Effect of Storage period and Antioxidants treatment on Physiochemical Characteristics and Stability of Cottonseed and Canola oils.

Iskander, M.H.[1], Hammam, A.M.[1], Sorour, M.A.[2] and, Mehanni, A.E.[2].
[1]Food Sci. Dep. Fac. of Agric. Minia Univ., Minia, Egypt, [2]Food and Dairy Sci. Dep. Fac. of Agric. Sohag Univ. Sohag, Egypt

Summary

This work was carried out to investigate the stability of cottonseed and canola oils as well as the effect of some commercial antioxidants. The obtained results indicated that the viscosity increased gradually in all oil samples during storage. The lowest increase in the viscosity was found in oil samples stored for three months and treated with 0.02 % of either B.H.A. or B.H.T. The refractive index was decreased gradually as storage period increased. The acid value increased gradually in all oil samples during storage. The lowest increase in acid value was found in oil samples stored for three months and treated with 0.02 % B.H.A. The oil samples treated with the concentration 0.01 % of antioxidants showed a little higher increase in acid value than oil samples treated with 0.02 %. The P.V. and T.B.A. values were increased gradually in all oil samples during storage; the rate of increase was higher in the oil samples stored for three months. Also, the rate of increase in P.V. and T.B.A values were higher in oil samples (either cottonseed or canola) treated with 0.01 % concentration of antioxidants than those treated with 0.02 % concentration. The iodine value (I.V.) of all oil samples was decreased during storage. The highest decrease in iodine value was recorded in control oil samples stored for either three or six months. The rate of decrease in iodine value of the oil samples treated with 0.01 % concentration of antioxidants was higher than those oil samples treated with 0.02 % either stored for three or six months. The saponification value (S.V.) increased gradually in all oil samples as storage period increased. The highest increase in S.V. was recorded in control oil samples stored for six months. The values of fatty acids; C_{10}, C_{12}, C_{14}, C_{16}, C_{18}, C_{20}, TSFA and ratio of $C_{18:2}$: $C_{18:1}$ were increased with increasing the storage period in all oil samples. In contrast, the values of $C_{16:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, TMFA, $C_{18:\ 2n-6}$, $C_{18:3n-3}$, TPUFA, TUFA and ratio of TUFA: TSFA were decreased. Finally, the storage of cottonseed and canola oils for long period at room temperature causes undesirable changes in their physical and chemical properties. Furthermore, it reduced the nutritive value of the stored oils through the reduction of their unsaturated fatty acid contents.

Keywords: Antioxidants, Cotton, Canola oils.

Introduction

Most edible oils and fats are consumed after subjecting to heating at high temperature; during which abroad series of physical, chemical and nutritional changes take place. These changes have been of considerable concern by many workers (Edward, 1967; Kaunitz, 1967 and Artman, 1969). When fats and oils are used for heating operations, thermal and oxidative deterioration of the lipid components take place producing volatile and non volatile decomposition products. Also, some of oxidation products have been reported to be harmful to human health (Ohfuji and Kaneda, 1973; Khattab, *et al*. 1974; Alexander, 1978 and June, 1981).

The extent and nature of the products which produce during heating of fats and oils are considerably affected by the composition of the fat and heating conditions; temperature, exposure to oxygen, heating period, mode of heat transfer, and metals in contact with the oil as well as initial quality of oil (Jose and Edward, 1987 and Dobarganes and Perez-Camino, 1988). The factors which can effect rancidity and flavour stability of fats and oils are: temperature, moisture, amount of air in contact with fat or oil, exposure to

light particularly that in the ultraviolet or near ultraviolet, presence or absence of antioxidants and prooxidants, metallic ions, synergists, substances which can decompose under reaction to yield free radical and the characteristics of packing materials (Meyer, 1960). In addition, many antioxidant additives are available to increase the oxidative stability of foods. Utilization of antioxidant additives and protection of endogenous antioxidants can be used as effective methods to increase the quality and shelf life of foods (Francis, 2000 and Kochhar, 2000).

These are correctly called oxidation inhibitors, but nowadays are mostly called antioxidants. These inhibitors represent a class of substances that vary widely in chemical structure, and have diverse mechanisms of action. The most important mechanism is their reaction with lipid free radicals, forming inactive products (Gordon, 2001). Cottonseed and canola oil are most edible oils and used as deep frying.

