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Effects of Sunlight Exposure on the Quality and Oxidative Stability of Sunflower and Soybean Oils

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The primary objective of the present study was to evaluate the effects of sunlight exposure on the quality and oxidative stability of sunflower and soybean oils. Samples of refined bleached and deodorized soybean oil and sunflower oil, packed in translucent polyethylene terephthalate bottles were exposed to sunlight (exposure period, *ca.* 10 h daily) over a period of 7 weeks. Control (oils stored at ambient in darkness) samples were also processed, concurrently. The levels of auto and photo-oxidative alterations in the oils investigated were assessed by determinations of colour, refractive index, peroxide, *p*-anisidine, conjugated dienes, conjugated trienes, free fatty acid contents and iodine numbers at appropriate intervals. Overall, the magnitude of oxidative changes was more distinct in the case of soybean oil; nevertheless, both the sunlight-exposed oils revealed significantly ($p < 0.05$) higher deterioration as compared with their respective controls.

Key Words: Sunflower oil, Soybean oil, Oxidative deterioration, Sunlight storage.

INTRODUCTION

Lipid oxidation is a dilemma, often faced during processing, storage and utilization of oils and fats and related products. It can seriously interfere with the efficiency of processing steps and therefore may lead to potential economic losses. It also contributes in imparting rancid and unpleasant flavours to the fat products, thus decreasing their organoleptic value and making these unfit for the consumers[1,2]. Moreover, lipid oxidation products such as free radicals, reactive oxygen species and aldehydic compounds are negatively associated with carcinogensis and other cardiovascular diseases[3,4].

Oxidative stability is one of the most important features for maintaining the quality of edible oils and fats. Oils and fats having high stability are less susceptible to oxidation and *vice-versa*[5]. Autoxidation of lipids is a catalytic process which proceeds through free radical chain reaction leading to formation of peroxides and other secondary oxidation products.

The mechanism of lipid oxidation is strongly affected at accelerated storage conditions. For instance, in contrast to ground state oxygen oxidation (common triplet oxygen oxidation, which proceeds quite slowly), the reaction of photoxidation (light-activated oxidation), also known as singlet oxygen oxidation proceeds about 1000-1500 times faster[6]. Photoxidation of oils and fats is of much concern because the commercially sold oils in addition to containing high proportions of unsaturated fatty acid also contain noticeable amounts of colouring pigments such as chlorophyll and its decomposition products. Such colouring compounds when present in oils and fats act as potential photosensitizers and thus lead to generation of highly reactive singlet oxygen ($^1O_2$*) in the presence of light and triplet oxygen ($^3O_2$). The singlet oxygen readily reacts with unsaturated fatty acids in oils to initially form hydroperoxides and other breakdown volatile products[7].

Storage stability and shelf-life of vegetable oils are now receiving much attention. Physical characteristics of the packaging material such as permeability and light transmittance and storage regimes are the major factors which can directly affect the quality of oil[8]. Studies have shown that the storage stability of vegetable oils/fats and lipid containing foods can be improved by suitable selection of packing materials and storage conditions[9,10].

Due to insufficient room, lack of awareness or for the sake of marketing; the containers (tins/bags and bottles) of vegetable oils and fats products are often kept outside the store rooms and shops, thus allowing them directly exposed to sunlight and elevated temperature. Such ill-controlled practices are a matter of common observation during storage, processing and transportation of commercial oils and fat products. This prompts the need to evaluate the effects of sunlight storage on the oxidative stability and shelf-life of commonly sold oils in Pakistan.

Sunflower (*Helianthus annuus*) and soybean (*Glycine soja*) oils, being main sources of poly unsaturated plus essential fatty acids are widely used in foods for cooking and frying purposes[11]. In Pakistan, both sunflower and soybean oils are commonly utilized for edible purposes accounting for major share of the commercially marketed branded cooking oils. However, such oils with high contents of unsaturated fatty acids, although nutritionally valuable, are also more susceptible to oxidation and this may affect their quality during improper storage and handling. The primary objective of the present study was to evaluate and compare the effects of sunlight exposure on the quality and oxidative stability of sunflower and soybean oils.

