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Effect of Long-Term Storage in Light and Dark at Room Temperature on Physicochemical Characteristics of Some Vegetable Oils

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Abstract

This work aims to study the effect of light and darkness during storage (12 months) on some edible oils (palm, sunflower, and soybean) on their physicochemical characteristics, oxidative stability and shelf life. The samples were stored in transparent PET bottles in the presence of light (Under illumination light 800 Lux) and darkness at room temperature. The effect of oxidation on oils during storage under light or darkness was evaluated the free fatty acid, peroxide value, thiobarbituric acid test, induction period, and the fatty acids composition, tocopherols, and tocotrienols. The induction period of the oil samples was 27.4, 9.50, and 5.10 h for palm, sunflower, and soybean oils, respectively. The percentages of free fatty acids increase with increased storage time; the highest values in light storage were (0.25, 0.70, and 0.85%) while in dark storage, they were the lowest (0.18, 0.37, and 0.41%) for palm, sunflower, and soybean oils, respectively. As a result, light leads to an accelerated breakdown of unsaturated fatty acids, causing palm, sunflower, and soybean oils to form hydroperoxides of 7.7, 11, and 11.9 meq O_2/kg oil, respectively. In contrast, samples stored in the dark produced 5.5,

7.5, and 8.9 meq O_2/kg oil, respectively. The values of the thiobarbituric acid were (7.53, 17.74, and 19.19 mg malonaldehyde kg1) in the samples stored in the light than in the dark (5.41, 11.85, and 13.34 mg malonaldehyde kg1 for palm, sunflower, and soybean oils, respectively). The results showed that artificial light deteriorated the quality of the oil samples faster than that stored in dark conditions. On the other hand, the dark storage slowed down the breakdown of tocopherols, which protected the unsaturated fatty acids from oxidation. The findings demonstrated that oils degraded during storage more quickly in the presence of light than in the absence of light. The presence of saturated fatty acids, tocopherol, and tocotrienol in palm oil contributes to its stability.

Keywords: Physicochemical Properties, Oxidative Stability, Edible oils, tocopherols, fatty acids.

Introduction

Vegetable fats and oils play a significant role in our diet. They are the primary source of essential fatty acids and are necessary for carrying lip soluble vitamins around the body ***(Chew et al., 2020).***

They are also good sources of energy from a nutritional standpoint. Since it has a high concentration of natural antioxidants and vitamins and has a high level of oxidative stability with a long shelf life, palm oil has grown to be the most popular oil eaten worldwide (***Wroniak, et al., 2021).***Sunflower oil, like the majority of vegetable oils, is mostly made up of triacylglycerol (98–99%), with a minor amounts of phospholipids, tocopherol, carotenoids, sterols, and waxes. ***Moradi et al. (2018)*** found that ordinary sunflower oil contains significant amounts of both linoleic acid and oleic acid. Sunflower oils' fatty acid content and the availability of antioxidants both affect how stable they are against oxidation ***(Kamal-Eldin,***

2006). In comparison to highly saturated oils, soybean oil oxidases more quickly due to its high content of polyunsaturated fatty acids (PUFAs). Unsaturated fatty acids, nevertheless, are strongly advised to lower the risk of various health issues ***(Micha and Mozaffarian, 2010).*** Certain quality indicators can change when oils are exposed to heat, light, or moisture. The length of exposure, temperature, and storage conditions all affect how much the object has been altered ***(Fekarurhobo et al., 2009).***

Four analogues make up the famous natural antioxidant tocopherol family: α-,β-,γ-and-tocopherols ***Lara et al., (2017).*** There are four distinct compounds in the tocotrienols family, which are extremely similar to tocopherols. In tocopherols, a saturated carbon chain coupled to a cycloramarole with methyl groups represents the molecular structure. The carbonic chains of tocotrienols are unsaturated. The most active version of tocopherol has three methyl groups. There are two methyl groups in both β- and γ-tocopherol. Alpha-tocopherol is the most powerful but least useful form of vitamin E since it only has one methyl group ***Pandyaet al., (2019).*** Tocopherols and tocotrienols are generally thought to have positive impacts on health. Vegetable fats, oils, and products derived from them are where humans acquire the majority of the active vitamin E molecules they require. Tocopherols may be found in large quantities in nuts and most vegetable oils. Palm oil contains a high concentration of tocotrienols ***Adam et al., (2007).***

Pignitter Holler et al., (2023) demonstrated that during storage for 56 days under fluorescent light, the level of oxidation increased in several sunflower oil samples; Peroxide concentration increased from 0.1 to 10.4 meq O2/kg. The amount of all tocopherols declined, including alpha-tocopherol, which fell between 53.4 and 57.9%, and beta-tocopherol, which fell between 27.9 and 40.3%. According to ***Abdellah and Ishag (2012),***the color parameter red decreased from 3.6 to 1.3, yellow=25 did not change, and other

physical and chemical properties of sunflower oil changed during storage for a year at room temperature (35^{o}C). The refractive index at (40^{o}C) increasing from 1.4720 to 1.4750, viscosity at (35^{o}C increasing from 54.1 to 60.3, and free fatty acid and peroxide values increasing from 0.The fatty acid composition and variations during storage showed that the control sample was influenced in C-18:3, and that C-16:0, C-18:0, and C-18:1 and C-18:2 gradually increased from 10.03 to 11.89, 5.26 to 5.86, and 37.94 to 33.05 and 46.74 to 44, respectively. ***Liang et al. (2011)***investigated how chosen oil blends' fatty acid content and physical qualities changed after being stored for a year.

Soft oils like sunflower and soybean may lose significant amounts of natural antioxidants such as tocopherols when stored improperly due to light, air, or high-temperature exposure. This will reduce the biological activity of the oils. Hydroperoxides are created when acyl groups are oxidized, and these hydroperoxides degrade into products of secondary and tertiary oxidation ***Laguerre et al., (2023).*** Two well-known oxidation mechanisms for lipids are autoxidation and photooxidation. While photooxidation is generally ignored, autooxidation has been the subject of extensive investigation.

When free radicals attack the alpha-methylene of the double carbon bonds in unsaturated fatty acids, auto oxidation takes place. It needs a lot of time and works to manufacture enough peroxides, which give lipid-containing products a bad taste. Still, photooxidation is a fast process that happens 1000–1500 times faster than autooxidation. Unsaturated fatty acids and highly electrophilic singlet oxygen react to form hydroperoxides and peroxy radicals, which is how it happens ***Menis et al., (2019).***This article aims to study the effects of long-term storage in light and dark at room temperature on

the physicochemical characteristics and the oxidative stability and shelf life of palm, sunflower, and soybean oils.

