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Research Article

Effect of packaging materials and storage conditions on the physicochemical compositions of groundnut oil in Nigeria

Ibraheem Adesina Kukoyi[1], Olukemi Adetutu Osukoya[2*] and Sidi Osho[3]

[1]Department of Tourism and Events Management, Afe Babalola University, Ado-Ekiti
[2]Department of Chemical Sciences, Afe Babalola University, Ado-Ekiti
[3]School of Postgraduate Studies, National Open University of Nigeria, Victoria Island, Lagos
*Corresponding author: *kemi210@yahoo.com*

Abstract

The aim of this paper was to investigate the changes in physicochemical and fatty acid composition of groundnut oil when stored in different packaging materials, exposed to light or stored in the dark. Physicochemical parameters such as specific gravity, refractive index, unsaponifiable matters, iodine values, peroxide values and free fatty acids of the oil were determined using standard procedures every 2 weeks for 14 weeks. The fatty acids (palmitic acid, stearic acid, oleic acid and linoleic acid) were analysed with the aid of an electronic acid profile analyzer. Statistical analysis showed that specific gravity, refractive index, unsaponifiable matter and iodine content of groundnut oil packaged with glass bottles and stored in an open space was significantly different from control (freshly bought) ($P > 0.05$). The free fatty acid contents of groundnut oil in all the storage materials were within the recommended codex standard for edible vegetable oils. The fatty acids (palmitic, stearic, oleic, and linoleic acid) compositions of the groundnut in all packaging materials and under different storage conditions were within the recommended codex standard for each of these fatty acids. This study showed that packaging, storage conditions and time have an effect on the stability of groundnut oil. It was observed that groundnut oil packaged with lacquered metal cans and stored in dark space (at room temperature) support longer shelf life and retention of quality attributes of the oil.

Keywords: peanut, *Arachis hypogaea*, fatty acids, unsaponifiable matter, linoleic acid, specific gravity, oil, refractive index, iodine, vegetable oil

Introduction

Groundnut, *Arachis hypogaea*, is an important oilseed crop in Nigeria. It is the world's fourth most important source of edible oil and third most important source of vegetable protein (CGIAR, 2005). Nigeria is one of the major groundnut producers in the world. Groundnut seeds contain high quality edible oil (50%), easily digestible protein (25%) and carbohydrates (20%). Groundnut is also a valuable source of vitamins E, K and B. It is the richest plant source of thiamine (vitamin B1).

Groundnuts are used for oil extraction, food and as an ingredient in confectionery products. Groundnut oil is obtained from roasted seeds. After extraction, the residual cake is processed largely for animal feed, and also for human consumption. Industrially, groundnut oil is the major ingredient in paint, varnish, lubricating oil, leather dressings, furniture polish, insecticides and nitroglycerin. Many cosmetics also contain groundnut oil. Groundnut shells are used in the manufacture of plastic, wallboard, abrasives, fuel, cellulose (used in rayon and paper) and mucilage (glue).

One-fourth of groundnut seeds is processed for edible oil in Nigeria. Groundnut oil is obtained from roasted seeds (Chu and Hsu, 1999). Groundnut oil is often used in cooking, because it has a mild flavor and a relatively high smoke point. It has high monounsaturated fatty acid contents, making it heart-healthy and resistant to rancidity.

The demand for edible oils has increased world-wide due to population growth, rising standard of living and consumer preference. Groundnut oil is one of the most common edible oils largely consumed in Nigeria. Storage is usually done to maintain harvesting quality of product and not to improve it (Sisman and Delibas, 2004). Edible oils have been recognized as an important valuable food ingredient. They contain significant level of essential fatty acids and are sources of fat soluble vitamins such as vitamin E (Olanrewaju and Ogunbusola, 2013). During storage, products, especially stored oil compositions, can be influenced by several storage conditions (Akowuah et al., 2012).
The stability and quality of food products is a matter of great concern for producers, sellers and consumers. Oxidation is the main cause of quality deterioration in triglycerides and its reaction rates determines the shelf life (Bendini et al., 2010). The extent of lipid peroxidation depends on many factors which include the fatty acid composition, packaging material and storage conditions (Liscanlen et al., 2000). Packaging helps in protecting foods against contamination and adverse environmental conditions that can initiate deterioration of such foods. Triglycerides are usually stored and packaged in materials that will protect them from conditions such as atmospheric oxygen, light, heat and metal contamination; conditions which are known to accelerate lipid peroxidation and rancidity. It is very important to maintain the volatile molecule content responsible for the organoleptic and nutritional properties of newly produced groundnut oil during storage.