EXPERIMENTAL

Samples of freshly prepared refined, bleached and deodorized sunflower oil (SFO) and soybean oil (SBO) were procured from the United Industries Limited, Kashmir Road, Faisalabad, Pakistan. The samples were immediately transferred to the experimental laboratory and subjected to experimental trials. All the chemicals and reagents (analytical grade) used were from Merck (Darmstadt, Germany) or Sigma-Aldrich Chemical Co. (St. Louis, MO).

Storage of samples: Samples of sunflower oil and soybean oil were packed in translucent polyethylene terephthalate (PET) bottles (capacity, 150 mL). The bottles were sealed and subjected to sunlight storage (day light exposure, *ca.* 10 h per day) for a period of 7 weeks through mid July to end of August. The mean values for maximum and minimum temperature (ºC) for the period under investigation were: 36.9 ± 3.5, 29.0 ± 2.5 (average 31.9) and 40.0 ± 3.0, 29.0 ± 2.5 (average 35.0), respectively. Control sunflower oil and soybean oil samples were preserved at ambient (room temperature in darkness) and were not exposed to sunlight.

Analysis of the stored samples: The analytical and control oil samples were analyzed for the magnitude of oxidative changes on weekly basis (after every 7 d samples were withdrawn for analysis). Following physico-chemical parameters, indicative of oxidative deterioration of oils, were selected for assessment trial: refractive index (RI), colour, free fatty acid contents (FFA), peroxide value (PV), iodine value (IV), *p*-anisidine value, conjugated diene and triene contents[10].

Determination of RI, IV, PV, FFA and colour: RI, IV, PV and FFA contents were determined following the AOCS official methods[12]. Refractive index was measured at 40 °C, using a Refractometer (Bellingham and Stanley Ltd. London, United Kingdom). The colour of the oils was checked in 1-in. cell using a Lovibond Tintometer (Tintometer Ltd., Salisbury, Wiltshire, United Kingdom), using.

Determination of *p*-anisidine value: The *p*-anisidine value of the oils under investigation was determined following an IUPAC method[13]. Briefly, the oils diluted in iso-octane were mixed with *p*-anisidine solution in acetic acid (0.25 % w/v) and allowed to react for 10 min resulting in a coloured complex, the absorbance of which was monitored at 350 nm by using spectrophotometer (U-2001, Hitachi Instruments Inc. Tokyo, Japan).

Determination of conjugated dienes and trienes: The conjugated dienes and trienes, in terms of specific extinctions at 232 and 268 nm, respectively were determined using spectrophotometer (U-2001, Hitachi Instrument Inc. Tokyo, Japan). Briefly, an appropriate amount of oil was diluted with iso-octane to bring the absorbance within permitted range, 0.2-0.8. The intensity of absorption was noted at 232 and 268 nm and $\epsilon^{1\%}$ 1 cm (λ) was calculated following an IUPAC method[13].

Statistical analysis: Each test was carried out in triplicate. The data are reported as mean ± SD. Statistical analyses of the data were performed by analysis of variance (ANOVA) using Statistica 5.5 (Stat Soft Inc, Tulsa, Oklahoma, USA) software. Differences were considered statistically significant at probability value of $p \leq 0.05$.

RESULTS AND DISCUSSION

The values of refractive index (RI) and colour determined for the sunlight-exposed sunflower oil and soybean oil and control (the samples of sunflower oil and soybean oil stored at ambient/ room temperature in darkness) are presented in Table-1. Generally, the RI of both the tested sunlight-exposed and control oils increased but to very small extents. The change in RI of sunlight-exposed sunflower oil and