The autoxidation of unsaturated fatty acids occurs by way of free radical mechanism. However, in the first step a hydrogen atom adjacent to the double bond in fatty acid is abstracted by exposure to heat, light, or metal catalyst to form a free radical. The free radical reacts with atmospheric oxygen to form unstable products like peroxides and hydroperoxids.

The objective of the present work was to investigate the keeping quality and stability of the cottonseed and canola oils by addition of some commercially available antioxidants.

Materials and Methods

Materials:

Oil samples

The two samples of vegetable oils used in this study were cottonseed and canola oils. The first oil was obtained from Alexandria Oil & Soap Company, Alexandria – Egypt. Canola oil was purchased from the Food Science and Technology Center, Ministry of Agriculture, Giza – Egypt. All oil samples are of refined grade and engaged in the production of various fried products.

Antioxidants treatment: Three types of antioxidants were used in this work, namely, Butyl-hydroxy toluene (BHT), Butyl-hydroxy anisol (BHA), and Propyl gallate (PG). They were chosen because of their effectiveness as antioxidants, relatively of low price and to their industrial utilization in fatty foods. The antioxidants BHT, BHA and PG were added at the levels of 0.01 % and 0.02 % on weigh bases to the oil.

Analytical Methods:

Viscosity

The viscosity of oils was detected according to the Brookfiled method (Brookfield Viscometer, Brookfield Engineering Labs Inc. MA, USA) cited in AOCS Official method Ja 10-87(1998) and AOAC (2000).

Colour

The colour of oil samples was measured by the colour Wesson methods using Lovibond glasses and calibrated (Lovibond and Tintometer model F. Tintometer LTD., Wiles, England). According to Cocks and VanRede (1966) and AOCS Official methods Cc 13- 92 (1998)**.** A one inch color cell was used.

Refractive index (RI)

The refractive index was tested according to the method as cited in the AOCS Official method Cc-25 (1998). An automatic refractometer was used and the results were standardized at 25 C^o for vegetable oils.

Acid value (A.V.)

The acidity of the investigated samples was examined according to the method described in the AOCS Official method Cd-3d-63 (1998) and was calculated in terms of free fatty acids percentage as oleic acid.

Iodine value (I.V.)

The iodine value defined as a number of grams of iodine required to saturate 100 grams of the oil sample. It was determined by the Hanus methods as described as in the AOCS Official method Cd 1-25 (1998).

Saponification value (S.V.)

The saponification value was investigated as outlined in the AOCS Official method Cd3-25 (1998). It was calculated as milligrams of KOH required to saponify one gram of oil sample.

Peroxide Value (P.V.)

This characteristic was tested according to the AOCS Official method Cd8-53 (1998) and AOAC (2000). The peroxide value was reported as milliequvalents of peroxide per kilogram sample.

Thiobarbituric acid (T.B.A.)
The TBA value was determined as outlined in the AOCS Official method Cd 19-90 (1998). The TBA value calculated as mg malonaldehyde / kg sample (Girgis, (1999).

The unsaponifiable matter
The unsaponifiable matter was separated from the vegetable oil samples after saponification according to the method cited in the AOCS (1998).

Fatty acids composition
Fatty acids of standard and samples were converted to methyl ester using etheral solution of diazo-methane. According to Vogel (1975) fatty acid were dissolved in 0.5 ml of anhydrous diethyl ether and methylated by drop wise addition of diazomethane solution until the yellow colour. The mixture was then left at room temperature for 15 min and the solvent was evaporated in a water bath maintained at 60 C^{o}. The methyl ester of fatty acids, were dissolved in pure chloroform and an aliquots of this solution were subjected to GLC analysis.

Results and Discussion

Effect of storage period and antioxidants treatment on physical properties:

