sample stored in LHPE as

shown in Fig. 2, the results indicated a significant ($p < 0.05$) increase in the peroxide value from 2.40 – 4.20 mEq kg^{-1} , for THPE samples, it increased from 2.40 – 5.05 mEq kg^{-1} while for APB samples, peroxide value increased from 2.40 – 5.30 mEq kg^{-1} . Igwenyi *et al.*¹⁶ reported a lower peroxide value of 0.45 mEq kg^{-1} for *Citrullus colocynthis* dried seed oils.

Nwakaudu *et al.*¹⁸ reported a peroxide value of 12.30-16.40 mEq kg⁻¹ which was above the standard values of 10 mEq O₂ kg⁻¹ oil specified by SON and NIS as reported by Zahir *et al.*¹⁹ and Samue *et al.*²⁰, respectively. The peroxide values obtained from the stored samples showed that LHPE, THPE and APB packaged GMS are safe at room temperature (26±2°C) during 4 weeks of storage with an increase in peroxide value which is below the acceptable limit (10 mEq O₂ kg⁻¹ oil). Peroxide value is used as a measure of the extent to which rancidity has occurred during storage and also as an indication of the quality and stability of fats and oils. It has been reported that rancid flavour becomes noticeable when the peroxide value lies between 20 and 40 mEq O₂ kg⁻¹ oil¹⁸, this was not attained in the samples and no off flavour developed throughout the storage. Samples stored in LHPE showed the least change in peroxide value.

Total titratable acidity (TTA): The total titratable acidity obtained for the GMS was 0.10% before storage (Table 1). The TTA of GMS samples stored in LHPE increased significantly ($p<0.05$) from 0.10-0.83% during the 4 weeks of storage, for THPE samples it increased from 0.10-0.85%, while the value for samples stored in APB increased from 0.10-0.89%. The value of 0.10% observed in this study before storage is less than the reported 0.24-0.36% by Onweluzo and Nwakalor²¹ for different vegetable milk extracts. Titratable acidity (TA) refers to the total concentration of free protons and un-dissociated acids in a solution that can react with a strong base and be neutralized. Titratable acidity is used because it is easier to measure the total acid content of a sample.

Water absorption capacity (WAC): The water absorption capacity obtained in this study for the GMS before storage was 1.49%. There was a significant ($p<0.05$) increase (1.49-1.71%) in water absorption capacity for samples stored in LHPE, for THPE samples WAC was 1.49-1.73% while for samples stored in APB, WAC increased from 1.49-1.75%. Water absorption is the amount of water taken up by flour to achieve the desired consistency and create a stipulated end-product quality. The higher the water absorption capacity of Egusi flour, the more its disposition to mould infestation and hydrolytic rancidity in the presence of heat²². High water absorption capacity is attributed to the loose structure of starch polymers while low values are an indication of the compactness of the structures²³. Peter-Ikechukwu *et al.*²⁴ reported a range of 1.79-3.40 g mL⁻¹ for melon seeds from five varieties which are higher than the result obtained in this study. The water absorption capacity of the ground melon seed before storage was low but increased

with storage time. Its low water absorption capacity before storage indicates that Egusi could form lumps when fresh instead of dissolving into a solution and therefore explains its property as usage in meat analogues²⁵. The increase in WAC of the GMS samples during storage indicates an increase in the loose structure of starch polymers and polar affinity sites in the GMS due to increased surface area and increased storage time which could reduce its property of forming meat analogue.

Oil absorption capacity (OAC): The oil absorption capacity obtained in this study for the GMS before storage was 1.47%, which is following the findings of Peter-Ikechukwu *et al.*²⁴ who reported a range of 1.35-1.57 g mL⁻¹. There was a significant ($p<0.05$) increase (1.47-1.62%) in oil absorption capacity for LHPE samples from the 3rd week, for samples stored in THPE, there was a significant ($p<0.05$) increase (1.47-1.66%) throughout the 4 weeks storage as well as for samples stored in APB (1.47-1.70%). Oil absorption capacity is the ability of the flour protein to physically bind fat by capillary action and it is of great importance since fat increases the mouth feel of foods and also acts as a flavour retainer²⁶. Higher oil absorption capacities with an increase in storage time showed an increase in non-polar sites of the protein structures and increased mouthfeel when used in food preparations such as meat analogues²⁷.