TABLE-1
RELATIVE CHANGE IN REFRACTIVE INDEX AND COLOUR OF SUNFLOWER AND SOYBEAN OILS SUBJECTED TO SUNLIGHT STORAGE

Storage periods (d)	Refractive index (40 ºC)				Colour (1 in. Cell)							
					Yellow				Red			
	SFO-C	SFO-SS	SBO-C	SBO-SS	SFO-C	SFO-SS	SBO-C	SBO-SS	SFO-C	SFO-SS	SBO-C	SBO-SS
0	1.4635 ± 0.002	1.4635 ± 0.002	1.4630 ± 0.002	1.4630 ± 0.002	20.0 ± 1.0	20.0 ± 1.0	20.0 ± 1.0	20.0 ± 1.0	2.0 ± 0.1	2.0 ± 0.1	2.0 ± 0.1	2.0 ± 0.1
7	1.4635 ± 0.002	1.4635 ± 0.001	1. 4630 ± 0.001	1.4630 ± 0.002	20.0 ± 1.0	20.1 ± 1.0	20.0 ± 1.0	20.0 ± 1.0	2.0 ± 0.2	2.0 ± 0.1	2.0 ± 0.1	2.0 ± 0.1
14	1.4635 ± 0.001	1.4635 ± 0.002	1.4630 ± 0.002	1.4630 ± 0.001	20.0 ± 1.0	20.0 ± 2.0	20.0 ± 1.0	20.0 ± 1.0	2.0 ± 0.1	2.0 ± 0.2	2.0 ± 0.1	2.0 ± 0.1
21	1.4637 ± 0.002	1.4640 ± 0.001	1.4631 ± 0.002	1.4636 ± 0.001	20.0 ± 1.5	20.1 ± 1.0	20.0 ± 1.5	20.1 ± 1.0	2.0 ± 0.1	2.0 ± 0.1	2.0 ± 0.1	2.1 ± 0.3
28	1.4640 ± 0.003	1.4641 ± 0.003	1.4640 ± 0.003	1.4644 ± 0.003	20.1 ± 1.5	20.1 ± 2.0	20.1 ± 1.5	20.1 ± 1.0	2.1 ± 0.2	2.1 ± 0.3	2.1 ± 0.2	2.2 ± 0.4
35	1.4651 ± 0.002	1.4650 ± 0.002	1.4651 ± 0.002	1.4655 ± 0.002	20.1 ± 1.5	20.1 ± 2.0	20.1± 1.5	20.2 ± 1.5	2.1 ± 0.3	2.1 ± 0.2	2.1 ± 0.2	2.2 ± 0.4
42	1.4651 ± 0.004	1.4660 ± 0.003	1.4651 ± 0.004	1.4660 ± 0.004	20.1 ± 1.5	20.2 ± 1.5	20.1 ± 1.5	20.2 ± 1.5	2.1 ± 0.2	2.2 ± 0.3	2.1 ± 0.2	2.2 ± 0. 4
49	1.4660 ± 0.003	1.4672 ± 0.002	1.4660 ± 0.003	1.4671 ± 0.003	20.2 ± 2.0	20.2 ± 1.0	20.2 ± 2.0	20.2 ± 1.5	2.2 ± 0.1	2.2 ± 0.2	2.2 ± 0.4	2.2 ± 0.4
Change from initial values	+0.0025[a]	+0.0037[a]	+0.0030[a]	+0.0041[a]	+0.2[a]	+0.2[a]	+0.2[a]	+0.2[a]	+0.2[a]	+0.2[a]	+0.2[a]	+0.2[a]
p –value	0.30	0.09	0.22	0.12	0.88	0.82	0.88	0.84	0.70	0.20	0.45	0.45

Values are mean ± SD of duplicate samples analyzed individually in triplicate;
SFO-C: Sunflower oil control; SFO-SS: Sunflower oil subjected to sunlight storage;
SBO-C: Soybean oil control; SBO-SS: Soybean oil subjected to sunlight storage;
$p < 0.05$ shows significant increase in refractive index and colours after the end of the storage period.

soybean oil, from initial (at the end of 7 weeks storage) was of the order of +0.0037 and +0.0041, revealing no significant ($p > 0.05$) differences as compared with those of respective control oils (+0.0025 and +0.0030, respectively). At the end of 49 days storage period, the levels of RI for sunlight-exposed sunflower oil and soybean oil samples, 1.4672 and 1.4671 were noted to be somewhat higher than those for the respective controls *i.e.*, 1.4660, 1.4660, an increment of 0.08 and 0.07 %, respectively. The increase in RI of the oils during storage might be attributed to oxidative deterioration and increased conjugation[14,15].