In Nigeria, groundnut oil is often stored, packaged and sold in different kinds of containers such as plastics, metal cans and glass bottles. It is important to know how groundnut oil quality will change over time due to the kind of material in which it is stored and also its exposure to light, especially for local producers who lack funds for adequate storage facilities. Hence, the aim of this study is to study the effect of packaging materials used in Nigeria and storage conditions on the physicochemical and fatty acid composition of groundnut oil.

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Materials and Methods

Freshly produced groundnut oil was purchased from a manufacturer at Ago-Iwoye Farm Settlement in Ago-Iwoye, Ogun State, Nigeria. All chemicals used were of analytical grade.

Sample preparation

Groundnut oil samples were placed in different packaging containers which include transparent plastic bottles (100 ml), transparent glass bottles (100 ml) and lacquered metal cans (100 ml). The oils in the containers were stored in a dark cupboard and others were left on a bench in the laboratory. The study was conducted at room temperature for a 98-day period. Parameters were analyzed at a 14-day interval.

Physical characteristics

Colour, odour, specific gravity and refractive index of the groundnut oil samples were determined. Refractive index was determined with a refractometer (Abbe refractometer).

Peroxide value

Peroxide value determination was done according to AOAC (1990).

Iodine value

Iodine value was determined according to Wij's method as reported by Pearson (1970).

Unsaponifiable matter

Unsaponifiable matter of groundnut oil is estimated according to AOAC (1990).

Fatty acids

Fatty acids were determined with the aid of an electronic acid profile analyzer.

Statistical analysis

Results were expressed as mean ± standard deviation and subjected to one-way analysis of variance (ANOVA). Tukey HSD test was used to determine the significant difference between the samples.

Results and Discussion

The effect of packaging materials, storage conditions (dark and light) and storage time were determined on physical and chemical characteristics and fatty acid contents of groundnut oil. The oil were pale yellow in colour and liquid at room temperature. No change in colour and odour were observed in all groundnut oil samples stored under various conditions in the different packaging materials employed in this study.

Specific gravity values in oil stored in different packaging materials under various conditions increased from 14 – 94 days as presented in Table 1. There were no significant differences (P < 0.05) in specific gravity values for samples in stored in lacquered metal cans in the dark for the duration of the study. The specific gravity of groundnut oil stored in other packaging materials increased rapidly every week till the end of the study.

Table 1: Specific gravity (ml/g) of groundnut oil

Days / **Packaging Materials and Conditions***	14	28	42	56	70	84	98
LMCOS	0.95±0.00[a,b,c]	0.95±0.00[a,b,c]	1.01±0.01[d]	1.02±0.00[d]	1.30±0.00[h]	1.27±0.06[h]	1.50±0.00[j]
LMCDC	0.94±0.00[a,b,c]	0.93±0.01[a,c]	0.94±0.00[a,b,c]	0.95±0.01[a,b,c]	0.95±0.00[a,b,c]	0.95±0.00[a,b,c]	0.95±0.01[a,b,c]
TPBOS	0.93±0.02[a,c,]	0.99±0.01[b,d]	1.09±0.02[f]	1.20±0.01[g]	1.30±0.02[h]	1.40±0.00[i]	1.50±0.01[j]
TPBDC	0.92±0.02[a]	0.93±0.02[a,c]	0.99±0.01[b,d]	0.99±0.00[b,d]	1.01±0.02[d]	1.01±0.02[d]	1.01±0.02[c,d]
TGBOS	0.97±0.03[a]	1.09±0.02[f]	1.20±0.01[g]	1.30±0.01[h]	1.40±0.01[i]	1.50±0.01[j]	1.62±0.03[k]
TGBDC	0.85±0.05[e]	0.92±0.01[a]	0.93±0.02[a,c]	0.99±0.01[b,d]	0.99±0.00[b,d]	1.01±0.02[d]	1.09±0.01[f]

