Effect of Various Packaging Materials on Storage Stability of Refined, Bleached, Deodorized Palm Oil

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Refined, bleached, deodorized palm oil (RBD palm oil) was packaged in lacquered metal cans (LMC), green glass bottles (GGB), amber glass bottles (AGB), clear glass bottles (CGB), clear plastic bottles (CPB) and sealed polyethylene film (POLET), and stored in direct sunlight (40 ± 1°C) or in darkness (27 ± 1°C). Measurements of free fatty acid (FFA), peroxide value and anisidine value, at 14-day intervals for a period of 98 days, were used to assess the stability of the oil towards hydrolytic and oxidative deterioration. Total oxidation values for packaged oils stored in direct sunlight showed that LMC gave the greatest protection against oxidative deterioration, followed by GGB and AGB. POLET offered the least protection to the oil against oxidative deterioration, while CPB and CGB proved superior to POLET but inferior to GGB and AGB. For storage in the dark, LMC, AGB and GGB gave the greatest protection to RBD palm oil against oxidative deterioration, with no significant statistical differences between them, while CPB, CGB and POLET followed in that order, with significant differences between their respective abilities to protect the oil against oxidative deterioration. Oils packaged in CPB gave the highest FFA levels (statistically significant). The investigations clearly indicated that LMC is superior to all other tested packaging materials in offering maximum protection to RBD palm oil against hydrolytic and oxidative deterioration. Amber and green glass bottles could serve as viable alternatives to LMC, while CGB and CPB could be tolerated as suitable packaging systems for RBD palm oil. However, the study also clearly showed that POLET is unsatisfactory for use as packaging material for RBD palm oil.

KEY WORDS: Fisher's least significant difference (LSD) test; Minitab; packaging materials; refined, bleached, deodorized palm oil; storage stability.

The choice of practical packaging materials for crude palm oil is limited because of the inherent congealing tendencies of palm oil. Refining crude palm oil eliminates its congealing tendencies (1). In Nigeria, the usual packaging materials for crude palm oil are also used for refined, bleached, deodorized (RBD) palm oil. The choice of packaging materials for RBD palm oil has expanded considerably. Recently, polyethylene film as packaging material for RBD palm oil has been introduced into the domestic market.

Several investigators have demonstrated that amber glass containers serve as the most effective packaging materials in minimizing oxidation of soybean oil (2). After a study of the flavor and oxidative stability of hydrogenated and unhydrogenated soybean oil, Warner and Mounts (3) concluded that plastic packaging materials of polyvinylchloride or acrylonitrile could serve as viable alternatives to clear glass bottles. Leo (4) discussed the effect of packaging on oil product quality and concluded that stability can be enhanced by proper selection of packing method. Sharma *et al.* (5) studied the effect of polyethylene and polypropylene films on the storage stability of sunflower and groundnut oils at 37°C. They concluded that the stability of vegetable oils packaged in plastic films is governed not only by the barrier properties of the film (oxygen transmission rate of the films) but also by the nature and extent of leached-out antioxidants from the films. The latter seem to exert a stabilizing effect on the stored oils against autoxidative degradation and consequently against the development of rancidity, which is the major cause of spoilage during storage. Investigations into the efficacy of various packaging materials on the storage stability of crude palm oil revealed that lacquered metal cans and amber glass bottles gave the greatest protection against oxidation (6).

RBD palm oil for retail in Nigeria is packaged in lacquered metal cans (LMC), green glass bottles (GGB), amber glass bottles (AGB), clear glass bottles (CGB), clear plastic bottles (CPB) of polyurethane, and recently in seated polyethylene film (POLET). In the open market, oils packaged in the various containers are stored in direct sunlight, while in the homes of consumers the oils in these packaging materials may be stored for months on wooden shelves in the dark. The increasing use of POLET for oils in domestic markets motivated the present study to compare the effect of packaging materials on storage stability of RBD palm oil. This paper focuses on the ability of the various locally utilized packaging materials to minimize hydrolytic and oxidative deterioration of RBD palm oil. It addresses storage in direct sunlight, which represents the prevailing condition in the open market, and in the dark, which represents the prevailing condition in the consumers' homes.