Water activity: Water activity is used as an index for the stability of food products. The water activity of GMS obtained before storage was 0.31. Significant ($p<0.05$) differences were noticed in water activity for samples stored in LHPE in the 3rd and 4th week (0.31-0.49), while there was a significant ($p<0.05$) increase (0.31-0.51) for samples stored in THPE throughout the 4 weeks of storage and as well as for samples stored in APB (0.31-0.54). Water activity, rather than moisture content, is a stronger indicator of microbial growth²⁸. Most bacteria won't grow if the water activity is less than 0.91 and most moulds won't grow if the water activity is less than 0.80. These samples had a low water activity to support microbial growth showing that spoilage in the packaged dried ground melon seed will not occur as a result of available water for microbial growth but by handling and environment. When water activity (a_w) is around 0.3, lipid oxidation is slowed and often results in a minimum rate. Small amounts of water are thought to protect lipids by lowering the catalytic activity of metal catalysts, quenching free radicals and/or obstructing oxygen access to the lipid. The rate of oxidation increases again at a slightly higher water activity ($a_w = 0.55-0.85$), presumably due to the enhanced catalyst and oxygen mobilization²⁸.

Table 2: Microbial studies of differently packaged ground melon seed

Packaging materials	Storage period (weeks)	TVC (CFU g ⁻¹)	Mould count (CFU g ⁻¹)
THPE	0	2.7×10^3	1.5×10
	1	2.3×10^4	2.5×10
	2	1.6×10^5	4.0×10
	3	1.7×10^6	9.0×10
	4	2.4×10^6	1.8×10^2
APB	0	2.7×10^3	1.5×10
	1	2.9×10^4	1.6×10^2
	2	2.1×10^5	1.8×10^2
	3	1.7×10^6	3.4×10^2
	4	2.8×10^6	3.9×10^2
LHPE	0	2.7×10^3	1.5×10
	1	2.6×10^4	2.0×10
	2	1.9×10^5	3.5×10
	3	1.4×10^6	1.1×10^2
	4	1.8×10^6	1.6×10^2

WK: Week, TVC: Total viable count and CFU: Colony forming unit per gram

Microbial studies of differently packaged ground melon seed (GMS): The results obtained for the microbial analysis of the ground melon seed samples for each packaging material for 4 weeks are as shown in Table 2.

Total viable count (CFU g⁻¹): The GMS packaged in LHPE showed an increase from 2.7×10^3 - 1.8×10^6 CFU g⁻¹ in the total viable count. Samples stored in THPE showed an increase from 2.7×10^3 - 2.4×10^6 CFU g⁻¹ and the samples stored in APB showed an increase from 2.7×10^3 - 2.8×10^6 CFU g⁻¹. The TVC before storage was high (2.7×10^3), there was a significant increase in the total viable count (TVC) in each packaging material throughout the storage period. The increase in TVC might be a result of contamination from the environment during handling for analysis since the water activity of the samples was low (0.31-0.54) and could not support microbial growth. Ground melon seed packaged in laminated polyethylene had the least TVC count throughout the storage time.

Mold count (CFU g⁻¹): The samples stored in LHPE showed an increase from 1.5×10 - 1.6×10^2 CFU g⁻¹ in mould growth, the samples stored in THPE showed (1.5×10 - 1.8×10^2 CFU g⁻¹) and the samples stored in APB (1.5×10 - 3.9×10^2 CFU g⁻¹) in mould growth. There was a noticeable increase in the mould count in each packaging material throughout the storage period but the mould count was within the acceptable limit for edible oil which is 2×10^4 CFU mL⁻¹ ²⁹. During the 4 weeks of storage, the increase in mould might be a result of contamination from the environment during handling for analysis as the water activity (0.31-0.54) of the packaged samples was low for mould growth throughout the storage period. GMS packaged in laminated polyethylene had the least mould growth throughout the storage period.