Means with different superscripts are significantly different ($p < 0.05$).
***Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

The results of the effect of storage and packaging on unsaponifiable matter of groundnut oil is as shown in Table 2. Unsaponifiable matter are substances that are not saponifiable by alkali hydroxides but soluble in ordinary fat solvents and products of saponification that are soluble in such solvents. There was a steady increase in unsaponifiable matter of the groundnut oil as storage progressed. The unsaponifiable matter value for all the groundnut oil samples were within the Codex standard range for groundnut oil which is less or equal to 10 g/kg (CODEX, 2001).

Table 2: Unsaponifiable matter composition of groundnut oil

Days / **Packaging Materials and Conditions***	14	28	42	56	70	84	98
LMCOS	2.10±0.00[a]	2.07±0.06[a,f]	2.03±0.06[b,f]	2.20±0.00[c]	2.17±0.06[c,e]	2.30±0.00[d]	2.47±0.06[o]
LMCDC	2.00±0.00[b]	2.00±0.00[b]	2.07±0.06[a,e,f]	2.10±0.00[a]	2.13±0.06[a,e]	2.20±0.00[c]	2.20±0.00[c]
TPBOS	2.20±0.17[c]	2.20±0.17[c]	2.33±0.15[d]	2.40±0.10[i]	2.33±0.29[d]	2.57±0.06[l]	2.67±0.06[n]
TPBDC	2.20±0.17[c]	2.20±0.17[c]	2.33±0.15[d]	2.40±0.10[i]	2.40±0.10[i]	2.40±0.10[i]	2.50±0.00[o]
TGBOS	2.37±0.32[d]	2.77±0.06[g]	3.13±0.12[h]	3.33±0.29[j]	3.50±0.35[k]	3.67±0.40[m]	4.00±0.00[p]
TGBDC	2.13±0.12[a,e]	2.33±0.15[d]	2.40±0.10[i]	2.33±0.29[d]	2.57±0.06[l]	2.67±0.06[n]	2.57±0.40[l]

Means with different superscripts are significantly different ($p < 0.05$).
* **Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Iodine value is a measure of the degree of unsaturation of fatty acids present in oils and it is used to quantify the amount of double bonds present in oils reflecting susceptibility of oil to oxidation (Afolayan et al., 2014). The groundnut oil samples stored in lacquered metal cans in the dark increased in slightly in iodine content as the time for storage increased. There were no significant differences (P > 0.05) in iodine content under these conditions. The samples stored in all other packaging containers were significantly different (P > 0.05) in iodine content as shown in Table 3.

Table 3: Effect of packaging materials and storage conditions on the iodine content (wij's) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	80.67±0.58^{a,b}	80.67±0.58^{a,b}	81.00±0.00^{a,b}	82.00±0.00^{a,b}	82.00±0.00^{a,b}	83.00±0.00^{a,c}	83.33±0.58^{c,d}
LMCDC	80.00±0.00^{b}	80.00±0.00^{b}	80.33±0.58^{a,b}	81.00±0.00^{a,b}	80.67±0.58^{a,b}	81.00±0.00^{a,b}	81.00±0.00^{a,b}
TPBOS	84.00±1.00^{c,d}	83.67±0.58^{c,d}	85.00±0.00^{d}	84.67±0.58^{c,d}	85.00±0.00^{c,d}	86.00±3.46^{d,e}	85.33±3.05^{c,d}
TPBDC	83.00±0.00^{a,c}	83.33±0.58^{a,c,d}	83.00±0.00^{a,d}	83.00±1.73^{c,d}	84.00±0.00^{c,d}	85.00±0.00^{c,d}	85.33±0.58^{c,d}
TGBOS	86.00±1.00^{c,d}	88.33±0.58^{d}	91.00±0.00^{e}	92.67±0.58^{e}	94.00±1.73^{f}	97.33±0.58^{f,i}	99.23±0.25^{i}
TGBDC	82.00±2.00^{b,c}	83.33±0.58^{a,c,d}	84.00±1.00^{c,d}	85.00±0.00^{c,d}	86.00±3.46^{d,e}	86.67±0.58^{c,d}	88.00±0.00^{c,d}