MATERIALS AND METHODS

Commercial RBD palm oil was used for this study. The methods and conditions employed were exactly the same as had been reported earlier (6). No nitrogen was used throughout the investigations. The packing containers, each having a capacity of about 750 mL, were filled two-thirds full with about 540 g RBD palm oil, with the headspace in each case of about 75 mL. The metal cans were constructed from polished iron and lacquered on the inside with a protective coating. The glass bottles were manufactured by the Delta Glass Co. (Ughelli, Nigeria). The plastic bottles were made of transparent polyurethane and molded in Nigeria. Low-density polyethylene was used in the manufacture of the polyethylene film. The polyethylene film was purchased and sealed to form containers in the laboratory of the Department of Food Technology, College of Science and Technology, University of Lagos, Abeokuta, Nigeria. All containers were purchased from domestic markets.

After the introduction of oil into the containers, they were tightly capped and stored without agitation. For

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cases where the oils were packaged in POLET, the containers were sealed after the addition of the oil. One set of containers comprising lacquered metal cans (LMC), green, amber and clear glass bottles (GGB, AGB and CGB, respectively), clear plastic bottles (CPB) and POLET was stored in direct sunlight at temperatues of 40 ± 1°C. An equivalent set of containers, also containing oil, was stored on wooden shelves in the dark at temperatures of 27 ± 1°C. Enough containers for each oil sample were subjected to each storage condition so that no container, once removed from storage and used for analyses, had to be reused.

At 14-day intervals, oils in the two sets of containers were removed from storage, shaken vigorously and analyzed for free fatty acid (FFA), peroxide value (PV) (7) and anisidine value (AV) (8). The total oxidation value (totox) was calculated from the relationship: Totox = 2 × PV + AV (9). All data were subjected to regression analysis and graphs were drawn with Minitab (10). In using Minitab, all regression lines were forced through the points representing data for day zero. Those data reflected the parameters of the oils as soon as they were purchased; the so-called initial FFA, PV and AV. A comparison of the slopes obtained from each regression line in each graph was carried out by Fisher's least significance difference (LSD) test.

RESULTS AND DISCUSSION

The fatty acid composition (wt%) of Nigerian RBD palm oil has been determined by several workers (11). Reported values are in the range C12:0 (0.2%), C14:0 (1.0%), C16:0 (45.4%), C16:1 (0.1%), C18:0 (4.6%), C18:1 (37.7%), C18:2 (10.6%), C18.3 (0.2%), C20:0 (0.3%). The initial FFA, PV and AV for RBD palm oil used for this investigation were 0.42% (expressed as palmitic), 1.2 meq O_2/kg oil and 1.1, respectively. The initial calculated totox was 3.5, and no moisture was detected in the oil *via* the Dean-Stark method with xylene as solvent.

In Figures 1–4, the graphs on the left refer to storage in sunlight (S), while the graphs displayed on the right refer to storage in the dark (D). Thus, Figure 1 shows the graphs for the FFA profile in RBD palm oil *vs.* storage period when the various packaging material were stored in sunlight (S) at 40 ± 1°C, and in darkness (D) at 27 ± 1°C. Similarly, Figures 2, 3 and 4 show the plots for peroxide formation, anisidine and total oxidation values, respectively, *vs.* storage period for storage in sunlight (S) and in darkness (D).

Table 1 gives the comparison of slopes obtained from Figures 1–4. For the various containers stored in direct sunlight, the slopes obtained for the FFA profile indicate