The results presented in tables (1) and (2) showed the changes that took place in the physical properties of cottonseed and canola oils treated by different types and concentrations of antioxidants and stored for six months at room temperature. The viscosity increased gradually in all oil samples during storage. However, the rate of increase was dependent on the oil brand, storage period, and type of antioxidants as well as antioxidants concentration. The highest increase in the viscosity was recorded in the control sample after six months of storage in either cottonseed oil (51.70 mPa.sec.) or canola oil (75.80 mPa.sec). On the contrary, the lowest increase in the viscosity was found in oil samples stored for three months and treated with 0.02 % of either B.H.A. or B.H.T. Generally, viscosity tends to increase with increasing degree of saturation and increasing chain length. As for as the unsaponifiable matter of the stored oil samples, the results obtained in tables (1) and (2) showed a slightly decrease in the unsaponifiable matter content during storage. This probably indicates that no major changes occurred during storage in oil composition that might affect the unsaponifiable matter content. Data in tables (1) and (2) indicated that the refractive index of oil samples was decreased gradually as storage period increased. The rate of decrease was dependent on the storage period, type of antioxidant used as well as antioxidants concentration. The decrease in the refractive index of the studied oil samples during storage could be explained on the basis of the double bonds saturation of the fatty acids during the production of hydroperoxides and intermediate compounds. On the basis of the color intensity change of the studied oil samples during storage at room temperature for six months, the results presented in tables (1) and (2) revealed that the colour intensity was increased during storage. The extent of increase was affected by the storage period; oil brand, type and concentration of antioxidants. The increase in colour intensity of the oil samples during storage could be attributed to the formation of fatty acid polymers which accumulate a result of triglycerides hydrolysis during storage On the other hand, White (1991) and Saguy, *et al*. (1996) reported that the increase in colour index is probably due to oxidation typically resulting in the generation of hydroperoxides, conjugated dienoic acids, epoxides, hydroxides and keteones. Oils and fats can also produce dimeric acids, and form polymers of higher molecular weight, causing a darker colour and a deposit of yellow or brown pigments (Blumenthal, 1991).

Effect of storage period and antioxidants treatment on chemical characteristics:

Acid value: Concerning the acidity of the stored cottonseed and canola oil samples, the obtained results in tables (3) and (4) showed that the acid value increased gradually in all oil samples during storage. However, the rate of increase was dependent on the storage time, oil brand, type and concentration of antioxidant used. Generally, it can be observed from the results in tables (3) and (4) that the control oil samples stored for six months had the highest increase in acid value either in

cottonseed oil (0.46) or in canola oil (0.98) followed by control oil samples stored for three months. The lowest increase in acid value was found in oil samples stored for three months and treated with 0.02 % B.H.A. (0.27 and 0.55 in cottonseed and canola oil samples, respectively). Results in table (3) and (4) also, revealed that the oil samples treated with the concentration 0.01 % of antioxidants showed a little higher increase in acid value than oil samples treated with 0.02 %. The slight gradual increase in the acidity could be attributed to the hydrolysis of some phosphatides and triglycerides into glycerol and free fatty acids. These results are in coincide with those reported by Swern, (1979); June, (1981); Moharam and Osman, (1982); Iskander, *et al.* (1985); Augustin, *et al.* (1988) and Rossell, (2001). In addition, Aziz (1982) reported that oils were considered to be unsuitable for edible purposes when their acid number increased to values greater than 2.0. Although the acid value is an index of hydrolytic rancidity, it was measured as acids contribute to the development of off-flavours and off-odours in the product (Noor and Augustin, 1984)**.**

Peroxide value (P.V.) and thiobarbituric acid (T.B.A.)

The data presented in tables (3) and (4) showed the changes that took place in peroxide value (P.V.) and thiobarbituric acid value (T.B.A.) of cottonseed and canola oils due to storage for six months at room temperature. Generally, it was noticed that the P.V. and T.B.A. values were increased gradually in all oil samples during storage; the rate of increased was higher in the oil samples stored for three months. Also, the rate of increased in P.V. and T.B.A values were higher in oil samples (either cottonseed or canola) treated with 0.01 % concentration of antioxidants than those treated with 0.02 % concentration. In addition, the control oil samples stored for six months had the highest increased in P.V. and T.B.A values. The gradual increased in the P.V. could be attributed to the accelerating effect of storage temperature in the presence of oxygen on oxidation and peroxide formation. The presented findings are in the same line with those reported by June (1981); Lorusso, *et al.* (1983); Iskander, (1986) and Yaghmur, *et al.* (2001). In addition, the increase in TBA value due to increasing in absorption at 532 nm could reflect increases in shorter chain dienals and malonaldehydes, which are not as pleasant in flavour (Jacobson, 1967). On the other hand, the spoilage of either cottonseed oil or canola oil was considered to have occurred when the peroxide value surpassed 10 meq /Kg. according to Codex (2004).

