American Journal of

# Food Technology

ISSN 1557-4571

Academic
Journals Inc.

www.academicjournals.com

American Journal of Food Technology 7 (11): 700-707, 2012
ISSN 1557-4571 / DOI: 10.3923/ajft.2012.700.707


# Effect of Storage Packaging on Sunflower Oil Oxidative Stability

Abdelmonem M. Abdellah and Khogali El Nour Ahmed Ishag
Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Sudan

*Corresponding Author: Abdelmonem M. Abdellah, Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Sudan*

## ABSTRACT

The sunflower is one of the four most important oilseed crops in the world and the nutritional quality of its edible oil ranks among the best vegetable oils in cultivation. Two samples of sunflower oil were evaluated for physicochemical properties to compare between different types of storage in order to minimize oil deterioration and prolong its shelf-life. One of which is sunflower variety PAN7411 that was recently grown in Gezira Agricultural Research Corporation to be tested for yield productivity. The second sample was commercial oil purchased from the local market. Both seeds of the variety, as a whole and its extracted oil was stored and compared. Commercial oil samples were stored in containers of different materials and colors. Stored seeds and oils were periodically sampled and tested for oil oxidative stability namely: color, refractive index, viscosity, refractive index, viscosity, acid value, peroxide value and iodine value. Results demonstrate that the immediately extracted oil after plant harvesting is more resistant to deterioration than the oil kept stored inside the seed, for the variety under the study. Glass container seemed to be more resistant to deterioration factors than polythene while galvanized container was found to be the worst. Brown container revealed more resistance to oxidative stability followed by colorless container and the black container was the worst. Peroxide value of commercial oil samples revealed high measurements even at 0.0 time oil storage.

**Key words:** Sunflower oil, deterioration, oxidative stability, rancidity, storage

## INTRODUCTION

Sunflower oil is obtained from the seeds of the plant *Helianthus annuus*. Daniel (1979), was estimated sunflower oil as the second largest production of any edible vegetable oil in the world. Sunflower oil is light yellow oil which is well suited for use as a salad and cooking oil, good grades of the oil are refined with low loss (Eckey, 1954). Total unsaturation of the oil is comparable with soybean oil and the linolenic found in soybean oil lacking in sunflower oil, a fact that is to the advantages of the sunflower oil when used as a food. Typically up to 90% of the fatty acids in conventional sunflower oil unsaturated, namely oleic (C 18:1, 16-19%) and linoleic (C 18:2, 68-72%) fatty acids. Palmitic (C 16:0, 6%), stearic (C 18:0, 5%) and minor amounts of myristic (C 14:0), myristoleic (C 14:1), palmitoleic (C 16:1), arachidic (C 20:0), behenic (C 22:0) and other fatty acids account for the remaining 10% (Skoric *et al*., 2008).

Pezzuto and Park (2002) reported that lipid oxidation is considered a principal mean of deterioration in the quality of foodstuffs imparts rancid and undesirable flavors to fat products, generates reactive oxygen species, which are linked to carcinogenesis, inflammation, aging and cardiovascular disorders.

Oils and fats packing a considerable factor prevents oils and fats during handling and storage from contamination by dirt, infestation of insects, rodents or microorganisms and loss or gain of moisture, odor or flavor (Daniel, 1979; Ngassapa and Othman, 2001).

It was reported that material of container is an important factor to prevent oils and fats from deterioration (Bahtia and Rao, 1959). Aluminum tinned, iron or stainless steel containers were recognized well suited for almost all types of edible oils and fats containers. In contrast, zinc, plain iron, black sheet metal or galvanized irons containers were reported drastically harm the shelf-life of oils and fats. Generally, it was well known that the glass containers rank the premier of all type of containers but their cost and difficulty in handling reduce their wide use.