Materials and Methods

Materials:

Oil samples

Palm oil (PO), sunflower oil (SFO), and soybean oil (SBO) all samples withoutsynthetic antioxidants were kindly supplied from Arma Food Industries, 10th of Ramadan City Industries Zone, Egypt. The oil samples were fresh, refined, and packed in Polyethylene terephthalate bottles of 60 mL (0.25-0.40 mm) were purchased from Inpaco Co., 10th of Ramadan City, Egypt. All chemicals used in the analysis were of analytical grade.The pure standards and fatty acid methyl esters for this study were purchased from Koch Light Laboratories, Ltd. in England.

Storage conditions.

Oil samples were split into two groups, the first of which was put within a wooden box that measured 150 by 100 by 200 cm **(Figure 1)**.Under illumination (800 lux) for 12 months at room temperature (25-35±2 ºC, humidity 37 ±2%).

Exposed to artificial light and measured with a B520 digital light meter (LMTGERMANPHOTOMER)Figure 2. The volume area above the sample from the source light to the bottle was 200 cm3, and the second group was kept in the dark condition, as illustrated in Figure 1.

Storage room design.

The studied oils were stored in a room 1 m long, 1.5 m wide, and 2.5 m high; the distance between the artificial light source and oil samples was 2 m, and oil sample bottles (vol. 60 ml for each withdrawn per month) were exposed to the light all day during the period from 1 to 12 months of storage, as were the equal bottles

stored in the dark. The room temperature ranged from (25 to 35 ºC) with an average of 32 ºC, and the relative humidity (46% - 61%) with an average of 53%. The room's intensity of temperature and humidity depended on the weather conditions; I checked it every time.

Sampling method

The oils were packed in bottles (Vol. 60 ml) the number of which is equal for months of storage, one sample is withdrawn for each month for storage time of 12 months when determining some the physical and chemical properties such as (refractive index, viscosity, free fatty acid, peroxide value, TBA value) and some properties such as (color, fatty acids profile, tocopherols and tocotrienols) a sample was withdrawn once at zero time and after 12 months storage.

Methods:

Refractive Index (RI)

RI was measured by refractometer according to ***Onwuka's (2005).***

Relative viscosity value:

The viscosity (P) of oils was determined using a Brokfield Viscometer following the methods described by the ***AOAC (2016).***

Color

The ***AOAC (2016)*** procedure was used to identify the color. A LovibondTintometer determined the color of tested samples PO, SFO, and SBO (Model E Made by the tintometar (L.T.D. Salis Bury, England) using interference colored scales (yellow, red, and blue) in a 5.25-inch glass cell.

Free fatty acids % (as oleic acid);

The procedure was taken from ***IUPAC (1987).***

Free fatty acids % as oleic acid = (V× N× 28.2)/ W

Where: V = volume of alkalibyml, N= normality of alkali

W= weight oil samplebyg.

Peroxide value (PV):

According to the procedure outlined in ***AOAC, 2016***, the PV of the tested samples was determined.

Thiobarbituric acid value (TBA):

The TBA value of vegetable oils was calculated using the methodology proposed **by *Pearson in (1976).***

Fatty acids composition:

Gas-liquid chromatography was used to determine that the methyl ester represented the fatty acid profile of the studied oils. The ***AOAC (2016)***states that 20% of methanol and BF3 were employed to methylate the methyl ester samples.

Tocopherols and tocotrienols

An HPLC Agilent 1100 integrated system with a G1313A automated injector, a G1311A pump, and a G1315B multi-wavelength diode-array detector was used for the chromatographic study. According to ***Shehata et al.,(2014)***tocopherol profiles were evaluated using HPLC.

Oxidative stability test (Rancimat method, induction period)

Using an automated Rancimat (Metrohm Ud. CH-9100 Herisau, Switzerland, model 679), the tested oils' oxidative stability was assessed according to***Tsaknis et al., (1999).*** The tested sample was subjected to an atmospheric oxygen stream at a rate of 20L/h at 100^{o}C. To reach the point where this curve breaks, the induction time is required (the point of most significant curvature).

Statistical analysis:

Using the SPSS statistical package programme, the data from three replicates were analyzed by ANOVA, and differences in means were evaluated using Duncan's Multiple Range Test for ***SPSS (1998).***The significance threshold was set at 0.05.

Results and Discussion

A study was done on how the physicochemical characteristics of the tested vegetable oils changed under artificial light (800 lux) and complete darkness throughout a storage duration of one to twelve months at room temperature.

Refractive index.

RI a crucial quality parameter feature, is a property of edible fats and oils. The oil's RI may be used to identify edible oils that are rancid as well as to learn more about the purity of the oil. This value has a particular range for each oil, and a departure from the established specification may signify oil adulteration ***(Olaleye et al., 2019).***

According to the findings in Figure 3, oil samples RI slightly increased during storage. The initial values of RI were 1.4545, 1.4722, and 1.4731 for PO, SFO, and SBO, respectively. These findings agree with those of ***Mansour et al., (2022).*** Figure 3 demonstrates that the RI after storage under various settings rises with increasing time; after a year of storage. The overall increase in RI of oil samples, higher values of RI subjected to exposure light compared with that of darkness storage might be attributed to the elevated rate of hydrolysis and photo-oxidation.Which accelerated the reaction rate, exposure light had the highest recorded values in light storage: PO 1.4584 (0.26 %), SFO 1.4835 (.76%), and SBO 1.4845 (0.78%). While the RI in storage darkness was recorded, the lowest values were 1.4563 (0.12%), 1.4811 (0.60%), and 1.4822 (0.61%) for PO, SFO, and SBO, respectively. Because SBO and SFO.havelong-chain and unsaturated fatty acids in their triglycerides, they have significant value for the RI. In contrast, PO has the lowest value because it includes highly saturated fatty acids . The RI

of oil can be used to assess the purity of the oil and identify rancidity in edible oil. This parameter has a specific range for each oil, and a deviation from the stated specification may signify oil adulteration ***(Alhibshi et al. (2016);Mengistie et al. (2018);Singh et al., (2022);Mansour et al., (2022).***

Viscosity (cp.);

Since it has a positive relationship with melting point, oil viscosity rises with high saturation and falls with unsaturation and chain length. Consequently, the highest viscosity value (63.5 Cp) was detected in PO oil, Figure (4), while the lowest value was detected in SBO (34.0 cp.) Some chemical properties of lipids, e.g., the amount of unsaturation and the length of the chains of the fatty acids that make up triacylglycerols, directly affect oil viscosity. Its value goes up as the saturation level goes up, and it goes down as the temperature goes up. These observations agree with ***Diamante and Lan (2014).*** The viscosity values increase with increasing storage time.