Means with different superscripts are significantly different (p < 0.05).
* **Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

The result of changes in refractive index of the groundnut oil samples in different packaging containers and under varying storage condition is as shown in Table 4. There were no significant differences (P < 0.05) in refractive index of groundnut oil samples stored in lacquered metal cans in the dark as storage time increased whereas there were significant differences (P > 0.05) in refractive index of groundnut oil in all other packaging materials as storage time progressed.

Table 4: Refractive index of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	1.46±0.00^{a}	1.46±0.00^{a}	1.47±0.00^{a}	1.50±0.00^{g}	1.50±0.00^{g}	1.60±0.00^{e}	1.60±0.00^{e}
LMCDC	1.46±0.00^{a}	1.46±0.00^{a}	1.46±0.00^{a}	1.46±0.00^{a}	1.46±0.00^{a}	1.46±0.00^{a}	1.46±0.00^{a}
TPBOS	1.47±0.06^{a}	1.54±0.06^{c}	1.60±0.00^{e}	1.60±0.00^{e}	1.60±0.00^{e}	1.60±0.00^{e}	1.70±0.00^{j}
TPBDC	1.40±0.00^{b}	1.40±0.00^{b}	1.47±0.06^{a}	1.50±0.00^{g}	1.50±0.00^{g}	1.60±0.00^{e}	1.60±0.00^{e}
TGBOS	1.47±0.06^{a}	1.57±0.06^{d}	1.16±0.86^{f}	1.77±0.06^{h}	1.87±0.06^{i}	2.00±0.00^{k}	2.10±0.00^{l}
TGBDC	1.40±0.00^{b}	1.40±0.00^{b}	1.47±0.06^{a}	1.50±0.00^{g}	1.70±0.00^{j}	1.70±0.00^{j}	1.80±0.00^{m}

Means with different superscripts are significantly different (p < 0.05).
* **Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

A predominant test for oxidative rancidity in oils and fats is peroxide assay because it measures the concentration of peroxides and hydro peroxides formed in the initial stage of lipid oxidation. Peroxide value is also a measure of the extent to which rancidity reactions have occurred during storage (Afolayan et al., 2014). The result of changes in peroxide values of groundnut oil samples stored in different packaging containers under varying storage conditions is shown in Table 5. Only the peroxide values of oils stored in lacquered metal cans in the dark were within range of standard peroxide value (10 mEq/kg) for vegetable oil

Table 5: Peroxide value (milliequivalents of active oxygen/ kg oil [mEq/kg]) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	10.03±0.02^{a}	10.10±0.01^{a,d}	10.01±0.01^{a}	10.10±0.00^{a,d}	10.15±0.01^{a,e}	10.15±0.00^{a,e}	10.19±0.03^{a,e}
LMCDC	10.00±0.01^{a}	10.10±0.00^{a,d}	10.10±0.00^{a,d}	10.11±0.01^{a,d}	10.11±0.00^{a,d}	10.11±0.00^{a,d}	10.11±0.00^{a,d}
TPBOS	10.80±0.00^{b,c,d,e}	10.85±0.00^{b,c,e}	11.00±0.00^{b,f}	12.06±0.01^{g}	13.01±0.02^{h}	14.03±0.02^{j}	15.02±0.02^{k}
TPBDC	10.45±0.61^{a,b}	10.30±0.01^{a,e,f}	10.45±0.61^{a,b}	10.48±0.58^{a,b}	10.82±0.58^{b,c,d,e}	10.83±0.03^{b,c,d,e}	10.80±0.00^{b,c,d,e}
TGBOS	10.70±0.56^{a,b}	11.07±0.01^{b}	12.06±0.01^{g}	13.00±0.00^{h}	14.01±0.01^{j}	15.02±0.01^{k}	16.02±0.01^{l}
TGBDC	10.15±0.00^{a,c}	10.31±0.01^{a,e,f}	10.12±0.03^{a,e}	10.48±0.58^{a,b}	10.52±0.06^{a,b}	10.83±0.03^{b,c,d,e}	10.86±0.06^{b,c,e}