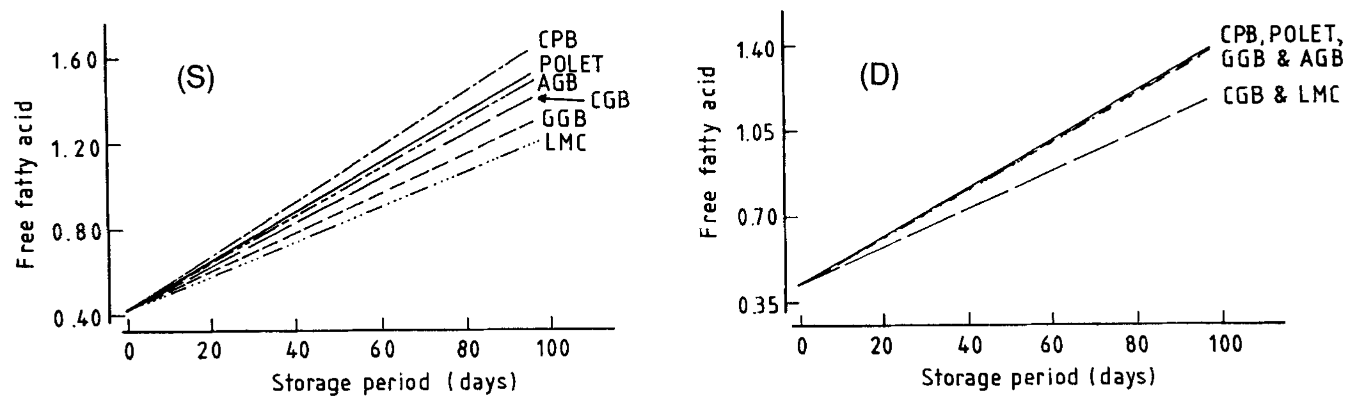

FIG. 1. Graph of free fatty acid (% palmitic acid) in RBD palm oil *vs.* storage period (days) in: S, direct sunlight at 40 ± 1°C; D, darkness at 27 ± 1°C. LMC, lacquered metal can; GGB, green glass bottles; AGB, amber glass bottles; CPB, clear plastic bottle; CGB, clear glass bottle; POLET, polyethylene film.

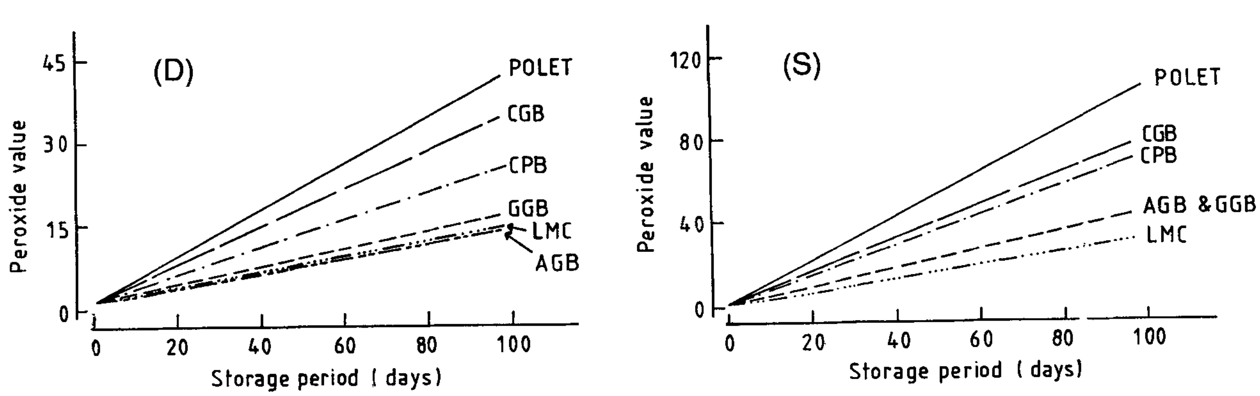

FIG. 2. Peroxide value (meq O_2/kg oil) in RBD palm oil *vs.* storage period (days) in: S, direct sunlight at 40 ± 1°C; D, darkness at 27 ± 1°C. Abbreviations as in Figure 1.

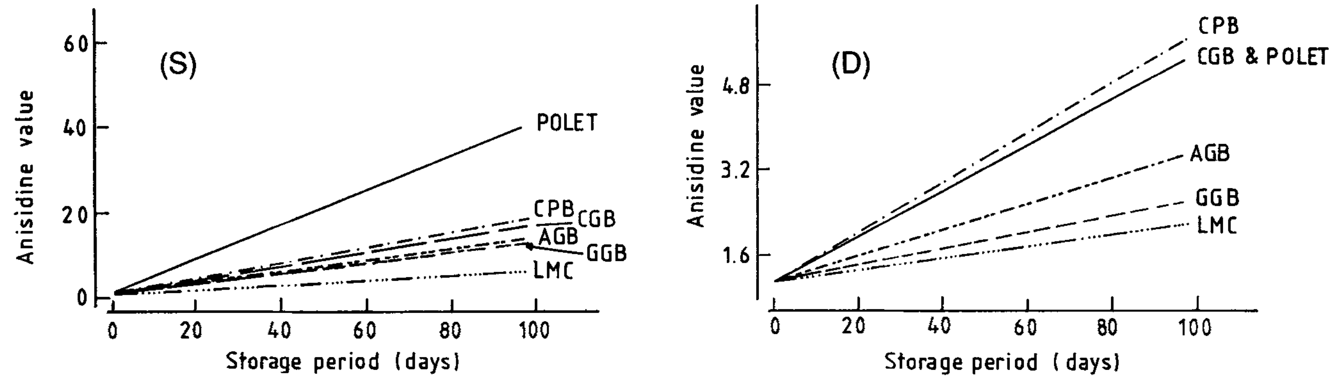

FIG. 3. Anisidine value in RBD palm oil *vs.* storage period (days) in: S, direct sunlight at 40 ± 1°C; and D, darkness at 27 ± 1°C. Abbreviations as in Figure 1.