Sensory scores: The results obtained from the sensory analysis of soup made from the ground melon seed (GMS) for each storage period and with the different packaging materials are shown in Table 3. The soup made from the ground melon seed packaged in laminated polyethylene was most preferred in colour (8.80-8.20) followed by THPE samples (8.80-7.80) and then APB samples (8.80-6.90). The colour of the samples was accepted to different degrees (from like very much (8.80) to slightly (6.90)). The preference for the colour of LHPE samples could be a result of the barrier property of LHPE against UV light as light is the usual cause of colour change in a photochemical reaction known as photo-degradation. Photo-degradation is the breakdown of molecules initiated by the absorption of light photons. Photo-degradation normally affects products with high amounts of fat, proteins and vitamins²⁸. It changes the colour of food, removes important vitamins and changes the taste³⁰. Also, the change in colour of the prepared soup could be a result of the rate and extent of heat treatment given to the samples during cooking which may have caused colour depletions.

A sensory test is the most accurate way to detect oxidized flavour in food. The value of any objective chemical or physical procedure is essentially determined by how well it correlates with sensory evaluation results. Flavour testing is normally done by skilled or semi-trained taste panellists who use very particular protocols²⁸.

The flavour score of soup made from GMS stored in LHPE ranged from (8.50-7.80), THPE (8.50-7.30) and APB (8.50-6.60). The flavour scores of the samples were accepted to different degrees (from very much (8.50) to slightly (6.90)). Soup from LHPE packaged GMS had the most acceptable flavour throughout the weeks, followed by the THPE package. This trend simply showed that LHPE may have superior barrier properties that retain the freshness and flavour of the GMS.

Table 3: Sensory scores of Egusi soup made from packaged, stored milled melon seed

Sample	Storage period (weeks)	Colour	Flavour	Taste	Aroma	Mouthfeel	Overall acceptability
LHPE	0	8.80±0.42 ^b	8.50±0.63 ^c	8.70±0.74 ^b	8.40±0.92 ^b	8.30±0.00 ^b	8.70±0.42 ^b
	1	8.60±0.52 ^b	8.40±0.69 ^c	8.60±0.52 ^b	8.40±0.69 ^b	8.30±0.95 ^b	8.60±0.52 ^b
	2	8.20±0.63 ^b	7.90±0.74 ^b	7.90±0.57 ^b	7.60±0.52 ^b	7.80±0.63 ^b	8.10±0.74 ^b
	3	8.00±0.00 ^b	8.20±0.42 ^b	8.10±0.74 ^b	8.20±0.79 ^b	7.80±0.91 ^b	8.30±0.48 ^b
	4	8.20±0.42 ^b	7.80±0.42 ^b	7.80±0.92 ^a	7.80±0.63 ^b	7.50±0.53 ^b	8.00±0.00 ^b
THPE	0	8.80±0.42 ^b	8.50±0.63 ^c	8.70±0.74 ^b	8.40±0.92 ^b	8.30±0.00 ^b	8.70±0.42 ^b
	1	8.00±0.67 ^a	7.50±0.84 ^b	7.60±0.84 ^a	7.50±0.71 ^a	7.00±0.94 ^a	7.30±0.67 ^a
	2	8.00±0.47 ^b	7.70±0.48 ^b	7.90±0.57 ^b	7.70±0.48 ^b	7.40±0.81 ^{ab}	7.60±0.52 ^b
	3	7.80±0.63 ^b	7.50±0.85 ^b	7.30±0.94 ^a	7.40±0.84 ^a	7.20±1.03 ^a	7.50±0.53 ^b
	4	7.80±0.79 ^b	7.30±0.95 ^{ab}	7.00±1.65 ^a	6.80±0.92 ^a	7.10±0.99 ^{ab}	7.60±0.69 ^{ab}
APB	0	8.80±0.42 ^b	8.50±0.63 ^c	8.70±0.74 ^b	8.40±0.92 ^b	8.30±0.00 ^b	8.70±0.42 ^b
	1	7.50±0.71 ^a	6.70±0.67 ^a	7.00±0.94 ^a	7.10±0.74 ^a	6.90±0.74 ^a	7.30±0.67 ^a
	2	7.10±0.74 ^a	6.70±0.67 ^a	6.60±0.52 ^a	7.00±0.67 ^a	6.90±0.88 ^a	6.80±0.63 ^a
	3	6.90±0.57 ^a	6.60±1.26 ^a	6.70±0.82 ^a	6.90±0.88 ^a	6.70±0.67 ^a	6.60±0.52 ^a
	4	7.10±0.74 ^a	6.90±0.99 ^a	6.80±1.14 ^a	6.90±1.10 ^a	6.60±1.07 ^a	7.10±0.99 ^a