Saponification value (S.V.): The changes in the saponification value of cottonseed and canola oils during storage at room temperature for six months are shown in tables (3) and (4). Generally, it can be observed from the results that the S.V. increased gradually in all oil samples as storage period increased. The rate of increase in S.V. was affected by storage time, type of oil, type and concentration of antioxidants. The highest increase in S.V. was recorded in control oil samples stored for six months. These results are in general agreement with those reported by Williams (1966); Moharram and Osman (1982) and Ibrahim (2000) who mentioned that the saponification value of oil increased during storage. High saponification values indicate a lower molecular weight, usually due to presence of lower fatty acids (Swern, 1979 and Hui, 1996).

Iodine value (I.V.): The data of this investigation in tables (3) and (4) revealed that the iodine value (I.V.) of all oil samples was decreased during storage. However, the rate of decrease was dependent on the oil brand, storage period, antioxidant type and concentration. The highest decrease in iodine value was recorded in control oil samples stored for either three or six months. This may be due to the absent of antioxidants. Also, it can be observed from the results in tables (3) and (4) that the rate of decrease in iodine value of the oil samples treated with 0.01 % concentration of antioxidants was higher than those oil samples treated with 0.02 % either stored for three or six months. The decrease in iodine value of oil samples during storage could be explained on the basis of the double bonds saturation of the fatty acids during the production of hydroperoxides and intermediate compounds. These results are in accordance with those reported by Swern, (1979); Gunstone and Norris (1983);

Frankel, *et al*. (1984); Iskander, *et al*. (1986); Przybyski, (1994) and Rossell, (2001).

Fatty acid composition

The data presented in tables (5) and (6) showed the change that took place in fatty acid composition of cottonseed and canola oils due to storage for six months at room temperature. In general, it can be observed from the results of the gas liquid chromatography in tables (5) and (6) that the values of C_{10}, C_{12}, C_{14}, C_{16}, C_{18}, C_{20}, TSFA and ratio of $C_{18:2}$: $C_{18:1}$ were increased with increasing the storage period in all concentrations of antioxidants. In contrast, the values of $C_{16:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, TMUFA, $C_{18:\ 2n-6}$, $C_{18:3n-3}$, TPUFA, TUFA and ratio of TUFA: TSFA were decreased. The rate of change (either increase or decrease) was dependent on the oil brand, antioxidant type and concentration. The decrease in unsaturated fatty acids either polyunsaturated fatty acids ($C_{18:\ 2n-6}$ and $C_{18:3n-3}$) or monounsaturated fatty acids could be attributed to the oxidation and hence the change in the degree of unsaturation. These results are in accordance with those reported by Swern, (1979); Iskander, *et al*. (1986); Leszkiewicz and Kasperek, (1988); Hui, (1996) and Ibrahim, (2000).

From the above results, it can be concluded that the storage of cottonseed and canola oils for long period at room conditions undoubtedly resulted in undesirable changes in their physical and chemical properties. Furthermore, it reduced the nutritive value of the stored oils through the reduction of their unsaturated fatty acid contents. Similar results were obtained by **Iskander, *et al.* (1986)** and **Ibrahim, (2000).** Furthermore, Frankel, *et al*. (1984) reported that the main problem of fats and oils is the oxidative deterioration. However, it causes more problems of use and storage of fats and oils. Oxidation of unsaturated fatty acids of fats and oils produce offensive odours and off-flavour. However, its limit their use and decreases the nutritional quality through the formation more of secondary reaction products.

Finally, the storage of cottonseed and canola oils for long period at room conditions causes undesirable changes in their physical and chemical properties. Furthermore, it reduced the nutritive value of the stored oils through the reduction of their unsaturated fatty acid contents.

References

Alexander, J.C. (1978). Biological effects due to changes in fats during heating. J. Am. Oil Chem. Soc. 55:711 – 717.

AOAC (2000). Official Methods of Analysis. Association of Official Analytical Chemists (17th ed.) Washington, D.C.

AOCS (1998). Official and Tentative Methods of the American Oil Chemists Society (5th ed.). American Oil Chemists Society, 35 East Waker Drive, Chicago, Illinois, USA.

Artman, N.R. (1969). The chemical and biological properties of heated and oxidized fats. Advances in lipid Research 7: 245 – 330.

Augustin, M.A., Lee, K.H. and You, K.T. (1988). Comparison of the frying performance of market samples of palm olein, corn oil and soya oil Malaysia. Pertanika 10 (3):295 – 304 (c.f. FSTA 20 (8) 109, 1988).