The colour values of the sunlight-exposed sunflower oil and soybean oil and control samples increased at a very slow rate with the passage of time (Table-1). At the end of storage period of 7 weeks, the overall change in colour (red + yellow) of sunlight-exposed sunflower oil and soybean oil from initial was + 0.2, + 0.2, respectively, showing no significant ($p > 0.05$) change as compared with corresponding control oils (+0.2, +0.2, respectively). These results revealing a slight increase in colour of the stored oils, however, were in disagreement to the findings of Anwar *et al.*[10] who reported a minor decrease in colour of soybean oil, subjected to sunlight storage for a period of 6 months. Generally, it is perceived that oxidation may lead to discolouration of oils[14,15].

The changes in free fatty acid (FFA) contents and iodine values (IV) of the investigated sunlight-exposed and control sunflower oil and soybean oil are shown in Table-2. The free fatty acid contents of both of the sunlight-exposed and control oils increased in a characteristic manner. At the end of storage trial of 7 weeks, the free fatty acid contents (% as oleic acid) for sunlight-exposed sunflower oil and soybean oil samples, 0.37 and 0.40 were noted to be significantly ($p < 0.05$) higher than those for the respective controls *i.e.*, 0.29, 0.28, an increment of 27.6 and 42.9 %, respectively. The overall change in free fatty acid contents of the sunlight-exposed sunflower oil, soybean oil and control sunflower oil, soybean oil as observed at the end of experimental trial of 7 weeks with reference to initial values were +0.31, +0.38, +0.29 and +0.26, respectively. The higher increase in contents of free fatty acid for the former oils might be attributed to elevated hydrolysis and oxidation as result of photoxidation of oils. Free fatty acid are principally the product of hydrolysis of triglycerides, however, their concentration often increases corresponding to oxidative deterioration of oils[15]. The statistical analysis of the data demonstrated the variations in free fatty acid contents of soybean oil to be significantly ($p < 0.05$) higher than those of SFO.

It was observed that as a result of sunlight exposure of 7 weeks, the initial levels of iodine values (IV) *i.e.*, 139.0 and 138.0 (g of I/100 g of oil) for SFO and SBO, were decreased to 123.3 and 122.0 (g of I/100 g of oil), respectively (Table-2). The extent of variation in IV of the sunlight-exposed SFO and SBO (-15.7 and -16.0, respectively from initial) was significantly ($p < 0.05$) pronounced as compared with those determined for respective control oils (-11.5 and -11.0, respectively from initial). A higher decrease in iodine value of the sunlight-exposed samples as

TABLE-2
RELATIVE CHANGE IN FREE FATTY ACID CONTENTS AND IODINE VALUE OF SUNFLOWER AND SOYBEAN OILS SUBJECTED TO SUNLIGHT STORAGE