The initial values of viscosity were (63.5 cp), (44.0 cp) and 34.0 PO, SFO, and SBO, respectively; these results are in agreement with ***Hoffman (1989).*** From the same Figure (4) showed that the viscosity after storage in different conditions increases with increasing storage time at the end of 12 months of storage. The overall orderly increase in viscosity of oil samples, higher values of viscosity subjected to in exposure light (photo-oxidation) the higher rate of photo-oxidation (photo-oxidation) and hydrolysis, which accelerated the reaction rate, may be responsible for the increased storage capability as compared to that of darkness storage. of PO (68.10 cp) 6.70%, SFO (52.32 cp) 15.9%, and SBO (43.92 cp) 22.5%, The viscosity increased a little less under the conditions associated with storage in the dark (autooxidation) because the decomposition rate was lower at SBO 41.78 (18.6%), followed by SFO 50.32 (12%). In contrast, the height values were recorded for PO 65.20 (7.13%) ***Okparanta et al., (2018).*** It was noted that the

increased viscosity and rapid rate of storage in light were due to the increased rate of degradation of oils and the rapid polymerization of oils during storage. These results are in agreement with ***Santos et al., (2014).***

Color

The color of edible oils is considered one of their most considerable commercial importance; the physical characteristics of deteriorated oil have apparent signs that can give you a sensory judgment. Oils undergo a complicated process that results in color changes while they are stored (***Abdellah and Ishag, 2012).*** The color difference is an important physical indicator of storage quality. Data presented in Table 1 indicate that the color index of oils decreased with increased storage time. The initial value of yellow was stable 35 units. While, the red color at (zero time) was 4.0, 0.9, and 1.08 for PO, SFO, and SBO, respectively. The value of the red color after storage decreased to 2.31, 0.0, and 0.03 in artificial light storage, while in darkness storage, it was 3.03, 0.00, and 0.05 for PO, SFO, and SBO, respectively. Vegetable oils often have a little concentration of minor oil components like tocopherol, carotenoids, and other pigments that give them their color***Jusman et al., (2021).*** With more time spent storing the oil, the pace at which the color values (red) changed due to these components' formation to undergo oxidation.In addition to storage in light, pigment destruction was faster in light than in darkness during 12 months; these findings are consistent with those of ***Abdella et al., (2012).***

Free fatty acids (FFA %).

FFA% is recognized as one of the key chemical constants for maintaining the quality of edible fats and vegetable oils since it is a trustworthy indication of the degree of hydrolysis that happens in these lipids before, during, and after extraction operations and processing. Nonetheless, it is necessary to manage the acidity of

edible oils because excessive concentrations of free fatty acids make the oils non-suitable for human consumption ***(Enyoh et al., 2017).***

Figure 5 details the variations in free fatty acid of PO, SFO, and SBO samples stored at room temperature and exposed to artificial light and darkness, showing that initially, FFA were (0.01 %, 0.02% and 0.03 %) respectively.Results from the same Figure (5) showed that after 12 month of storage, FFA gradually increased with increasing storage duration under artificial light and darkness conditions.Higher values of FFA of all oil subjected to artificial light storage compared with that of darkness storage might be attributed to the elevated rate of hydrolysis and photo-oxidation of oils, which accelerated the reaction rate. Artificial light storage had the highest recorded values of SBO 0.03 to 0.85 %, followed by SFO 0.02 to 0.70 %, ***Khor et al., (2019).*** Due to the high amount of SFA and natural antioxidants like tocopherol and tocotrienol profiles, which make it more stable and less prone to change in storage, the lowest rate of growth in FFA was recorded at 0.01 to 0.25% for PO. Because of the lower decomposition rate, the lower elevation associated with storage in dark storage was the lower elevation recorded for PO (0.18 %).

In contrast, SFO and SBO are relatively higher; they were 0.37% and 0.41 %, respectively**.** According to previous results, these oil samples hydrolyzed and oxidised more quickly under artificial light than they did in the dark at ambient temperature. These findings correspond to those of ***Anwar et al., 2007 and Ramli et al., 2021.***

Peroxide value

An oil's or fat's peroxide value measures how much oxidation has occurred during production and storage. Although there are other options, peroxide is the most popular. As peroxides are intermediates in the autoxidation cycle, measuring PV is the best technique to check for autoxidation (oxidative rancidity). According to ***Rehab and***

El Anany (2012), thePV, or concentration of peroxide in an oil or fat, aids in determining the degree of deterioration.

Data from Figure 6 indicated a gradual slight increase in PV with increased storage time in different storage conditions (artificial light and darkness) at the end of 12 months of storage increased the PV of all sample oils; higher values of PV subjected to artificial light storage. An increased rate of oil hydrolysis and photo-oxidation, which sped up the reaction rate, may be the cause of the difference between light and dark storage. Artificial light storage had the highest recorded values of SBO within 0.41 – 11.9 meq O2/kg oil, followed by SFO within 0.43 – 11 meq O2/kg oil, while the lowest recorded value of PV was PO within 0.33-7.7 meq O2/kg oil,a higher rate of oil hydrolysis and photo-oxidation compared to dark storage might be the reason for the increased reaction speed.

The lower elevation associated with storage in dark storage because of lower decomposition rate was the lower elevation coded for PO 5.5 meq O_2/kg oil, which was in the accepted range as recommended by the regulation (<10 meq O_2/kg oil) according to ***FAO/WHO, (2009).*** While SFO, and SBO are relatively higher, they were 10 meq O_2/kg oil and 10.5 meq O_2/kg oil, respectively. The generation of peroxy radicals and hydroperoxides is caused by the photooxidation of unsaturated fatty acids, which is a quick process that occurs at a pace at least 1000–1500 times quicker than autooxidation ***(Raza et al., 2009 andSiepmann et al.,2019).***

The oil samples in light and dark are in two phases of change in peroxide value. The first stage was within month 4- month 9 showed substantial increases in peroxide values in the primary storage stage, resulting in the formation of hydroperoxides until a maximum was reached to the rise SBO was 11.9 – 10.5 meq O_2/kg oil within month -5 in light and dark storage flowed by SFO was 11.0 -

10.0 meq O_2/kg oil within the 6th–7th month in light and dark, respectively, while PO was in the accepted range as recommended by the regulation (<10 meq O_2/kg oil) ***(Ramli et al., 2021).***