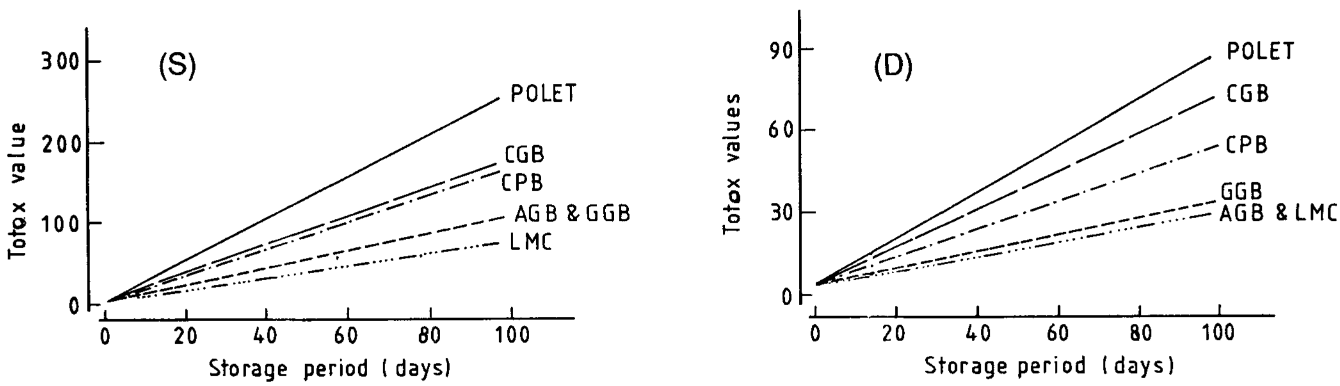

FIG. 4. Total oxidation value in RBD palm oil *vs.* storage period (days) in: S, direct sunlight at 40 ± 1°C; and D, darkness at 27 ± 1°C. Abbreviations as in Figure 1.

TABLE 1

Comparison of Slopes (value × 10^{-3}) of Graphs Presented in Figures 1-4[a]

Packaging materials[b]	Free fatty acids		Peroxide value		Anisidine value		Totox	
	S[c]	D	S	D	S	D	S	D
LMC	7.89^{d}	7.98^{b}	318^{d}	138^{d}	52.4^{c}	10.9^{c}	688^{d}	288^{d}
GGB	9.10^{c,d}	10.0^{a}	438^{c}	157^{d}	120^{b}	14.9^{c}	996^{c}	330^{d}
AGB	11.0^{a,b}	9.92^{a}	438^{c}	132^{d}	128^{b}	24.3^{b}	1000^{c}	288^{d}
CGB	10.2^{b,c}	8.08^{b}	765^{b}	339^{b}	157^{b}	43.2^{a}	1690^{b}	723^{b}
CPB	12.7^{a}	10.1^{a}	710^{b}	246^{c}	176^{b}	47.0^{a}	1600^{a}	539^{c}
POLET	11.4^{a,b}	10.0^{a}	1050^{a}	414^{a}	399^{a}	42.6^{a}	2500^{a}	871^{a}

[a]Values in each column with the same superscript are not significantly different at the 5% probability level ($P \leqslant 0.05$) by Fisher's LSD test.
[b]Packaging materials: LMC, lacquered metal can; GGB, green glass bottle; AGB, amber glass bottle; CGB, clear glass bottle; CPB, clear plastic bottle; POLET, polyethylene film.
[c]S, stored in sunlight; D, stored in the dark.

that RBD palm oils packaged in LMC gave the least increase in FFA with increased storage time, while oils packaged in CPB gave the highest increase in FFA. Statistically, there were significant differences in the development of FFA with time for RBD palm oil samples packaged in LMC and GGB on the one hand, and for oil samples packaged in CPB, POLET and AGB on the other hand. No significant differences were found in the development of FFA for oils packaged in CPB, POLET and AGB.