Means with different superscripts are significantly different ($p < 0.05$).
*Legend: LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

deterioration. The low peroxide values in these oils indicated slow oxidation of the oils (Demian, 1990) suggesting that these containers do not favour rancidity reactions and can rsist lipolytic hydrolysis and oxidative deterioration.

Acid value is used to indicate the quality, age, edibility of oil for use in industries (Akubugwo et al., 2008). Acid values can be used to measure the extent to which the glycerides in oils have been decomposed by lipase and other factors such as light and heat (Demian, 1990). The presence of free fatty acids (FFA) in oil or fat is an indication of previous lipase acitivity, other hydrolytic action or oxidation (Afolayan et al., 2014). Free fatty acids determination is a measurement linked to the quality and degree of purity of oil (Osawa et al., 2007). Fatty acid composition is the most important factor which determines oils susceptibility to oxidation (Ghasemnezhad and Honermeier, 2004). As shown in Table 6, there was steady increase in the free fatty acid contents of groundnut oil stored in different packaging materials and under different conditions. Free fatty acid content of groundnut oil stored in lacquered metal cans in the dark were not significantly different ($P < 0.05$) as storage time increased in contrast to groundnut oil samples stored in other containers exposed or not exposed to light. The results of palmitic, stearic, oleic, and linoleic acids content of groundnut oil samples studied in different packaging material and storage conditions is as shown in Tables 7, 8, 9 and 10 respectively.

Table 6: Free fatty acids (mg KOH/g) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	0.11±0.01^{a}	0.12±0.00^{a,c,d}	0.13±0.01^{a,b}	0.16±0.01^{b}	0.16±0.00^{e}	0.23±0.03^{e}	0.25±0.01^{e}
LMCDC	0.11±0.01^{a}	0.10±0.01^{a}	0.11±0.00^{a}	0.12±0.00^{a,c,d}	0.12±0.01^{a,c,d}	0.14±0.01^{a,b}	0.15±0.00^{b,c}
TPBOS	0.16±0.01^{b}	0.16±0.00^{b}	0.25±0.01^{e}	0.25±0.01^{e}	0.35±0.00^{f}	0.37±0.01^{f}	0.43±0.03^{g}
TPBDC	0.13±0.00^{a,b}	0.15±0.00^{b,d}	0.25±0.00^{e}	0.25±0.01^{e}	0.36±0.01^{f}	0.36±0.01^{f}	0.37±0.01^{f}
TGBOS	0.15±0.00^{b,c}	0.25±0.01^{e}	0.35±0.02^{f}	0.46±0.01^{g}	0.56±0.01^{h}	0.66±0.01^{i}	0.76±0.01^{j}
TGBDC	0.12±0.00^{a,c}	0.14±0.01^{a,b}	0.15±0.00^{b,d}	0.27±0.02^{e}	0.36±0.01^{f}	0.46±0.01^{g}	0.56±0.01^{h}