Several factors accelerate rancidity of oils and fats: (a) exposure to heat and light, (b) moisture and (c) by the presence of traces of certain metals e.g., copper, nickel and iron (Daniel, 1979). Whereas, the oxidation of oils and fats was reported to be brought about by: (a) bacterial action, (b) enzyme catalyzed hydrolysis and oxidation and (c) direct chemical attack by oxygen of the air (Hartly, 1967). Other studies incriminated many factors that affecting oils and oilseeds oxidative stability: (a) atmospheric oxygen, (b) light (Schultz *et al.*, 1962; Sattar and de Man, 1975), (c) temperature (Canvin, 1965; Fernandez-Martinez, 1974) and (d) moisture (Richard *et al.*, 2005). It has been reported that there are three types of deterioration of oils and fats during storage: (1) Oxidation: It requires oxygen more rapidly at high temperature and speeded up by contact with copper or copper containing alloys, other metals such as iron also has a catalytic effect though less than of copper, (2) Hydrolysis: The breakdown of fats to fatty acids was found to be promoted by the growth of microorganisms in the presence of water and free fatty acids also promote hydrolysis and (3) Contamination: It is from residues of a previous material handled in the equipment, from dirt, rain, or sea water or through the accidental addition of different product (Berger, 1986). Mikolajcza *et al.* (1970) reported that the deterioration of oilseeds through enzyme action or infestation by microorganisms is greatly stimulated by mechanical damage to the seed cells. Furthermore, the un-decorticated seed kept better than decorticated ones and deterioration was rapid after the seed have been ground or rolled in preparation for expression of the oil. On contrast, it was reported that, not all changes occurred in stored seed are undesirable, Markley (1950) found that the yield of oil from newly harvested soybeans was less than from the same beans after a period of storage, moreover, the storage of soybeans caused diminution in the chlorophyll content of green beans. De Haro and Fernandez-Martinez (1991) found that the high oleic sunflower oil was more stable than the high linoleic sunflower oil and mentioned that this correlation depend mainly on the environmental temperature under which the crop was grown. Generally, vegetable seeds with high natural antioxidants exerted high oxidative stability compared to vegetable seeds with low levels of antioxidants, like sunflower seeds. In addition, the vegetable oils stability of polyunsaturated oils could be improved by blending oils with different portion of high oleic sunflower oil (Frankel and Huang, 1994; Toliwal *et al.*, 2005; Gulla *et al.*, 2010). Furthermore, a considerable work done recently on the development of high-oleic hybrids with altered tocopherol levels, the oil of which will have 10-20 times greater oxidative stability than that of conventional SO (Skoric *et al.*, 2008). Hence, the objective of the present study was to: (1) Investigate the comparison between SO kept in different containers of different material and different color, (2) Finding out the best choice of storage condition; storing oil inside the seeds or storing the pressed oil-seed and (3) Investigate oil characteristics of the newly introduced sunflower variety PAN7411.

## MATERIALS AND METHODS

The sunflower oil which has been used in the present study were two different samples, one of which was extracted from new harvested sunflower seeds that grown in the Gezira Agricultural Research Corporation farm. The other sample was commercial oil which had been already extracted, bleached and deodorized under industrial processing.

**Oil extraction:** Sunflower seed of the variety PAN7411 was extracted by utilizing local made oil presser and Chinese presser. First oil samples were extracted after harvesting and the second after end of storage period. The extracted crude oil was laboratory purified by using filter paper No. 40 under suction in order to accelerate oil filtration. The filtrated oil was then let to settle for about two days in room temperature and then filtered again. After complete sediment, all settled and impurities were removed and the oil becomes markedly clear and suitable to subsequent analyses.

**Oil packaging and storage period:** Commercial oil samples were stored in three types of containers' material: (1) Galvanized tin, (2) Polythene and (3) Colorless glass container. Furthermore, the commercial oil samples also were stored in glass containers of different colors: (1) Brown, (2) Black and (3) Colorless bottle. In respect of PAN7411 variety, first extracted oil samples were stored in colorless glass bottle to be compared with that extracted at the end period of seed storage. Commercial oil samples were stored for 12 months at room temperature (35°C) and were sampled periodically every 4 months.

**Proximate analysis of seed composition:** Determination of total oil content was carried out according to AOAC (1984). Crude protein was determined by semi micro Kjeldahi method as described by Pearson (1981). Crude fiber was estimated by the method described by Pearson (1981). Moisture content was determined by air oven as described by AOAC (1984). Total ash also determined by the method that described by AOAC (1984).

**Oil characteristics analysis:** Refractive index of all samples was determined at 35-40°C index by Abb-Refractometer according to AOAC (1984). Color intensity was recorded using a lovibond tintometer, unites of red, yellow and blue according to AOCS (1973). Viscosity of the oil samples under investigation was recorded using Ostwald-U-tube viscometer according to Cocks and van Rede (1966). Acid value, peroxide value and iodine value of all samples were determined according to the AOCS (1973).