Storage periods (d)	Free fatty acid contents (% as oleic acid)			
	SFO-C	SFO-SS	SBO-C	SBO-SS
0	0.06 ± 0.003	0.06± 0.001	0.02 ± 0.001	0.02 ± 0.001
7	0.08 ± 0.001	0.09 ± 0.004	0.05 ± 0.001	0.07 ± 0.001
14	0.09 ± 0.002	0.14 ± 0.003	0.09 ± 0.002	0.13 ± 0.001
21	0.14 ± 0.005	0.20 ± 0.007	0.14 ± 0.003	0.20 ± 0.002
28	0.20 + 0.008	0.27 ± 0.012	0.19 ± 0.006	0.26 ± 0.002
35	0.24 ± 0.009	0.31 ± 0.014	0.24 ± 0.007	0.33 ± 0.003
42	0.28 ± 0.010	0.34 ± 0.013	0.26 ± 0.014	0.40 ± 0.005
49	0.29 ± 0.008	0.37 ± 0.015	0.28 ± 0.013	0.40 ± 0.004
Change from initial values	$+0.23^{d}$	$+0.31^{b}$	$+0.26^{c}$	$+0.38^{a}$
p-value	0.00	0.00	0.00	0.00
	Iodine value (g I/100 g of oil)			
0	139.0 ± 2.5	139.0 ± 2.5	138.0 ± 2.0	138.0 ± 2.0
7	138.0 ± 6.0	134.4 ± 7.0	137.0 ± 1.5	135.0 ± 1.2
14	136.0 ± 5.5	133.0 ± 5.0	136.0 ± 2. 2	133.0 ± 1.7
21	135.0 ± 7.5	130.5 ± 5.5	135.0 ± 2. 3	130.5 ± 2.0
28	134.1 ± 6.0	126.0 ± 4.5	134.0 ± 1.8	127.0 ± 1.4
35	133.5 ± 4.0	125.5 ± 6.0	133.5 ± 2. 0	125.5 ± 2.0
42	132.6 ± 5.5	124.0 ± 3.0	131.0 ± 1.6	124. 0 ± 1.4
49	127.5 ± 2.9	123.3 ± 2.7	127.0 ± 1. 5	122.0 ± 1.6
Change from initial values	-11.5^{b}	-15.7^{b}	-11.0^{b}	-16.0^{a}
p-value	0.00	0.00	0.04	0.01

Values are mean ± SD of duplicate samples analyzed individually in triplicate;
SFO-C: Sunflower oil control; SFO-SS: Sunflower oil subjected to sunlight storage;
SBO-C: Soybean oil control; SBO-SS: Soybean oil subjected to sunlight storage;
$p < 0.05$ shows significant change in free fatty acid contents and iodine values after the end of the storage period.

compared with control might be attributed to the greater losses of unsaturated fatty acids as a result of the photooxidative degradation at accelerated sunlight storage conditions. At the end of 7 weeks storage, the levels of iodine value for sunlight-exposed SFO and SBO samples, 123.3 and 122.0 were noted to be quite lower than those for the respective controls *i.e.*, 127.5, 127.0. It is important to note that decrease in iodine value due to loss of unsaturation is strongly correlated to the deterioration of oils[16].

The data indicative of changes in peroxide value (PV) of the tested SFO and SBO in Table-3 are given. Determination of PV (which is a characteristic of hydroperoxide formed) is generally accepted as a reliable approach to measure the extent of primary oxidation products of oils[15]. As expected, both the SFO and SBO exhibited an appreciable rise in PV during storage over the course of seven weeks. At the end of 7 weeks storage, the levels of PV for sunlight-exposed SFO and SBO samples,