When the second phase started, we saw a dip in PV as a result of the hydroperoxides' breakdown into secondary oxidation products. Although the final PV value in the second phase is less than the benchmark of 10 Meq (O_2)/kg, this does not reflect the quality of the oil because, generally speaking, oil oxidation occurs in two stages, the first of which results in the formation of hydroperoxides and the second of which results in the proliferation of hydroperoxides, which are then transformed into secondary oxidation products such as aldehydes and ketones ***(Tan et al., 2009).***

Thiobarbituric acids value

A condensation process occurs when thiobarbituric acid (TBA) and malonaldehyde, the main byproduct of the secondary oxidation of fatty acids in dietary lipids, are present. To assess the first secondary oxidation extent in these lipids and to determine the oxidative condition of fresh edible oils and fats, the TBA value is therefore regarded as an acceptable chemical quality criteria ***(Taluri et al., 2019).***There are two stages of oil oxidation. First, hydroperoxide is made. Then, hydroperoxide breaks down to make secondary oxidation products that can react with TBA reagent to make colored compounds that usually absorb light at 530 nm. Figure 7 shows changes in the TBA value of the tested oil during the storage period. Before storage, TBA values were 0.00, 0.01, and 0.41 mg of malonaldehyde/kg oil for PO, SFO, and SBO, respectively.

Concerning storage process in artificial light for 12 months led to increasing in TBA value, reaching 7.532, 17.740, and 19.981 for PO, SFO, and SBO, respectively; the end of dark storage, a low increase of TBA to 5.414, 11.223, and 13.345malonaldehyde/kg for PO, SFO, and SBO, respectively. These results are in agreement with **Gharbi et al., 2015).**

Effect of storage condition on fatty acids composition for tested oils.

Table (2) shows the impact of storage time on the fatty acid composition of oils; while all fatty acids saw only minor changes, the level of like mono unsaturated fatty acids (MUSFA) oleic acid (18:1), polyunsaturated fatty acids (PUSFA) linoleic acid (18:2), and linolenic acid (18:3) declined. In contrast, and in agreement with ***Suleiman et al., (2006)*** saturated fatty acids such as palmitic acid (16:0) and stearic acid (18:0) increased.The proportion of total saturated fatty acids (TSFA) increased, whereas the percentage of total unsaturated fatty acids decreased, according to data shown in Table 2

The percentages of TSFA were (49.76%, 11.72%, and 15.85%). These values increased to (55.56%, 17.12%, and 22.56% after storage in light, while storage in darkness increased rates slowly at (52.21%,16.03%, and 20.09%. The percentages of MUSFA were (39.99%, 28.38%, and 22.50%. These values decrease to (37.22%, 26.99%, and 19.62%) in light storage, respectively. In comparison, the storage of dark was (39.18%,27.29%, and 20.56%) and the percentage of PUSFA was (10.25%, 59.90%, and 61.65%. These values decreased to (7.22%, 55.89%, and 57.53%, respectively, at the end of light storage, while storage for darks was 8.61%, 56.68%, and 59.58%. ***Zaunschirm, et al., (2018).***

Table 2 display the fatty acid content and changes that occur during storage. The results indicated that control is deficient in C18:1, C18:2, and C18:3. In the course of storage, there is a steady rise in C-16:0, C18:0 of all oil samples. C-16:0 increase of PO, SFO, and SBO oils increased from 43.68 to 46.42 (6.2%), 6.92 to 8.11 (1.7%), and 10.48 to 13.85 (3.2%), respectively, while in dark storage, they increased from 43.68 to 45.31 (3.7%), 6.92 to 7.90(1.4%), and 10.48 to 11.73 (1.1%), respectively. C18:0 increase of PO, SFO, and SBO

oils, the percentage went from 4.31 to 6.78 (5 MUFA:PUFA is 1:2.4:3 for the same). ***Mansour et al., (2022).***

From the same table 2 showed a decrease in C18:1, C18:2, C18:3, and overall time storage in different conditions. Oleic acid C18:1 decreased in PO, SFO, and SBO samples; the percentages were from 39.75 to 37.01 (6.8%), from 28.23 to 26.72 (5.3%), and from 22.15 to 19.45 (13.8%) in light storage. While from 39.75 to 38.39 (2.2%), from 28.23 to 27.00 (4.5%), and from 22.15 to 20.38 (8.7%) in dark storage. C18:2 decreasedinPO, SFO and SBO samples,the percentage were from 9.53 to 7.22 (24.4%), from 58.81to 55.89 (5.1%) and 53.23to 52.14 (2.05%) in light while in dark storage from 9.53 to 8.61(8.61%), from 58.81 to 56.68 (3.7%), and from 53.23 to 53.22 (0.18%) respectively in dark storage. C18:3 decrease of PO, SFO and SBO oils the percentage were from 0.16 to 0 (100%), from 0.34 to 0 (100%)and from 7.41to5.33(25.3%) respectively in light.While0.16 to 0 (100%), from 0.34 to 0 (100%)and 7.41to 6.04 (15.4%) respectively in dark storage.

Our findings align with those of ***Lewinska et al. (2015)*** who examined how the fatty acid content of oil changed during storage for a year. Their findings are consistent with those of the current study. Slowly rising levels of saturated fat and decreasing levels of unsaturated fat were seen over time in the oil during study, which was substantially different from the control. According to ***Olagunju et al., (2022)***this may be caused by the oxidative cleavage of these fatty acids during storage.

These results showed that storing oils with light caused unsaturated fatty acids and tocopherols to break down. Many studies revealed that light has a negative impact on the preservation of oils ***(Kim et al., 2013).*** By providing the required energy to separate a hydrogen atom from an unsaturated fatty acid molecule (RH), which changes into alkoxyl free radicals (ROO) in the presence of oxygen, light is a factor that catalyses oxidation. As they are unstable, the

alkoxyl radicals take a hydrogen atom from a different unsaturated fatty acid molecule to transform into hydroperoxides (ROOH). This causes all of the oil's unsaturated fatty acids to undergo oxidation processes ***(Haloui2015).***

Changes in tocopherols and tocotrienols (mg/kg product) of oils during the storage

The content of individual and total tocols (tocopherols, tocotrienols) in Table (3,4) respectivelyshowed that total tocols in oils decreased during storage, total tocopherols decreased compared to the original amount before storage. The losses of total tocopherols in oils ranged from 40.0 to 68.2% of oils, PO, reduce from 445 to 221.85 (mg/kg) while SFO from 646.5 to 235 mg/kg (63%), SBO from 905 to 287.6 mg/kg (68.2%) respectively in light storage while dark storage of POdecreased from 445 to 265.9 mg/k (40%), SFO from 646.5 to 318.6 mg/kg.The development of the parameters examined revealed that, in contrast to oil samples held in darkness, those exposed to light suffered oxidative damage early (Table 3,4). This period was extended by additional days because to the storing of darkness.