## RESULTS AND DISCUSSION

Table 1 shows seed composition of sunflower PAN7411-variety. This variety has revealed, relatively, high oil and protein contents (44.3 and 18.5%), respectively. Crude fiber content was 17% while each of moisture content and total ash was found to be only 3%. Previous evidence reported that sunflower oil content ranged between 25 and 48% and for protein content the range is between 15 and 20% (Weiss, 1983).

As shown in Table 2, oil samples extracted from the new fresh harvested PAN7411-variety seeds exhibited more resistance to color degradation compared to those of stored ones. Therefore, oil samples of stored seed seemed to be the worst in term of oil deterioration. This means that it is better to extract oil immediately after harvesting and store it as crude oil than to store the seeds itself (storing oils inside the seeds) and extracted thereafter. It was reported that color intensity of

Table 1: Sunflower seed composition of PAN7411-variety

| Seed analysis | Percentage |
|---|---|
| Total oil content | 44.3 |
| Crude fiber content | 17.0 |
| Crude protein content | 18.5 |
| Moisture content | 3.0 |
| Total ash content | 3.0 |

Table 2: Physicochemical characteristics of sunflower oil PAN7411-variety stored for one long storage time (12 months)

| | Physical parameters | | | | | Chemical parameters | | |
|---|---|---|---|---|---|---|---|---|
| | Color | | | | | | | |
| Type of sample | Yellow | Red | Blue | Refractive index (at 40°C) | Viscosity (at 35°C) | Acid value (mg KOH/g oil) | Peroxide value (meq/kg) | Iodine value (Wijs method) |
| A | 25 | 3.6 | 0.0 | 1.4720 | 54.1 | 0.447 | 7.98 | 127 |
| B | 25 | 3.4 | 0.0 | 1.4745 | 51.9 | 0.538 | 78.5 | 112.5 |
| C | 25 | 2.4 | 0.0 | 1.4750 | 60.3 | 2.112 | 69.5 | 112.5 |

A: Fresh oil extracted from newly harvested seeds, B: Stored oil extracted from newly harvested seeds, C: Fresh oil extracted from stored seeds

edible oils is due to the natural pigments and their derivatives. On prolong storage, pigments and their derivatives undergo more oxidation that eventually leads to colorless products which affect oil color (Nolen *et al*., 1967). Arya *et al.* (1969) reported that refractive index of oils increased by storage time. Similar results have been confirmed by the current study and refractive index of all of the oil samples were increased progressively. Stored seed oil samples found to be having the highest refractive index whereas fresh oil samples extracted from the newly harvested seeds seemed to be the best. As shown in Table 2, viscosity of stored oil samples has been decreased during storage time from 54.1-51.9. On contrast, viscosity was increased up to 60.3 in oil samples extracted from stored seeds. Presumably, this high viscosity could be attributed to glycerol formation generated by fatty acid hydrolysis caused by enzymatic reactions. Increasing of viscosity by formation of polymerized products accumulated during storage time is not excluded and may contribute to increase it in stored seeds. Relatively, small changes were observed in acid values of stored oil samples which increases from 0.447-0.538 whereas, the acid value in oil sample extracted from stored seeds was increased up to 2.112. High acidity in oil samples extracted from stored seeds may attribute to decomposition of oil glycerides to their original fatty acids which caused by enzymatic reactions that remains kept inside the stored seeds. It has been reported that oil of stored seeds is more exposure to hydrolysis factors (Humeid and Abu Blan, 1987). Moreover, damage of seeds during harvesting and/or handling leads to a stringent deterioration during prolonged storage (Daniel, 1979). Obvious increase was observed with respect to peroxide value in each of the three oil samples investigated. Conversely, oil of stored seeds seemed to be more resistant to peroxidation compared to the stored oil. Probably, this resistance may be attributed to the natural protection by the seed's shell. Furthermore, stored oils may be more affected by light which promoted photo oxidation. As reported previously by Lea *et al.* (1960), iodine value of oil samples studied tended to decrease by the increase of storage time. Each of stored oil sample and oil sample of stored seeds showed iodine values reduction from 127-112.5, demonstrating the similarity of oil resistance to double bond destruction factors whether being stored inside the seeds or as extracted oil.