Aziz, Y. (1982). Studies on deep frying oils. M.Sc. Thesis, Faculty of Agric. Cairo Univ. Cairo- Egypt.

Blumenthal, M.M. (1991). A new look at the chemistry and physics of deep-fat frying. Food Technol. 45 (2): 68.

Cocks, L.V. and Van Rede, C. (1966). Laboratory Handbook for Oil and Fat Analysis. Academic Press, London and New York.

Codex (2004). Food chemicals codex/ committee on Food Chemical Codex, Food and Nutrition Board (5th ed). The national Academics Press, Washington, D.C.

Dobarganes, M.C. and Perez-Camino, M.C. (1988).Systematic evaluation of heated fats based on quantitative analytical methods. J. Am. Oil Chem. Soc. 65 (1): 101 – 105.

Edward, G.P. (1967). Formation of non-volatile decomposition products in heated fats and oils. Food Technol. 21 (4): 125 – 130.

Frankel, E.N.; Smith, L.M.; Hamblin, C.L.; Creveling, R.K. and Clifford, A.J. (1984). Occurrence of cyclic fatty acid monomers in frying oils used for fast foods. J. Am. Oil Chem. Soc. 61: 87 – 90.

Girgis, N.A.A. (1999). Physical and technological studies on Margarine and Shortening. M.Sc.Thesis, Faculty of Agriculture, Minia Univ. Minia, Egypt.

Gordon, M. (2001).The development of oxidative rancidity in foods.In: Antioxidants in food; practical applications. Pokorny, J.; Yanishlieva, N. and Gordon, M. (editors). ch.4. Woodhead Publishing Limited, Abington Hall, Abington Cambridge CB1 6AH, England.

Gunstone, F.D.; Norris, F.A. (1983). Lipid in foods, chemistry, biochemistry and technology. Pergamon Press.

Hui, Y.H. (1996). Bailey's industrial oil and fat products. 5theds. Vol. 2. Edible oil and fat products, Oils and oilseeds. Awiley-interscience puplication. John Wiley & Sons Inc. New York.

Ibrahim, F.F.A. (2000). Chemical and technological studies on canola oil. M.Sc. Thesis, Faculty of Agric. Assuit Univ. Assuit, Egypt.

Iskander, M.H.; El-Morsi, A.E. and Hatour, F.S. (1985). Some physical and chemical changes in cottonseed oil properties during frying of some vegetables.Minia J. Agric. Res. & Dev. 7 (4): 1575 – 1589.

Iskander, M.H; Dawood, A.A. and Hatour, F.S. (1986). Effect of storage conditions on the stability and fatty acid composition of sunflower oil. Minia J. Agric. Res. & Dev. 8 (3): 879 – 892.

Jacobson, G.A. (1967). Quality control of commercial deep fat frying. Food Technology 21 (2): 43 – 48.

Jose, A.R. and Edward, G.P. (1987). Cyclic fatty acid monmer formation in frying fats- I- determination and structural study. J. Am. Oil Chem. Soc. 64 (3): 414 – 421.

June, C.G. (1981). Basic foods (2ed). Holt, Rinehart and Winston.

Kaunitz, H. (1967). Nutritional aspects of thermally oxidized fats and oils. Food Technology 21: 147 – 152.

Khattab, A.H.; El-Tinay, H.A.; Khalifa, A.H. and Mirghani, S. (1974).Stability of peroxidized oils and fats to high temperature heating. J. of the Sci. and Food Agric. 25: 689 – 696.

Kochhar, S.P. (2000). Stabilization of frying oils with natural antioxidative components. Eur. J. Lipid Sci. Technol. 102: 552 – 559.

Leszkiewicz, B. and Kasperek, M. (1988). The effect of heat treatment on fatty acids of rapeseed oils. J. Am. Oil Chem. Soc. 65(9): 1511 – 1515.

Lorusso, S.; Zelinotti, T. and Betto, P. (1983). Chemical and physiochemical characteristics of heated oils, groundnut oil. Riv. Ital. Sostanze Grasse 59 (3):141 – 148.

Meyer, L.H. (1960). Food chemistry. Reinhold Book Corporation, New York.

Moharram, Y.G. and Osman, H.O.A. (1982). Some changes in cottonseed oil during frying Falafel and eggplant. Food chemistry 9: 159 – 165.