PO contains the highest amount of natural tocotrienols and not detected in the other oils at zero time ***Jusman andHandayani(2021).*** The results illustrated a decrease in total tocotrienols of PO, from 501 mg/kg to 204(59%) mg/kg. In light storage, while storage of dark was from 501 mg/k to 272.02 mg/kg (45%), the tocopherols deliver powerful oxidative stability to oil stored in the dark against autoxidation and under light contra photo-oxidation, ***Imoisi et al., 2015***.

According to the same Tables (3,4), the effect of storage on the profiles of four tocopherol isomers and tocotrienols of PO, SFO, and SBO oils α-tocopherolsdecrease from 150mg/kg to 70.85 mg/kg (52.77%), 575mg/kg to 215 mg/kg (62.6%), and 105 mg/kg to 21

mg/kg (80%) **γ-**tocopherols decrease from 250 mg/kg to 132 mg/kg (43.6%), from 51 mg/kg to 20.4 mg/kg (60%) and from 497 mg/kg to 258.6 mg/kg (47.9%) in light storage while those of dark storage **γ-**tocopherols decrease slowly from 250 mg/kg to150 mg/kg (40%), from 51 mg/kg to35.6 mg/kg (30.2%) and from 497 mg/kg to 270.3mg/kg (45.67%) of PO, SFO, and SBO respectively, SBO oil is the richest γ-tocopherols content ***(Naz et al 2011).*** Their results showed an appositive correlation between linolenic acid and α-tocopherols content in vegetable oils, δ-tocopherols decreased from 45 mg/kg to 24.75 mg/kg (45%), from 8.8 mg/kg to 0 mg/kg (100 %) and from 266 mg/kg to 110.68 mg/kg (58.3 %) in light storage, storage in the dark decreased slowly from 45 mg/kg to32.4 mg/kg (28.8%), from 8.8 mg/kg to ND mg/kg (100%) and from 266 mg/kg to 129.6 mg/kg (51.2%) ***Khan et al(2015).***

The results showed that light storage had a greater effect on the deterioration of tocopherols and tocotrienols in oil content than dark storage after 12 months of storage, PO was more stable followed by SFO followed SBO

Changes in oxidative stability of oils during the storage

It is well known that the oxidation state of edible oils is strongly linked to their purity, composition, and healthy, safe quality. During oxidation, many different and complicated things happen to edible oils, creating many other waste products and changing how these oils work. Also, understanding the oxidative condition of edible oils provides an idea of what to expect from their shelf-life and susceptibility to oxidative rancidity during their preparation and storage, as well as their potential usage for industrialor edible reasons ***(MacArthur and Darkwa (2021).***

The oxidative stability of tested oils used in the investigation was measured, and the obtained results were recorded inTable 5.At zero time, the oils were tested for their resistance to oxidation, and the results are shown in Table 5. PO showed the highest stability

among the tested oils; its induction period reached 27.4, while SFO and SBO had the lowest stability among the tested oils (IP 9.50 and 5.10 h, respectively). This may be attributed to the unsaturation degree of the oilsamples***(Womeni et al., 2016).*** Data showed that the stability decreased with increasing the storage period, and the result showed the variations in IP of oil samples stored at the artificial light condition to be significant ($P \leq 0.05$). At the beginning of storage, IP were 27.4, 9.50, and 5.10 h, respectively), for PO, SFO, and SBO.

Concerning the storage process in artificial light for 12 months, this led to a decrease in the (IP). Which reached 2.5, 0.027, and 0.020 h for PO, SFO, and SBO, respectively.While the same samples stored in the dark at room temperature had an induction period that decreased non-significantly to 14.2, 0.63 and 0.39 h for PO, SFO, and SBO, respectively.

These results supported by ***Mariod et al., (2014).*** When oil samples were kept at room temperature and exposed to light, the induction periods were considerably shorter than when the samples were kept in the dark. Due to the potent destructive action of light on oil, the reduction in the induction time of oil samples under light is a reflection of their high oxidative instability. Peroxide values and TBA, which shown that oil samples exposed to light underwent considerablealteration and lost their resistance to oxidation, supports these findings ***(Tarapoulouzi et al., 2022).***

Conclusion

This study underlined the need of adequate storage in preserving the quality of vegetable oil. It is supported by data showing that effect of light degrade the quality of vegetable oil. These results showed that storing oils with light caused unsaturated fatty acids and tocopherols to break down. This research makes it abundantly obvious that oil has to be kept in a dark without any exposure to oxygen. Higher values of FFA of all oil samples and higher values of FFA subjected to artificial light storage compared with that of darkness storage might be attributed to the elevated rate of hydrolysis and photo-oxidation of oils, which accelerated the reaction rate. Market-sold vegetable oil should be kept the oil faraway from light locations.

The findings demonstrated the impact of natural antioxidants on changes in the quality of edible oil when consumed at home, away from light, potentially as indicated. The current study came to the conclusion that tocopherols, a type of natural antioxidant, are crucial for regulating oil quality. Individual tocopherols are important for preventing oil degradation as well. Tocopherol content must be maintained at its ideal level in order to extend the shelf life of the oil. To retain the highest tocopherol content, proper storage settings, and appropriate refining procedures should be taken into account.

Table (1)

Effect storage condition of color index for tasted oil

RBD OIL	Zero time		After storage (12 months)		
	Yellow colour	Red colour	Yellow colour	Red colour in light	Red colour in darkness
PO	35Aa±0.6	4.0Ab±0.2	35Aa±0.4	2.31Ad±0.3	3.03Ac±0.2
SFO	35Aa±0.4	0.09Cb±0.06	35Aa±0.1	0.00	0.00
SBO	35Aa±0.6	1.05Bb±0.04	35Aa±0.2	0.03Bc±0.02	0.05Bc±0.03

PO: palm oilSFO: sunflower oil SBO: soybean oil Red colour Yellow colour
Means ± Standard deviation with different capital letters within each row are significant at 5% level. Means ± Standard deviation with different small letters within each column are significant at 5% level.