For packaged oils stored in closed wooden cupboards in the dark, the results were readily amenable to interpretation (Table 1). The containers were clearly demarcated into two sets with respect to the development of FFA with increased storage period. The set comprising LMC and CGB proved superior to the set comprising AGB, GGB, POLET and CPB, with statistically significant differences between the two sets. When one compares the development of FFA in stored RBD palm oil with that in stored crude palm oil (CPO), it becomes evident that, in terms of absolute numbers, RBD palm oil showed no substantial increases throughout the storage period, whereas CPO subjected to the same storage conditions increase significantly in FFA levels (6).

Figure 2 shows, as expected, that during the 98-day storage period the peroxide values for the oil samples stored in direct sunlight increased substantially. The highest PV of 117.5 meq O_2/kg oil was recorded for the oil sample packaged in POLET. This may be due to the combined effects of the relatively higher permeability of POLET to oxygen and of the transmittance of sunlight. From Table 1 it is clear that, during storage in direct sunlight, LMC gave the greatest protection to the oils against oxidative deterioration. The order of the packaging materials, with respect to their abilities to offer protection to the oil against primary oxidation, is LMC > AGB,GGB > CPB,CGB > POLET. The data in Table 1 suggest that POLET is unsatisfactory as packaging material for RBD palm oil because it offers comparatively poor protection to the oil against the deleterious effects of primary oxidation, regardless of whether the oil was stored in direct sunlight or in the dark.

Figure 3 shows that the anisidine values increased steadily for oils stored in direct sunlight from an initial value of 1.1 to between 5.0 and 53.0. From the data in Table 1, it is evident that LMC gave the greatest protection to the oil against secondary oxidative deterioration, while POLET proved unsatisfactory in this regard. No significant differences were found in the capability of all the bottles (GGB, AGB, CGB and CPB) to protect the oil against the deleterious effects of secondary oxidation. For oils stored in darkness there was a steady but less substantial increase in AV over the 98-day storage period. The slopes presented in Table 1 indicate that, for oils stored in the dark, the order of the containers, with respect to the ability to protect RBD palm oil against the formation of carbonyl compounds, is LMC, GGB > AGB > POLET,CGB,CPB. No significant difference was found, in the dark, in the ability of POLET, CGB and CPB to offer protection to the oils against the formation of breakdown products from peroxides and hydroperoxides.

Because neither PV nor AV independently describes adequately the extent of oxidative deterioration in an oil or fat, the combined effects of primary and secondary oxidative deterioration can be evaluated by calculating the total oxidation value (12). Plots of totox values are depicted in Figure 4 for oils stored in direct sunlight and in darkness. Comparisons of slopes from these plots are shown in the last two columns of Table 1. Data from Table 1 reveal that, for packaged oils stored in direct sunlight and in darkness, totox values for RBD palm oil packaged in LMC were the least, while those for RBD palm oil packaged in POLET were the highest. Specifically, when storage was effected in direct sunlight, the established order of preference for the packaging materials was LMC < GGB,AGB < CGB,CPB < POLET, with statistically significant differences between the four groups. For storage in darkness, the order of preference for the packaging materials was LMC,GGB,AGB < CGB < CPB < POLET, with statistically significant differences between the four groups.

Based on all these determinations of FFA, PV, AV and calculated totox values for both storage conditions in direct sunlight and in darkness, some trends have clearly emerged. Firstly, exposure of containers to direct sunlight enhances the rate of deterioration of the oil, regardless of the packaging system employed. This behavior of RBD palm oil agrees with the general pattern of behavior of fats and oils. Secondly, the increase in free fatty acids is minimal and can be considered negligible, which is in marked contrast to the development of free fatty acids in stored crude palm oil. Thirdly, the order of suitability of the various packaging systems employed in these investigations is not exactly identical for storage in sunlight and in darkness. Despite these discrepancies, it is undisputedly clear that lacquered metal cans are the most suitable of all the packaging materials examined. It is also evident that polyethylene film is the least satisfactory packaging material used. It is difficult to make a clear-cut choice between green and amber glass bottles. These two bottles clearly exhibited their superiority as viable packaging materials for RBD palm oil over clear plastic and clear glass bottles. There is a thin dividing line in the choice between clear glass and clear plastic bottles, probably tilting in favor of clear plastic bottles. Therefore, we conclude that, to minimize hydrolytic and oxidative deterioration of RBD palm oil after production and distribution, it is most preferable that the oil be packaged in lacquered metal cans and stored in the dark. Green glass and amber glass bottles provide excellent alternatives to packaging in LMC. Clear plastic and clear glass bottles could serve as acceptable alternative packaging materials. Polyethylene film is an unsatisfactory packaging material for RBD palm oil.

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