Means with different superscripts are significantly different ($p < 0.05$).
*Legend: LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Table 7: Percentage composition of palmitic acid (%) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	8.50±0.00^{a,b}	8.47±0.06^{a,b}	8.33±0.12^{b}	8.33±0.12^{b}	8.47±0.06^{a,b}	8.50±0.00^{a,b}	8.53±0.12^{a,b,f}
LMCDC	8.37±0.06^{b}	8.37±0.06^{b}	8.40±0.00^{b}	8.37±0.06^{b}	8.43±0.06^{b}	8.37±0.06^{b}	8.40±0.00^{b}
TPBOS	8.83±0.12^{c,d}	8.77±0.06^{c,f,h}	8.90±0.00^{c,d,e}	9.00±0.00^{d,f,g}	9.10±0.10^{e,g,h}	9.20±0.00^{g}	9.33±0.06^{g,i}
TPBDC	8.70±0.17^{a,c,h}	8.70±0.00^{a,c,h}	8.83±0.12^{c,d}	8.90±0.00^{d,h}	9.07±0.06^{d,g}	9.00±0.00^{d,f,g}	9.00±0.00^{d,f,g}
TGBOS	8.93±0.12^{c,d,e}	9.07±0.12^{d,g}	9.20±0.00^{g}	9.54±0.06^{i}	9.80±0.00^{j}	10.09±0.01^{k}	10.21±0.02^{k}
TGBDC	8.70±0.00^{a,c,h}	8.70±0.17^{a,c,h}	8.83±0.12^{c,d}	8.90±0.00^{d,h}	9.00±0.00^{d,f,g}	9.10±0.10^{e,g,h}	9.20±0.00^{g}

Means with different superscripts are significantly different ($p < 0.05$).
***Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Table 8: Percentage composition of stearic acid (%) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	2.77±0.06^{a}	2.77±0.06^{a}	2.90±0.00^{a}	2.87±0.06^{a}	3.00±0.00^{a,b}	3.07±0.06^{a,b}	3.10±0.00^{a,b}
LMCDC	2.77±0.06^{a}	2.77±0.06^{a}	2.77±0.06^{a,b}	2.77±0.06^{a}	2.80±0.00^{a}	2.80±0.00^{a}	2.80±0.00^{a}
TPBOS	2.93±0.12^{a,b}	3.00±0.00^{a,b}	3.13±0.06^{a,b}	3.20±0.00^{b,d}	3.30±0.00^{b,c}	3.50±0.35^{c,d,e}	3.70±0.00^{c,e}
TPBDC	2.80±0.17^{a}	2.87±0.06^{a,b}	2.87±0.06^{a,b}	3.00±0.00^{a,b}	3.00±0.00^{a,b}	3.10±0.00^{a,b}	3.07±0.06^{a,b}
TGBOS	3.00±0.00^{a,b}	3.17±0.29^{a,b}	3.50±0.00^{c,d,e}	3.70±0.00^{c,e}	3.87±0.06^{e}	4.00±0.00^{e}	4.07±0.06^{e}
TGBDC	2.80±0.17^{a}	2.87±0.06^{a}	2.93±0.12^{a}	2.93±0.12^{a,b}	3.00±0.00^{a,b}	3.13±0.06^{a,b}	3.17±0.06^{a,b}

Means with different superscripts are significantly different ($p < 0.05$).
* LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Table 9: Percentage composition of oleic acid (%) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	16.20±0.17^{a}	16.30±0.00^{a,b}	16.27±0.06^{a,b}	16.90±0.00^{f,j}	17.03±0.06^{i,j}	17.00±0.00^{i,j}	17.27±0.12^{i,k}
LMCDC	16.23±0.12^{a,b}	16.30±0.00^{a,b}	16.23±0.12^{a,b}	16.30±0.00^{a,b}	16.40±0.00^{b,d}	16.40±0.00^{b,d}	16.40±0.00^{b,d}
TPBOS	16.58±0.02^{c,d}	16.69±0.01^{c,e,g}	16.77±0.02^{e,f,h}	16.93±0.06^{f,i}	17.03±0.06^{i,j}	17.10±0.00^{i}	17.20±0.00^{i,k}
TPBDC	16.51±0.01^{d}	16.50±0.01^{d}	16.58±0.01^{c,d}	16.61±0.01^{c,d,h}	16.69±0.01^{c,g,h}	16.69±0.01^{c,g,h}	16.70±0.01^{c,h}
TGBOS	16.70±0.00^{c,e}	16.93±0.06^{f,i}	17.10±0.00^{i}	17.37±0.12^{k}	17.63±0.12^{l}	18.00±0.00^{m}	18.37±0.12^{n}
TGBDC	16.50±0.01^{d}	16.51±0.02^{d,g}	16.58±0.01^{c,d}	16.61±0.01^{c,d,h}	16.69±0.01^{c,g,h}	16.70±0.01^{c,h}	14.74±3.43^{c,h,j}