Table (2):

Effect storage condition on fatty acids composition for tested oils

Fatty acids		PO			SFO			SBO	
	Zero	Light	Dark	Zero	Light	Dark	Zero	Light	Dark
Luaric acid C12:0	0.15± 0.05	0.26B± 0.02	0.18C± 0.02	ND	0.45A± 0.03	0.25B± 0.04	ND	ND	ND
Myristic acid C14:0	1.06A± 0.13	1.19A± 0.07	1.10A± 0.06	0.07D± 0.02	0.47C± 0.07	0.31C± 0.14	0.08D± 0.01	0.84B± 0.18	0.67B± 0.12
Palmitic acid C16:0	43.68A± 3.01	46.42A± 1.09	45.31A± 2.13	6.92C± 1.12	8.11C± 0.77	7.90C± 1.01	10.48B± 1.29	13.85B± 2.77	11.73B± 2.14
Palmitoleic acid 16:1	0.22A± 0.05	0.12B± 0.02	0.18A± 0.01	0.12B± 0.02	0.08B± 0.05	0.09B± 0.04	0.10B± 0.03	ND	ND
Margaric acid C17:0	0.10C± 0.01	0.12C± 0.03	0.13C± 0.04	0.04D± 0.01	0.44A± 0.06	0.34A± 0.07	0.10C± 0.03	0.18B± 0.03	0.19B± 0.01
Margolic acid C17:1	0.02A± 0.01	ND	ND	0.03A± 0.01	ND	ND	0.04A± 0.01	ND	ND
Stearic acid C18:0	4.31B± 0.09	6.78A± 1.41	5.00A± 0.56	3.75B± 0.52	6.15A± 0.90	5.91A± 0.88	4.37B± 0.03	6.09A± 0.89	5.96A± 0.83
Oleic acid C18:1	39.75A± 3.11	37.01A± 2.15	38.89A± 2.03	28.23B± 1.57	26.72B± 0.64	27.00B± 0.99	22.15C± 0.78	19.45C± 2.63	20.38C± 1.08
Linoleic acid C18:2t	0.27B± 0.03	ND	ND	ND	ND	ND	0.47A± 0.04	0.01C± 0.01	0.05C± 0.03
Linoleic acid C18:2	9.53B± 1.66	7.22B± 1.79	8.61B± 0.99	58.81A± 3.91	55.89A± 1.88	56.68A± 1.15	53.23A± 2.71	52.14A± 3.12	53.22A± 2.63
(ω−6) Linolenic acid C18:3n6	0.06C± 0.01	ND	ND	0.20B± 0.01	ND	ND	0.81A± 0.03	0.05C± 0.01	0.04C± 0.02
(ω−3) Linolenic acid C18:3n3	0.16C± 0.11	ND	ND	0.34C± 0.14	ND	ND	7.14A± 0.12	5.33B± 0.48	6.04B± 0.51
Arachidic acid C 20:0	0.38C± 0.03	0.58B± 0.06	0.39C± 0.02	0.28C± 0.09	0.58B± 0.07	0.48B± 0.05	0.35C± 0.03	0.97A± 0.13	0.79A± 0.09
(ω−7) Paullinic acid C 20:1	0.15AB± 0.03	0.09B± 0.04	0.11B± 0.02	0.23A± 0.04	0.19A± 0.01	0.20A± 0.01	0.21A± 0.03	0.17A± 0.02	0.18A± 0.03
Behenic acid C 22:0	0.06 D± 0.04	0.21C± 0.04	0.10D± 0.02	0.72A± 0.09	0.92A± 0.15	0.84A± 0.08	0.47B± 0.03	0.92A± 0.11	0.78A± 0.14
Total SFAs	49.76A± 3.22	55.56A± 4.01	52.21A± 1.88	11.72D± 0.33	17.12C± 0.55	16.03C± 0.95	15.85C± 1.01	22.85B± 2.17	20.09B± 0.94
Total MUFAs	39.99A± 1.87	37.22A± 1.66	39.18A± 1.07	28.38B± 1.11	26.99B± 0.96	27.29B± 0.82	22.50C± 0.99	19.62C± 2.55	20.56C± 1.44
Total PUFAs	10.25B± 1.91	7.22B± 1.78	8.61B± 0.89	59.90A± 2.88	55.89A± 2.74	56.68A± 2.48	61.65A± 3.99	57.53A± 2.94	59.35A± 2.83

PO: palm oil SFO: sunflower oil SBO: soybean oil TSFAs:PO: palm oil SFO: sunflower oil SBO: soybean oil TSFAs: Total saturated fatty acids MUFAs: Monounsaturated fatty acids PUFAs: Poly unsaturated fatty acids ND: not dMeans ± Standard deviation with different capital letters within each column are significant at 5% level.

Table (3):

Changes in tocopherols and tocotrienols (mg/kg product) of oils during the storage.

Total tocopherols		Tocopherols (mg/kg)							
		α		β		γ		Δ	
Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth
445Ca± 5.99	221.85Fb± 3.11	150Ba± 7.88	70.85Db± 2.21	ND	ND	250Ba± 5.32	132Db± 3.08	45Ba± 4.82	24.75Db± 1.04
646.8Ba± 7.12	235.4Eb ± 5.65	575Aa± 5.41	215Bb± 7.81	12Ba± 3.71	ND	51Ca±8.44	20.4Fb± 1.31	8.8Ca± 2.55	ND
908Aa± 6.27	398.28B± 7.09	105Ca± 9.01	21Fb± 1.36	40Aa± 4.90	8Bb± .12	497Aa± 7.06	258.6Bb± 4.03	266Aa± 8.01	110.68Bb± 3.10
445Ca± 5.99	265.9Db± 3.67	150Ba± 7.88	82.5Cb± 6.03	ND	ND	250Ba± 5.32	150Cb± 1.89	45Ba± 4.82	32.4Cb± 1.67
646.8Ba± 7.12	325.1Cb ± 4.89	575Aa± 5.41	290.5Ab± 6.31	12Ba± 3.71	ND	51Ca± 8.44	35.6Eb± 3.17	8.8Ca± 2.55	ND
908Aa± 6.27	450.12Ab± 8.23	105Ca± 9.01	32.02Eb± 2.04	40Aa± 4.90	18.2Ab± 3.37	497Aa± 7.06	270.3Ab± 2.02	266Aa± 8.01	129.6Ab± 1.34

Means ± Standard deviation with different capital letters within each row are significant at 5% level.
Means ± Standard deviation with different small letters within each column are significant at 5% lev

Table (4):

Changes in tocotrienols (mg/kg product) of oils during the storage.

Storage	Oils	Total tocotrienols		Tocotrienols (mg/kg)							
				α		β		γ		Δ	
		Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth	Zero	After 12 moth
LIGHT	PO	501Aa± 7.48	204.85Bb± 2.05	130Aa± 1.82	52Bb± 3.41	16Aa± 2.34	ND	288Aa± 3.55	128.7Bb± 3.17	69Aa± 5.81	24.15Bb± 3.03
	SFO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	SBO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DARK	PO	501Aa± 7.48	272.02Ab± 6.61	130Aa± 1.82	71.5Ab± 2.27	16Aa± 2.34	ND	288Aa± 3.55	163.02Ab± 4.20	69Aa± 5.81	37.5Ab± 1.66
	SFO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	SBO	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

PO: palm oil SFO: sunflower oil SBO: soybean oil α: alpha tocopherol and tocotrienols β: beta tocopherol and tocotrienols γ: gamma tocopherol and tocotrienols δ: delta tocopherol and tocotrienols N.D: non detecte Means ± Standard deviation with different capital letters within each row are significant at 5% level.