Table 3: Physicochemical characteristics of oil samples stored in containers of different materials

| | Type of container-material | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Glass | | | Polythene | | | Galvanized tin | | |
| Oil parameter test | 0 month | 4 month | 8 month | 0 month | 4 month | 8 month | 0 month | 4 month | 8 month |
| Color | | | | | | | | | |
| Yellow | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Red | 2.9 | 2.6 | 2.3 | 2.9 | 2.5 | 2.1 | 2.9 | 2.1 | 1.7 |
| Blue | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Refractive index (at 40°C) | 1.467 | 1.468 | 1.469 | 1.467 | 1.469 | 1.471 | 1.467 | 1.471 | 1.474 |
| Viscosity (at 35°C) | 67.0 | 62.3 | 58.5 | 67.0 | 54.9 | 48.0 | 67.0 | 49.0 | 45.0 |
| Acid value (mg KOH/g oil) | 0.059 | 0.100 | 0.338 | 0.059 | 0.192 | 0.458 | 0.050 | 0.220 | 0.518 |
| Peroxide value (meq/kg) | 19.0 | 56.0 | 96.5 | 19.0 | 84.0 | 135.7 | 19.0 | 182.0 | 342.5 |
| Iodine value (Wijs method) | 119.4 | 114.5 | 110.2 | 119.4 | 109.4 | 106.5 | 119.4 | 107.5 | 103.5 |

Physicochemical parameters of commercial sunflower oil samples stored in different container-material were presented in Table 3. Initial reading of color measurements were recorded as 25, 2.9 and 0.0 for yellow, red and blue, respectively. Consecutive analyses showed no changes of reading records for each of yellow and blue while reading record for red was becoming fade during storage time. At the end of storage period, glass container revealed acceptable resistance to color degradation (2.3), seconded by polythene container (2.1) and galvanized tin container was the lowest (1.7). Color of vegetable oils is attributed to minor oil components present in a very small concentration, such as tocopherols, carotenoids and other pigments. These components were formed to undergo oxidation during oil storage which ultimately caused oil decolorization (Daniel, 1979). As reported previously by Arya *et al.* (1969) that refractive index of oils increased by storage time. At the end of storage period, class container has the lowest refractive index (1.469), followed by polythene (1.471) while galvanized tin was the highest (1.474). Table 3 showed a clear decrease of viscosity during storage time for all oil samples under investigation. Slight decrease in viscosity has been noticed for oil samples stored in glass and polythene containers, whereas oil sample stored in galvanized tin container showed a remarkable decrease in viscosity which has fallen to 49.0 after the first period and to 45.0 at the end of storage period. It could be noticed that (Table 3) the acidity increased with storage time for all oil samples. Primer acidity of the refined commercial sample was 0.059 which over storage increased slightly in all containers. Generally, glass and polythene containers seemed to be better than galvanized tin as described previously by Jaimand and Rezaee (1995). Peroxide value of commercial oil sample at 0.0 time was 19.0, indicating that the oil has already undergone to previous oxidation after industrial processing or while being stored at the industry site. High increase in peroxide values was observed over storage time in all oil samples. Glass and polythene containers seemed to be better when compared to galvanized tin container. Presumably, high peroxide formation may attribute to climatic conditions that characterized arid and semi-arid region where the Sudan is located. During the first period of storage, iodine value was decreased in the three container types. Primer analysis iodine value was 119.4. At the end of storage period iodine values were found to be 110.2, 106.5 and 103.5 for glass, polythene and galvanized tin containers, respectively.

Physicochemical parameters of commercial SO samples which stored in different colored containers were presented in Table 4. As previously mentioned, yellow and blue colors were

Table 4: Physicochemical characteristics of oil samples stored in containers of different colors

| | Type of glass container-color | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Brown | | | Clear (colorless) | | | Black | | |
| Oil parameter test | 0 month | 4 month | 8 month | 0 month | 4 month | 8 month | 0 month | 4 month | 8 month |
| Color | | | | | | | | | |
| Yellow | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Red | 2.9 | 2.8 | 2.7 | 2.9 | 2.6 | 2.3 | 2.9 | 2.5 | 2.2 |
| Blue | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Refractive index (at 40°C) | 1.467 | 1.468 | 1.469 | 1.467 | 1.469 | 1.471 | 1.467 | 1.469 | 1.470 |
| Viscosity (at 35°C) | 67.0 | 66.6 | 61.9 | 67.0 | 62.3 | 58.5 | 67.0 | 59.2 | 51.0 |
| Acid value (mg KOH/g oil) | 0.059 | 0.100 | 0.328 | 0.059 | 0.100 | 0.338 | 0.050 | 0.150 | 0.392 |
| Peroxide value (meq/kg) | 19.0 | 54.0 | 92.8 | 19.0 | 56.0 | 96.0 | 19.0 | 58.5 | 98.6 |
| Iodine value (Wijs method) | 119.4 | 116.3 | 113.0 | 119.4 | 114.5 | 110.2 | 119.4 | 110.2 | 107.2 |