Noor, N. and Augustin, M.A. (1984). Effectiveness of antioxidants on the stability of banana chips. J. of the Sci. of Food and Agriculture 35 (7): 805 – 812.

Ohfuji, T. and Kaneda, T. (1973). Characterization of toxic components in thermally oxidized oil. Lipids 8: 353 – 359.

Przybylski, R. (1994). Canola oil: physical and chemical properties. Canola council of Canada, 400 – 167. Lombard Avenue, Winnipeg, Manitoba, Canada.

Rossell, J. B. (2001). Factors affecting the quality of frying oils and fats. In: Frying ; Improving quality. Rossell, J. B. (editor). Ch.7, pp. 115 – 140. Woodhead Publishing Limited and CRC Press LLC, Abington Hall, Abington Cambridge CB1 6AH, England.

Saguy, I.S.; Shani, A.; Weinberg, P. and Grati, I. (1996). Utilization of jojoba oil for deep fat frying of

foods. Lebensm.-wiss. U-Technol. 29: 573 – 577.

Swern, D. (1979). Bailey's industrial oils and fats (vol. 1, fourth edition) John Wiley and Sons, Inc. London.

Vogel, A.J. (1975). A textbook of practical original chemistry (3rd ed.) pp. 969 – 971. English Language Book Society and London Group LTD, London.

White, P.J. (1991). Methods for measuring changes in deep fat frying oils. Food Technol. 45 (2): 75 – 80.

Williams, K.A. (1966). Oils, fats and fatty foods (4th Ed). J. and A Churchill LTD., London.

Yaghmur, A.; Aserin, A.; Mizrahi, Y.; Nerd, A. and Grati, N. (2001). Evualtion of Argan oil for deep- fat frying. Lebensm.-wiss. U-Technol. 34: 124 – 130.

Table (1): Effect of storage period and antioxidants treatment on the physical properties of cottonseed oil*.

Antioxidants		Storage Period (months)	Viscosity (mPa.Sec.) at 25°C	Unsaponif-iable matter (%)	Refractive Index at 25°C	Colour***	
Type**	Concentration (%)					R	B
Control	0.00	0	44.80	1.07	1.4685	6.8	0.0
		3	48.20	1.07	1.4683	7.3	1.0
		6	51.70	1.06	1.4676	8.7	2.7
B.H.A.	0.01	3	45.70	1.06	1.4684	7.7	1.6
		6	47.00	1.05	1.4683	8.9	0.8
	0.02	3	45.00	1.05	1.4685	7.1	1.8
		6	46.20	1.05	1.4683	9.4	0.0
B.H.T.	0.01	3	45.60	1.06	1.4680	7.6	3.2
		6	46.70	1.05	1.4679	9.3	3.6
	0.02	3	45.00	1.06	1.4684	8.1	2.0
		6	46.30	1.06	1.4680	8.9	1.4
P.G.	0.01	3	46.00	1.06	1.4680	7.9	0.2
		6	47.10	1.05	1.4679	9.1	0.9
	0.02	3	45.30	1.06	1.4681	8.7	0.0
		6	47.00	1.06	1.4684	9.3	0.0

Table (2): Effect of storage period and antioxidants treatment on the physical properties of canola oil*.

Antioxidants		Storage Period (months)	Viscosity (mPa.Sec.) at 25°C	Unsaponif-iable matter (%)	Refractive Index at 25°C	Colour***	
Type**	Concentration (%)					R	B
Control	0.00	0	57.00	1.42	1.4691	6.6	0.0
		3	63.90	1.41	1.4680	8.3	2.1
		6	75.80	1.40	1.4682	8.8	4.7
B.H.A.	0.01	3	61.10	1.41	1.4681	8.1	1.3
		6	67.30	1.40	1.4671	8.6	2.7
	0.02	3	59.80	1.42	1.4679	8.4	1.1
		6	65.40	1.41	1.4677	9.2	0.0
B.H.T.	0.01	3	60.70	1.41	1.4677	8.7	3.0
		6	64.10	1.40	1.4674	8.9	4.4
	0.02	3	59.00	1.42	1.4677	8.7	2.5
		6	63.00	1.41	1.4673	9.1	4.1
P.G.	0.01	3	62.20	1.41	1.4673	7.9	1.7
		6	69.10	1.40	1.4671	8.4	2.1
	0.02	3	62.90	1.41	1.4677	7.4	2.3
		6	70.10	1.40	1.4676	8.8	4.7

Where: * Each figure given in this table is mean of three determinations.
** B.H.A Butlated hydroxyl anisole, B.H.T. Butlated hydroxyl toluene, P.G. Propyl gallate.
*** Colour was determined by lovibond Tintometer, using a one inch cell colour and yellow = 35, R = Red and B = Blue.