TABLE-3
RELATIVE CHANGE IN PEROXIDE AND *p*-ANISIDINE VALUES OF SUNFLOWER AND SOYBEAN OILS SUBJECTED TO SUNLIGHT STORAGE

Storage periods (d)	Peroxide value (meq/kg of oil)			
	SFO-C	SFO-SS	SBO-C	SBO-SS
0	0.85 ± 0.03	0.85 ± 0.03	0. 04 ± 0.00	0.04 ± 0.00
7	1.10 ± 0.05	4.55 ± 0.20	1.13 ± 0.11	11.81 ± 0.81
14	2.56 ± 0.09	7.31 ± 0.60	2.46 ± 0.12	19.02 ± 0.61
21	3.48 ± 0.14	9.80 ± 0.50	3.39 ± 0.19	22.53 ± 0.81
28	4.34 ± 0.12	11.51 ± 1.09	4.52 ± 0.18	25.01 ± 1.72
35	5.60 ± 0.33	14.71 ± 1.00	5.65 ± 0.33	30.53 ± 2.13
42	6.35 ± 0.22	15.73 ± 1.20	6.85 ± 0.32	35.54 ± 1.91
49	7.09 ± 0.42	17.36 ± 1.21	7.00 ± 0.42	40.02 ± 2.44
Increase from initial values	+6.24[c]	+16.51[b]	+6.96[c]	+39.98[a]
p -value	0.00	0.00	0.00	0.00
	p-Anisidine value			
0	1.45 ± 0.05	1.45 ± 0.05	1.10 ± 0.06	1.10 ± 0.06
7	1.51 ± 0.10	1.56 ± 0.04	2.70 ± 0. 06	4.10 ± 0.22
14	2.68 ± 0.24	3.73 ± 0.06	4.50 ± 0.11	7.83 ± 0.33
21	3.81 ± 0.22	5.84 ± 0.12	6.11 ± 0.31	11.50 ± 0.25
28	4.85 ± 0.11	8.92 ± 0.31	8.31 ± 0.34	16.42 ± 1.01
35	7.95 ± 0.31	11.97 ± 0.55	10.12 ± 0.23	20.50 ± 1.33
42	9.98 ± 0.22	15.04 ± 0.50	12.22 ± 0.45	23.22 ± 1.56
49	10.03 ± 0.52	17.16 ± 1.02	18.53 ± 1.01	25.01 ± 1.45
Increase from initial values	+8.58[c]	+15.71[b]	+17.43[b]	+23.91[a]
p -value	0.00	0.00	0.00	0.00

Values are mean ± SD of duplicate samples analyzed individually in triplicate;
SFO-C: Sunflower oil control; SFO-SS: Sunflower oil subjected to sunlight storage;
SBO-C: Soybean oil control; SBO-SS: Soybean oil subjected to sunlight storage;
$p < 0.05$ shows significant change in peroxide and *p*-anisidine values after the end of the storage period.

17.4 and 40.0 were noted to be significantly ($p < 0.05$) higher than those for the respective controls *i.e.*, 7.1, 7.0, an increment of 145.1 and 471.0 %, respectively. The rate of photoxidation reaction also know a singlet oxygen oxidation is very fast as compared with common triplet oxygen oxidation that might contribute to the greater levels of PV in the present analysis of sunlight-exposed SFO and SBO[6,7].

It was further observed that SBO had exhibited greater susceptibility to primary level photoxidative degradation as compared with its counterpart. The higher levels of PV in sunlight-exposed SBO may be attributed to the presence of appreciable amounts of linolenic acid, a polyunsaturated fatty acid, highly susceptible to oxidation.

p-Anisidine value (P-AV) is an important indicator of the extent of secondary oxidation products such as aldehydes, principally 2-alkenals and 2,4-alkadienals[17]. *p*-Anisidine value for sunlight-exposed SFO and SBO over the period of 7 weeks of storage were noted to be increased from initial levels of 1.5 and 1.1 to the points

of 17.2 and 25.0, respectively showing an increment of 15.7 and 24.0, respectively. This can be seen from the Table-3, that the increase in *p*-anisidine values of SBO samples under sunlight storage were significantly ($p < 0.05$) higher than its counter part SFO samples. Moreover, the sunlight-stored SFO and SBO samples showed significantly ($p < 0.05$) higher increase in *p*-anisidine values as compared with the respective control samples which might be attributed to the higher rate of formation of secondary oxidation products due to sunlight exposure. At the end of storage periods (7 weeks), the extent of P-AV for sunlight-exposed SFO and SBO samples, 17.2 and 25.0 were noted to be quite higher than those for the respective controls *i.e.*, 10.0, 18.5, an increment of 71.1 and 34.9 %, respectively. An elevated rate of formation of such aldehydic secondary oxidation products in soybean oil subjected to photoxidative conditions has been reported in the literature[10,18].