remained stable and was not affected by storage time while red color were faded in all types of colored containers. Slight degradation was observed with respect to a lovibond tintometer red color which faded from 2.9 (at 0.0 time) to 2.8, 2.6 and 2.5 at the end of the second period of storage time (4.0 months) and to 2.7, 2.3 and 2.2 at the end of the third period (8.0 months) for brown, clear and black glass containers, respectively. Refractive index was remained stable in brown colored container after the first period of storage time whereas in clear and black containers were found to have a slight increase from 1.467 (at 0.0 time) to 1.468 and 1.469 at 4.0 months, respectively. At the end of storage period (8.0 months), refractive indexes were increased in all containers. Records were: 1.468, 1.469 and 1.470 for brown, clear and black color, respectively. Viscosity was decreased from 67.0 (at 0.0 time) to 66.6, 62.3 and 59.2 at 4.0 months and to 61.9, 58.5 and 51.0 at 8.0 months for brown, clear and black container, respectively. Acid values were increased from 0.059 (at 0.0 time) to 0.100, 0.100 and 0.150 (at 4.0 months) and to 0.328, 0.338 and 0.392 (at 8.0 months) for brown, clear and black container, respectively. Peroxide value was increased from 19.0 (at 0.0 time) to 54.0, 56.0 and 58.5 (at 4.0 months) and to 92.8, 96.0 and 98.6 (at 8.0 months) for brown, clear and black container, respectively. Iodine value was decreased from 119.4 (at 0.0 time) to 116.3, 114.5 and 110.2 (at 4.0 months) and to 113.0, 110.2 and 107.2 (at 8.0 months) for brown, clear and black container, respectively. From the above mentioned results, the brown container revealed more resistance to oil deterioration. Brown color may act as a protective shelter from light, since light has been incriminated among factors breakdown pigments and vitamins present in small quantities in vegetable oils (Sattar and de Man, 1975). Relative degradation of oil sample stored in black container may be attributed to temperature absorbed by black color. Temperature plays a significant role of breakdown of oils and fats to fatty acids and glycerol (Humeid and Abu Blan, 1987).

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the present investigation, the following conclusions may be drawn:

- Sunflower PAN7411-variety has acceptable properties as vegetable oil for both seed components and oil characteristics. Total of seed components were: 44.3, 17.0, 18.5 and 3.0% for oil, crude fiber, protein and each of moisture and total ash contents, respectively

- Storage of oil after extraction from newly harvested seeds is seemed to be better than storage of seeds. Oil extracted from stored seeds revealed high acidity at the end of period of storage time and exhibited less resistance to oil deterioration factors. On contrast, peroxide values of stored oil (78.5) was higher than that (69.5) of stored seeds
- Regardless of difficulties in handling, glass container of brown color seemed to be the best choice to prolong oil edibility
- It is recommended to extract oil immediately after harvesting, as possible, in order to avoid high oil losses due to breakdown of oil glycerides to fatty acids
- It is not advisable to store oils in galvanized tin containers
- Due to high increase in peroxide values of stored oil even within the first period of storage time (4.0 months), the study recommended every country to set standards for food stuff as general and for edible vegetable oils in specific according to regional climatic conditions

## ACKNOWLEDGMENT

The authors acknowledge the assistance of all those who contributed to this study.

## REFERENCES

AOAC, 1984. Official Methods of Analysis. 12th Edn., Association of Official Analytical Chemists, Washington, DC., USA.

AOCS, 1973. Official and Tentative Methods of American Oil Chemist's Society. 3nd Edn., Champion IL, Washington, DC, USA.

Arya, S.S., S. Ramanujam and P.K.V. Pharan, 1969. Refractive index as a mounts of gauging the development of oxidative rancidity in fats and oils. JAOCS, 46: 28-30.

Bahtia, D.S. and B.Y. Roa, 1959. Storage of vegetable oils and fats in containers. Indian Oilseeds J., 3: 144-144.

Berger, K.G., 1986. Recommended Practices for Storage and Transport of Edible Oils and Fats. Institute Penyeidican Minak Kelapa Sawit Malaysia, Malaysia, pp: 3-4.