Table (3): Effect of storage period and antioxidants treatment on chemical characteristics of cottonseed oil.

Antioxidants		Storage period (months)	Chemical characteristics*				
Type **	Concentration (%)		A.V.	P.V.	I.V.	T.B.A.	S.V.
Control	0.00	0	0.18	9.40	103.00	0.78	198.45
		3	0.38	10.80	96.20	1.21	208.55
		6	0.46	18.80	83.70	1.47	213.45
B.H.A.	0.01	3	0.31	9.40	101.20	0.87	200.15
		6	0.37	12.60	100.30	1.03	201.65
	0.02	3	0.27	9.18	102.00	0.87	199.45
		6	0.33	10.78	101.15	0.98	201.25
B.H.T.	0.01	3	0.31	9.62	100.90	0.85	199.45
		6	0.36	12.10	98.55	0.97	202.45
	0.02	3	0.28	9.46	101.20	0.93	199.45
		6	0.34	11.26	99.35	0.98	201.45
P.G.	0.01	3	0.34	9.45	99.00	1.01	201.45
		6	0.38	12.69	98.30	1.07	203.65
	0.02	3	0.33	9.23	99.80	0.98	200.65
		6	0.36	11.97	98.75	1.13	202.55

Where: * A.V = Acid value (mg. KOH / g. oil), P.V. = Peroxide value (meq. peroxide / Kg. oil), I.V. = Iodine value (g. iodine saturate 100 g. oil), T.B.A. = Thiobarbituric acid (mg. malonaldehyde / Kg. oil), S.V. = Saponification value (mg. KOH saponify gram oil), ** B.H.A Butlated hydroxyl anisole, B.H.T. Butlated hydroxyl toluene, P.G. Propyl gallate.

Table (4): Effect of storage period and antioxidants treatment on chemical characteristics of canola oil.

Antioxidants		Storage period (months)	Chemical characteristics*				
Type **	Concentration (%)		A.V.	P.V.	I.V.	T.B.A.	S.V.
Control	0.00	0	0.53	1.82	111.15	1.42	191.80
		3	0.73	2.55	104.20	1.62	198.70
		6	0.98	2.97	101.20	2.16	202.00
B.H.A.	0.01	3	0.57	1.99	109.35	1.44	194.50
		6	0.64	2.70	108.20	1.46	194.80
	0.02	3	0.55	1.97	109.70	1.46	193.30
		6	0.59	2.10	109.00	1.65	195.80
B.H.T.	0.01	3	0.59	1.99	109.45	1.56	193.30
		6	0.66	2.65	108.50	1.92	194.80
	0.02	3	0.58	1.88	109.85	1.52	193.80
		6	0.61	2.30	108.75	1.82	195.80
P.G.	0.01	3	0.60	2.10	109.35	1.60	194.80
		6	0.66	2.90	108.85	2.02	197.30
	0.02	3	0.59	2.00	109.65	1.57	194.00
		6	0.58	2.70	109.00	1.98	195.80

Where: * A.V = Acid value (mg. KOH / g. oil), P.V. = Peroxide value (meq. peroxide / Kg. oil), I.V. = Iodine value (g. iodine saturate 100 g. oil), T.B.A. = Thiobarbituric acid (mg. malonaldehyde / Kg. oil), S.V. = Saponification value (mg. KOH saponify gram oil).
** B.H.A Butlated hydroxyl anisole, B.H.T. Butlated hydroxyl toluene, P.G. Propyl gallate.

Table (5): Effect of storage at room temperature for six months and antioxidants treatment on fatty acid composition of cottonseed oil.