TABLE-4
RELATIVE CHANGE IN CONJUGATED DIENE AND CONJUGATED TRIENES CONTENTS OF SUNFLOWER AND SOYBEAN OILS SUBJECTED TO SUNLIGHT STORAGE

Storage periods (d)	Conjugated dienes content ($^{1\%}\varepsilon_{1cm\ (\lambda 232)}$]			
	SFO-C	SFO-SS	SBO-C	SBO-SS
0	0.09± 0.00	0.09± 0.00	0. 08 ± 0.02	0. 08 ± 0.02
7	3.11 ± 0.18	3.94 ± 0.21	3.00 ± 0.10	4.33 ± 0.09
14	4.50 ± 0.27	7.04 ± 0.22	4.74 ± 0.12	7.32 ± 0.21
21	6.50 ± 0.22	9.33 ± 0.41	6.23 ± 0.19	9.51 ± 0.44
28	8.41 ± 0.34	12.54 ± 0.70	8.54 ± 0.33	12.60 ± 0.39
35	9.33 ± 0.52	15.12 ± 0.54	9.72 ± 0.42	15.80 ± 1.00
42	13.04 ± 0.45	17.22 ± 1.03	13.71 ± 0.54	20.50 ± 0.91
49	15.54 ± 0.93	19.33 ± 1.20	17.10 ± 1.11	22.33 ± 1.40
Increase from initial values	$+15.45^{c}$	$+19.24^{b}$	$+17.02^{bc}$	$+22.25^{a}$
p -value	0.00	0.00	0.00	0.00
	Conjugated trienes content ($^{1\%}\varepsilon_{1cm\ (\lambda 268)}$]			
0	0.15 ± 0.00	0.15 ± 0.00	0.04 ± 0. 00	0.04 ± 0. 00
7	1.91 ± 0.01	3.30 ± 0. 90	2.01 ± 0.05	3.11 ± 0.03
14	3.50 ± 0.09	5.40 ± 0.13	3.71 ± 0.21	5.22 ± 0.14
21	4.30 ± 0.21	6.12 ± 0.12	4.90 ± 0.29	6.32 ± 0.25
28	5.01 ± 0.20	6.42 ± 0.22	6.11 ± 0.28	8.12 ± 0.40
35	6.10 ± 0.25	7.34 ± 0.19	8.20 ± 0.33	10.23 ± 0.34
42	7.51 ± 0.23	8.15 ± 0.32	10.51 ± 0.54	13.54 ± 0.68
49	7.95 ± 0.31	10.55 ± 0.53	13.02 ± 0.53	18.05 ± 1.04
Increase from initial values	$+7.80^{d}$	$+10.40^{c}$	$+12.98^{b}$	$+18.01^{a}$
p -value	0.00	0.00	0.00	0.00

Values are mean ± SD of duplicate samples analyzed individually in triplicate;
SFO-C: Sunflower oil control; SFO-SS: Sunflower oil subjected to sunlight storage
SBO-C: Soybean oil control; SBO-SS: Soybean oil subjected to sunlight storage
$p < 0.05$ shows significant change in conjugated diene and triene values after the end of the storage period.

The specific extinctions at 232 and 268 nm, which compute the contents of conjugated diene (CD) and conjugated trienes (CT), respectively for sunlight-exposed and control SFO and SBO are presented in Table-4. Measurement of CD and CT is considered as an important parameter for assessment of oxidative deterioration and purity of the oils[15]. The values of CD and CT for both the sunlight-exposed and control oils increased over the period of storage of 7 weeks. At the end of 49 d storage period, the levels of CD for sunlight-exposed SFO and SBO samples, 19.2 and 22.2 were noted to be quite higher than those for the respective controls *i.e.*, 15.5, 17.0, an increment of 23.9 and 30.6 %, respectively. Similarly, the levels of CT for sunlight-exposed SFO and SBO samples, 10.6 and 18.0 were notably higher than those for the respective controls *i.e.*, 7.8 and 13.0, an increment of 35.9 and 38.5 %, respectively. Higher levels of CD and CT in the light-exposed SFO and SBO samples as compared with those of control might be in due part to the photo-oxidation process due to exposure of oils to sunlight radiations[18,19]. Statistical analysis of the data showed that the variations in the CD and CT contents of the sunlight stored and control SFO and SBO were significant ($p < 0.05$).