Values are Mean ± Standard deviation of duplicate readings. Means on the same column with different superscripts are significantly ($p < 0.05$) different, LPE: Laminated polyethylene packaged Egusi, ABE: Amber bottle packaged Egusi, CLE: Cellophane packaged Egusi, sensory score range: 9: Like extremely, 8: Like very much, 7: Like moderately, 6: Like slightly, 5: Neither like nor a dislike, 4: Dislike slightly, 3: Dislike moderately, 2: Dislike very much and 1: Dislike extremely

There was a significant ($p < 0.05$) difference in the taste of soup made from LHPE and THPE in the 1st and 3rd week but the taste did not differ significantly ($p > 0.05$) in the 2nd and 4th weeks. There was a significant ($p < 0.05$) difference in LHPE and APB samples from the 1st-3rd week. The taste of the soup from the different samples was accepted to different degrees, from very much to slightly (8.70-6.80) through the 4 weeks storage period with soup from LHPE samples being most preferred.

There was a significant ($p < 0.05$) difference in the aroma of soup made from LHPE and THPE in the 3rd and 4th week but the aroma did not differ significantly ($p > 0.05$) in the 2nd week. There was a significant ($p < 0.05$) difference in the aroma of soup from LHPE and APB throughout the storage period. The aroma of the samples was accepted to different degrees from very much to slightly (8.40-6.90) throughout the 4 weeks storage period with LHPE samples being the most preferred.

There was a significant ($p < 0.05$) difference in the mouthfeel of soup made from LHPE and THPE in the 1st and 3rd week but the mouthfeel did not differ significantly ($p > 0.05$) in the 2nd and 4th weeks. There was a significant ($p < 0.05$) difference in the mouthfeel of LHPE and APB samples throughout the storage studies, The mouthfeel of the samples was accepted from like very much (8.30) to like slightly (6.60) by the 4 weeks storage period with LHPE samples being the most preferred than THPE samples while APB samples were least preferred.

Soup made from the three samples was accepted to different degrees whereby soup made from LHPE was the most preferred in overall acceptability throughout the 4 weeks of storage studies followed by transparent high-density polyethylene packaged and then amber coloured bottle

packaged. LHPE could be said to be the best material for packaging ground melon seed (GMS) among the other packaging materials as its rate of change in organoleptic properties was the least, followed by transparent high-density polyethylene while amber coloured bottle packaged GMS was the least accepted. A longer storage study of 6-12 months should be carried out to ascertain the stability of the ground melon seed (GMS) at a longer duration under ambient conditions ($28 \pm 2^\circ\text{C}$).

CONCLUSION

The result of this study showed that out of the three different packaging materials used to store GMS for 4 weeks, the laminated polyethylene showed the best stability effect and a much better-enhanced shelf-life on the ground melon seed (GMS) stored for 4 weeks along with high overall acceptability in soups made from them compared to THPE and APB packaging materials. There was a minimal increase in rancidity markers in the peroxide value, free fatty acid, water and oil absorption capacity and total titratable acidity in LHPE samples as compared to GMS stored in the transparent high-density polyethylene and amber coloured bottle.

SIGNIFICANCE STATEMENT

This study has shown that ground melon seed can be stored best with laminated high-density polyethylene for 4 weeks and therefore could be produced commercially with procedures to limit the incidence of rancidity, as a ready-to-use shelf-stable product to minimize queue and save time when purchasing it in the market.

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