Table (5):

Changes in oxidative stability of oils during the storage by Rancimat test method (h)

oils	Zero timr	After12 months storage	
		Light	Dark
PO	27.4Aa±0.4	2.5Ac±0.1	14.2Ab±0.3
SFO	9.50Ba±0.2	0.027Bc±0.004	0.63Bb±0.07
SBO	5.10Ca±0.5	0.020Bc±0.006	0.39Cb±0.09

PO: palm oil SFO: sunflower oil SBO: soybean oilh: hour

Means ± Standard deviation with different capital letters within each row are significant at 5% level.

Means ± Standard deviation with different small letters within each column are significant at 5% level.

Mean s ± Standard

deviation with different small letters within each column are significant at 5% level.

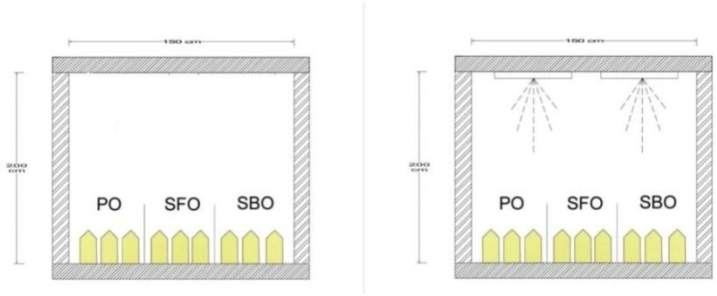

Fig. 1:

A; (dark condition) B: (artificial lightcondition)

PO: palm oil SFO: sunflower oil SBO: soybean oil

Storage room, light and dark condition design.

Fig. 2:

Digital light meter.

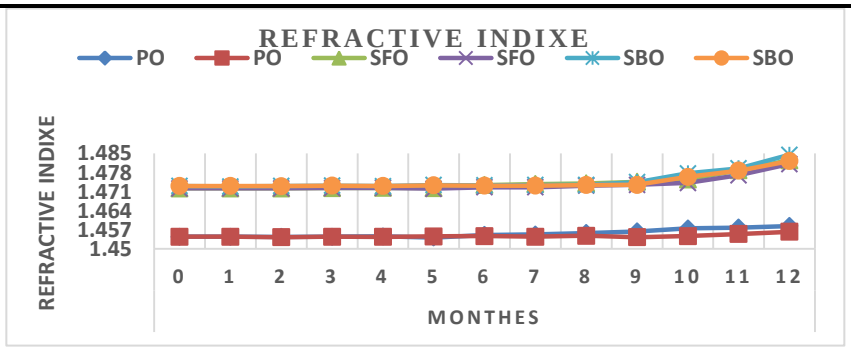

Fig. 3:

Effect of lightand dark storage on refractive index of oil samples during time.

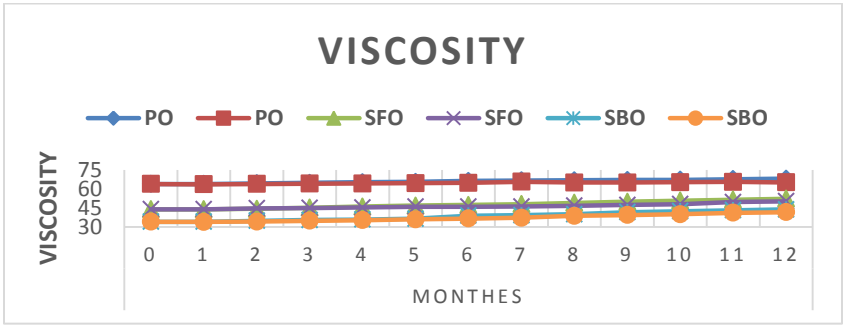

Fig. 4:

Effect of lightand dark storage on viscosity of oil samples during time.

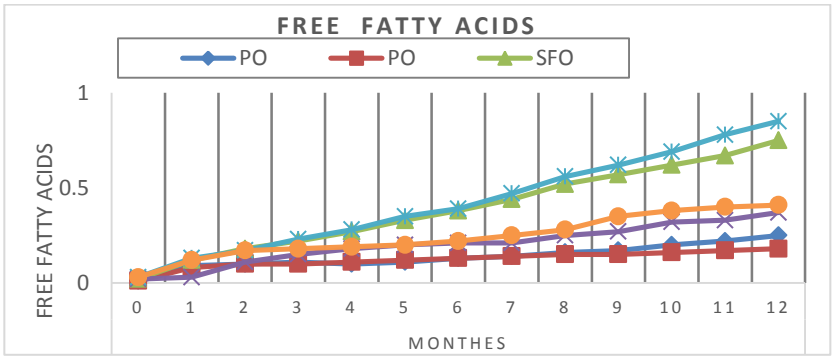

Fig. 5:

Effect of lightand dark storage on free fatty acids (% FFA) of oil samples during time.

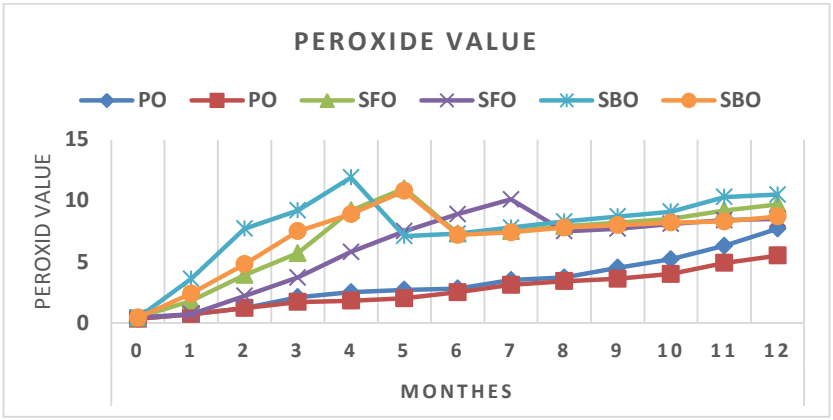

Fig. 6:

Effect of lightand dark storage on peroxide value (meq. O_2/kg oil) of oil samples during time.