It could be concluded from the results of the present study that the oxidative stability of SFO and SBO is extensively affected due to sunlight-exposure. Changes in oxidative state and enhanced degradation of the sunlight-stored oils can be generally linked to the photoxidation of oils. The results of different oxidation parameters investigated in the present study also suggest that sunlight exposure may exhibit more marked deleterious effects on the oxidative stability and quality of SBO as compared with SFO. Such cooking oils and related products are recommended to be handled and preserved under proper storage conditions for securing their quality.

REFERENCES

1. D.B. Min and H.O. Lee, in eds.: C.C. Akoh and D.B. Min, Lipid Oxidation of Edible Oil, Food Lipid: Chemistry, Nutrition and Biochemistry, Marcel Dekker, New York, pp. 283-296 (1998).
2. F. Anwar, M.I. Bhanger and S. Yasmeen, in eds.: N. Murata, M. Yamada, I. Nishida, H. Okuyama, J. Sekiya and W. Hajime, Antioxidant Activity of Some Natural Extracts in Corn Oil, Advanced Research of Plant Lipids 24-27, Kluwer Publishers, Netherland (2003).
3. J.M. Pezzuto and E.J. Park, in eds.: J. Swarbrick and J.C. Boylan, Autoxidation and Antioxidants, Encyclopedia of Pharmaceuticals Technology, Marcel Dekker Inc., New York, Vol. 1, edn. 2, pp. 97-113 (2002).
4. P. Siddhuraju and K. Becker, *J. Agric. Food Chem.*, **51**, 2144 (2003).
5. C.P. Tan, Y.B. Che-Man, J. Selamat and M.S.A. Yusoff, *Food Chem.*, **76**, 385 (2002).
6. S. Cuppett, M. Schnepf and C. Hall, in ed.: F. Shahidi, Natural Antioxidants-Are They a Reality, Natural Antioxidants, Chemistry, Health Effects and Applications, AOCS Press, Champaign IL, USA, pp. 12-24 (1997).
7. E. Maforimbo, *J. Food Tech. Africa*, **7**, 68 (2002).
8. J.H. Hotchkiss, in eds.: P. Ackermann, M. Jagerstad and Ohlsson, Overview on Chemical Interaction Between Food and Packing Materials, In Foods and Packing Materials-Chemical Interactions, The Royal Society of Chemistry Special Publication No. 162, Cambridge, U.K, pp. 3-11 (1995).

9. M. Kucuk and C. Cancer, *J. Food Lipids*, **12**, 222 (2005).
10. F. Anwar, S.A.S. Chatha and A.I. Hussain, *Grasa Y Aceites*, **58**, 390 (2007).
11. M. Willis, W. Lencki and G. Marangoni, *Crit. Rev. Food Sci. Nutr.*, **38**, 639 (1998).
12. American Oil Chemists Society (AOCS), Official and Recommended Practices of the American Oil Chemists Society, AOCS Press, Champaign IL, USA, edn. 5 (1997).
13. C. Paquot and A. Hautfenne, International Union of Pure and Applied Chemistry (IUPAC), Standard Methods for the Analysis of Oils, Fats and Derivatives, 7th revised and enlarged ed., Blackwell Scientific, London (1987).
14. E.R. Sherwin, *J. Am. Oil. Chem. Soc.*, **55**, 809 (1978).
15. L. McGinely, in eds.: J.B. Rossell, J.L.R. Printed, Analysis and Quality Control for Processing and Processed Fats, Analysis of Oilseeds, Fat and Fatty Food, Elsevier Applied Science, New York, pp. 440-470 (1991).
16. S. Naz, H. Sheikh, R. Saddiqi and S.A. Sayeed, *Food Chem.*, **88**, 253 (2004).
17. F. Shahidi and U.N. Wanasundara, in eds.: C.C. Akoh and D.B. Min, Methods for Measuring Oxidative Rancidity in Fats and Oils, In Food Lipids-Chemistry, Nutrition and Biotechnology, Marcel Dekker, Inc., New York, edn. 2, pp. 465-487 (2002).
18. M. Khan and F. Shahidi, *Food Chem.*, **79**, 47 (2002).
19. X. Pan, H. Ushio and T. Ohshimam, *J. Am. Oil Chem. Soc.*, **81**, 773 (2004).

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