Canvin, D.T., 1965. The effect of temperature on the oil content and fatty acid composition of the oils from several oil seed crops. Can. J. Bot., 43: 63-69.

Cocks, L.V. and C. van Rede, 1966. Laboratory Handbook for Oil and Fat Analysis. Acdemic Press Inc. Ltd., New York, USA.

Daniel, S., 1979. Bailey's Industrial Oils and Fats Product. 4th Edn., Wiley, New York, USA.

De Haro, A. and J.M. Fernandez-Martinez, 1991. Evaluation of wild sunflower (*Helianthus*) species for high content and stability of linoleic acid in the seed oil. J. Agric. Sci., 116: 359-367.

Eckey, E.W., 1954. Vegetable Fats and Oils. Reinhold, New York, USA., Pages: 836.

Fernandez-Martinez, J., 1974. Variability in the fatty acid composition of the seed oil of *Helianthus* species. M.Sc. Thesis, University of California, USA.

Frankel, E.N. and S.W. Huang, 1994. Improving the oxidative stability of polyunsaturated vegetable oils by blending with high-oleic sunflower oil. J. Am. Oil Chem. Soc., 71: 255-259.

Gulla, S., K. Waghray and U. Reddy, 2010. Blending of oils-does it improve the quality and storage stability, an experimental approach on soybean and palmolein based blends. Am. J. Food Technol., 5: 182-194.

Hartly, C.W.S., 1967. The Oil Palm, Oil Palm Products their Fermintation and Characteristics. 2nd Edn., West African Institute for Oil Palm Research, London, New York, USA., pp: 693-703.

Humeid, M.A. and H.A. Abu Blan, 1987. Effect of molds invading olive fruits during storage on oil acidity and aflatoxin (B1) production. Dirasat: Agric. Sci., 14: 191-196.

Jaimand, K. and M.B. Rezaee, 1995. Studies on the quality of sunflower oil. Agrochemica, 39: 177-183.

Lea, C.H., L.J. Parr and R.J. Carpenter, 1960. Chemical and nutritional changes in stored herring meal. 2. Br. J. Nutr., 14: 91-113.

Markley, K.S., 1950. Soybean and Soybean Products. Vol. 1, Interscience Publishers, New York, USA.

Mikolajcza, K.L., C.R. Smith and I.A. Wolff, 1970. Unusual seed oils and their fatty acids. J. Am. Oil Chem. Soc., 47: 24-25.

Ngassapa, F.N. and O.C. Othman, 2001. Physicochemical characteristics of some locally manufactured edible vegetable oils marketed in Dae es Salaam. Tanzania. J. Sci., 27: 49-58.

Nolen, G.A., J.C. Alexander and N.R. Artman, 1967. Long-term rat feeding study with use frying fats. J. Nut., 93: 337-348.

Pearson, N.D., 1981. Pearson Chemical Analysis of Food. 8th Edn., Churchill Livingstone London, New York.

Pezzuto, J.M. and E.J. Park, 2002. Autoxidation and Antioxidants. In: Encyclopedia of Pharmaceuticals Technology, Swarbrick, J. and J.C. Boylan (Eds.), Marcel Dekker Inc., New York, USA., pp: 97-113.

Richard, D., L.A. Jones, C.C. King, P.J. Wakelyn and P.J. Wan, 2005. Cottonseed Oil. In: Bailey's Industrial Oil and Fat Product, Shahidi, F. (Ed.). 6th Edn. John Willey and Sons Inc., USA.

Sattar, A. and J.M. de Man, 1975. Photo oxidation of milk and milk products. CRC Crit. Rev. Food Sci. Nutr., 7: 13-37.

Schultz, H.W., E.A. Day and R.O. Sinnhuber, 1962. Symposium of Food: Lipid and Their Oxidation. AVI Publishing, Westport, USA., pp: 215-229.

Skoric, D., S. Jocic, Z. Sakac and N. Lecic, 2008. Genetic possibilities for altering sunflower oil quality to obtain novel oils. Can. J. Physiol. Pharmacol., 86: 215-221.

Toliwal, S.D., M.R. Tiwari and S. Verma, 2005. Studies on thermal stability of palm-corn oil blends. J. Oil Technol. Assoc. India, 37: 18-20.

Weiss, E.A., 1983. Oil Seed Crops. Pub. In USA Longman Inc., New York, USA., pp: 402-426.