Means with different superscripts are significantly different ($p < 0.05$).
***Legend:** LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Table 10: Percentage composition of linoleic acid (%) of groundnut oil

Days	14	28	42	56	70	84	98
Packaging Materials and Conditions*							
LMCOS	2.23±0.12^{a,b}	2.47±0.06^{a,b,c}	2.43±0.06^{a,b,d}	2.53±0.06^{a,b,c}	2.77±0.06^{c,d,e}	2.80±0.00^{c,d,e}	3.00±0.00^{e,f}
LMCDC	2.23±0.21^{b}	2.20±0.17^{b}	2.23±0.12^{a,b}	2.23±0.12^{a,b}	2.23±0.12^{a,b}	2.30±0.00^{a,b}	2.27±0.06^{a,b}
TPBOS	2.50±0.00^{a,b,c}	2.50±0.00^{a,b,c}	2.60±0.00^{a,b,c}	2.67±0.06^{a,b,e}	2.57±0.40^{a,b,c}	2.90±0.00^{c,e}	3.00±0.00^{e,f}
TPBDC	2.40±0.10^{a,b,d}	2.27±0.23^{a,b}	2.27±0.23^{a,b}	2.33±0.29^{a,b,d}	2.33±0.29^{a,b,d}	2.60±0.00^{a,b,c}	2.57±0.06^{a,b,c}
TGBOS	2.70±0.17^{a,c,e}	2.80±0.17^{c,d,e}	2.93±0.12^{c,e,f}	3.13±0.06^{e,f,g}	3.40±0.00^{f,g,h}	3.53±0.31^{g,h}	3.80±0.10^{h}
TGBDC	2.40±0.10^{a,b,d}	2.27±0.23^{a,b}	2.33±0.29^{a,b,d}	2.50±0.00^{a,b,c}	2.60±0.00^{a,b,c}	2.57±0.06^{a,b,c}	2.67±0.06^{a,b,c,e}

Means with different superscripts are significantly different ($p < 0.05$).

*__Legend:__ LMCOS, lacquered metal can in open space; LMCDC, lacquered metal can in dark cupboard; TPBOS, transparent plastic bottle in open space; TPBDC, transparent plastic bottle in dark cupboard; TGBOS, transparent glass bottle in open space; TGBDC, transparent glass bottle in dark cupboard.

Palmitic acid and stearic acid are saturated fatty acids and there were no significant differences ($P < 0.05$) in their contents in groundnut oil samples stored in lacquered metal cans whether exposed to light or not. On the other hand, oleic and linoleic acids are unsaturated fatty acids and there were no significant differences in their contents in groundnut oils samples stored in lacquered metal cans in the dark but there was significant differences ($P > 0.05$) in oleic acid and linoleic acid in groundnut oil samples stored in lacquered metal cans and exposed to light. This could be because when vegetable oils are exposed to light, photo-oxidation occurs through the action of natural photosensitizers (i.e. chlorophyll), which react with triplet oxygen to form the excited state singlet oxygen. Singlet oxygen then forms free radicals from unsaturated fatty acids leading to the production of hydroperoxides and eventually to carbonyl compounds resulting to the development of undesirable off flavours in oils (Skibsted, 2000).

This study showed that packaging, storage conditions and time have an effect on the stability of groundnut oil. It was observed that groundnut oil packaged with lacquered metal cans and stored in dark space (at room temperature) support longer shelf life and retention of quality attributes of the oil. Exposure to light causes great changes in groundnut oils so it is best to store groundnut oils in the dark.

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