Fatty acids* (wt. % of total fatty acids)	Control	Antioxidants type and concentration					
		B.H.A.		B.H.T.		P.G.	
		0.01%	0.02%	0.01%	0.02%	0.01%	0.02%
Saturated fatty acids (SFA)							
Capric $C_{10:0}$	0.13	0.20	0.18	0.38	0.22	0.39	0.38
Lauric $C_{12:0}$	0.35	0.43	0.40	0.65	0.50	0.68	0.60
Myristic $C_{14:0}$	0.70	0.95	0.90	1.30	1.05	1.40	1.25
Palmitic $C_{16:0}$	23.20	24.24	24.10	25.05	24.71	25.17	24.73
Stearic $C_{18:0}$	2.15	3.20	2.51	3.47	3.29	3.50	3.40
Arachidic $C_{20:0}$	-	-	-	-	-	-	-
Total SFA	26.53	29.02	28.09	30.85	29.77	31.14	30.36
Unsaturated fatty acid (UFA)							
MUFA**							
Palmitoleic $C_{16:1}$	1.46	1.40	1.25	1.10	1.00	1.00	1.00
Oleic $C_{18:1}$	25.06	23.33	24.51	22.20	23.63	22.11	23.14
Gadoleic $C_{20:1}$	-	-	-	-	-	-	-
Erucic $C_{22:1}$	-	-	-	-	-	-	-
Total MUFA	26.52	24.73	25.76	23.30	24.63	23.11	24.14
PUFA**							
Linoleic $C_{18:2n-6}$	46.85	46.15	46.05	45.85	45.60	45.75	45.50
Linolenic $C_{18:3n-3}$	00.10	00.10	00.10	00.00	00.00	00.00	00.00
Total PUFA	46.95	46.25	46.15	45.85	45.60	45.75	45.50
TUFA**	73.47	70.98	71.91	69.15	70.23	68.86	69.64
TUFA: TSFA	2.77	2.45	2.56	2.24	2.36	2.21	2.29
$C_{18:2:}$ $C_{18:1}$	1.87	1.98	1.88	2.07	1.93	2.07	1.97

Where: * wt. % of total fatty acids. ** SFA= Saturated fatty acids, UFA = Unsaturated fatty acids, MUFA= Monounsaturated fatty acids, PUFA= Polyunsaturated fatty acids.

Table (6): Effect of storage at room temperature for six months and antioxidants treatment on fatty acid composition of canola oil.

Fatty acids* (wt. % of total fatty acids)	Control	Antioxidants type and concentration					
		B.H.A.		B.H.T.		P.G.	
		0.01%	0.02%	0.01%	0.02%	0.01%	0.02%
Saturated fatty acids (SFA)							
Capric $C_{10:0}$	0.10	0.15	0.10	0.20	0.17	0.16	0.14
Lauric $C_{12:0}$	0.04	0.10	0.05	0.15	0.10	0.10	0.10
Myristic $C_{14:0}$	0.20	0.54	0.43	0.51	0.45	0.45	0.39
Palmitic $C_{16:0}$	5.82	6.84	6.10	6.40	6.30	6.29	6.15
Stearic $C_{18:0}$	2.05	3.18	3.15	3.25	3.20	3.20	3.15
Arachidic $C_{20:0}$	0.72	0.90	0.85	0.95	0.90	0.90	0.85
Total SFA**	8.93	11.71	10.68	11.46	11.12	11.10	10.78
Unsaturated fatty acid (UFA)							
MUFA**							
Palmitoleic $C_{16:1}$	-	-	-	-	-	-	-
Oleic $C_{18:1}$	56.54	54.29	55.57	54.74	55.08	55.05	55.47
Gadoleic $C_{20:1}$	1.72	1.60	1.55	1.50	1.50	1.50	1.50
Erucic $C_{22:1}$	0.20	0.20	0.15	0.15	0.15	0.15	0.15
Total MUFA	58.46	56.09	57.27	56.39	56.73	56.70	57.12
PUFA**							
Linoleic $C_{18:2n-6}$	25.81	25.75	25.65	25.70	25.75	25.75	25.70
Linolenic $C_{18:3n-3}$	6.80	6.45	6.40	6.45	6.40	6.45	6.40
Total PUFA	32.61	32.20	32.05	32.15	32.15	32.20	32.10
TUFA	91.07	88.29	89.32	88.54	88.88	88.90	89.22
TUFA: TSFA	10.20	7.54	8.36	7.73	7.99	8.00	8.28
$C_{18:2:}$ $C_{18:1}$	0.46	0.47	0.46	0.47	0.47	0.47	0.46

Where: * wt. % of total fatty acids.

**SFA= Saturated fatty acids, UFA = Unsaturated fatty acids, MUFA= Monounsaturated fatty acids, PUFA= Polyunsaturated fatty acids.