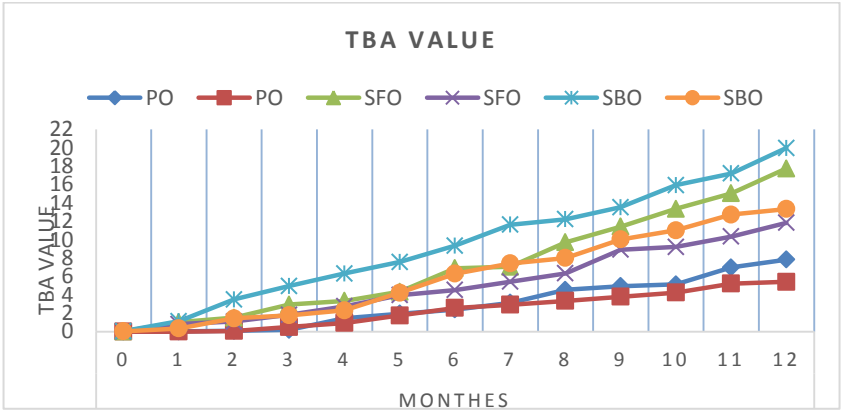

Fig.7:

Effect of lightand dark storage on TBA value of oil samples during time.

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تأثير التخزين طويل الأمد في الضوء أوالظلام عند درجة حرارة الغرفة على الخصائص الفيزيائية والكيميائية لبعض الزيوت النباتية

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الملخص العربي

تختلف الزيوت النباتية الغذائية فى قدرتها على مقاومة الاكسدة والتغيرات غير المرغوب بها وبالتالى يؤثر ذلك على مدة صلاحية الزيوت للتخزين والتى تستخدم فى التغذية او التصنيع الغذائي. ويهدف هذا البحث الى دراسة اسباب اختلاف الصفات الطبيعية والكيميائيةللزيوت عند تخزينها للاستفادة منها فى اختيار الزيوت الصالحة للاستهلاك الغذائي الادمي او الملائمة للاستخدام فى مجال الصناعات الغذائية. وتطرق هذا البحث الى دراسة تأثير ظروف التخزين المختلفة مثل الضوء والظلام لمدة 12 شهر فى درجة حرارة الغرفة العادية لزيوت نباتية وهى زيت النخيل، زيت زهرة الشمس وزيت الصويا واظهرت النتائج ان زيت النخيل كان اعلى فى درجة فى الثبات التأكسدي25.5 ساعة يليه زيت دوار الشمس 9.5 ساعة ثم اخيرا زيت الصويا 5.5 ساعة. واظهرت النتائج ايضا بعد عملية التخزين ارتفاع رقم الحموضة ورقم البيروكسيد للزيوت محل الدراسة للدلاله على صلاحية الزيوت، رقم الحموضة كانت اعلى قيم فى التخزين فى الضوء فكانت كالتالى (0.25, 0.70و 0.85%) على التوالى لزيت النخيل وزيت زهرة الشمس وزيت الصويا بينما كان التخزين فى الظلام اقل فى القيم (0.18 ,0.37 و 0.41%) على التوالى لزيت النخيل وزيت دوار الشمس وزيت الصويا,اما التغير فى رقم البيروكسيد اثناء التخزين فكانت اعلى نتجية لزيت الصويا في الشهر 4 يليها زيت دوار الشمس فى الشهر 5 واقل نتيجة لزيت النخيل فى شهر 12 (11.9،11، 7.7)على التوالى فى التخزين فى الضوء بينما الخزين فى الظلام كانت النتائج اقل عند فى نفس الشهور (10.5، 7.5 ،1.5) ، واظهرت النتائج ايضا ارتفاع فى رقم الثيوبربتيوريك اسيد فكانت النتائج كالتالي (19.8، 17.74، 7.53) لزيت

الصويا وزيت دوار الشمس وزيت النخيل على التوالى للتخزين فى الضوء بينما كانت الزيادة والتغير في الظلام بنسبة افل (13.34 ،11.85، 5.74) على النوالى واظهرت النتايج اختلاف تركيب الاحماض الدهنية للزيوت محل الدراسة فكانت الاحماض الدهنية المشبعة الكلية لزيت النخيل هى الاعلى 49.76% يلية زيت الصويا 15.85% يليها زيت دوار الشمس 11.72%، واظهرت النتائج ارتفاع النسبة المئوية للاحماض الدهنية المشبعة لزيت النخيل من (49.76 الى 55.56 و 52.21٪) ، زيت زهرة الشمس (11.72 الى 17.2 و 16.03٪) ، زيت الصويا (15.85 الى 22.85و 20.09٪) فى الضوء والظلام على التوالى ، واظهرت النتائج ايضا انخفاض الاحماض الدهنية الغير مشبعة الاحادية المشبعة لزيت النخيل من (39.99 الى 37.22 و 39.18٪) ، زيت زهرة الشمس (28.38 الى 26.99 و 27.29٪) ، زيت الصويا (22.50 الى 19.62و 20.56٪) فى الضوء والظلام على التوالى ، واظهرت النتائج ايضا انخفاض الاحماض الدهنية الغير مشبعة الثنائية المشبعة لزيت النخيل من (10.25 الى 7.22 و 8.61٪) ، زيت دوار الشمس (59.90 الى 55.89 و 56.68٪) ، زيت الصويا (61.65 الى 57.53و 59.35٪) فى الضوء والظلام على التوالى.واظهرت النتائج ايضا انخفاض التوكوفيرول والتوكوترابنول الكلية(بالمليجرام لكل كيلو جرام) لزيت النخيل من (445 الى 221.85 و 265.9ملليجرام/كيلواجرام) ، زيت دوار الشمس من (646.8 الى 235.4 و 325.1) ، زيت الصويا من (908 الى 398.2 و 450.12) فى الضوء والظلام على التوالى ، كما اظهرت النتائج ايضا انخفاض محتوى زيت النخيل من التوكوترابنول من (501 الى 204.85 و 272.02ملليجرام/كيلواجرام) .وعدم احتواء زيت دوار الشمس وزيت الصويا شقوق التوكوترابنول ولذلك اثبتت الدراسة بان زيت النخيل هو الاكثر ثباتا واقل فى تغير الصفات الطبيعية والكيميائية اثناء فترة التخزين لمدة 12 شهر فى الظروف المختلفة لثبات تركيب الاحماض الدهنية له ومحتواه من مضادات الاكسدة الطبيعة خصوصا التوكوترابنول يليه زيت دوار الشمس وزيت الصويا .

الكلمات الدالة: الصفات الطبيعية والكيميائية، الثبات التأكسدي ، مضادات الاكسدة الطبيعية ، الاحماض الدهنية ، الزيوت النباتية, التخزين