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Assessment of oxidative deterioration of soybean oil at ambient and sunlight storage

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RESUMEN

Evaluación de la degradación oxidativa del aceite de soja almacenado a temperatura ambiente y a la luz solar.

Se lleva a cabo un estudio para conocer las diferencias en la oxidación del aceite de soja conservado a temperatura ambiente y a la luz solar durante un periodo de 180 días. Los cambios en la oxidación fueron evaluados mediante medidas periódicas del índice de peroxidos, color, acidez libre, índice de refracción (RI), índice de p-anisidina, dienos conjugados e índice de yodo. Al final del periodo de almacenamiento, los niveles de acidez e índice de peroxidos fueron 1,77 y 2,90% y 20.52, 41.89 meq/kg de aceite, respectivamente para los aceites a temperatura ambiente y a la luz solar. Los valores iniciales de RI (40°C), *p*-anisidina, dienos conjugados y trienos conjugados a los 180 días fueron 1.4647 y 1.4659; 36.13 y 50.40; 23.97 y 41.49; y 13.81 y19.35, respectivamente. Por el contrario, el índice de iodo (g I_2 /100 g aceite) disminuyó desde 138.0 to 126.18 y 118.04, respectivamente. Los resultados de los distintos parámetros analizados demostraron que la magnitud de la degradación oxidativa de las muestras de aceite de soja expuestas a la luz solar fue en todos los casos, significativamente superior (P < 0.05) a la que ocurre a temperatura ambiente.

PALABRAS-CLAVE: Aceite de soja – Conservación – Dienos y trienos conjugados – Indice de peróxidos – Oxidación.

SUMMARY

Assessment of oxidative deterioration of soybean oil at ambient and sunlight storage.

This study was carried out in order to probe the extent of oxidative alterations in soybean oil (SBO), subjected to ambient and sunlight storage, over a period of 180 days. The magnitude of oxidative changes was monitored by the periodical measurement of peroxide value (PV), color, free fatty acid (FFA) contents, refractive index (RI), *p*-anisidine-, conjugated dienes-, conjugated trienes-, and iodine- values. At the end of storage period (180 days), the initial contents of FFA (0.02 % as oleic acid) and PV (0.02 meq/kg of oil) of the SBO samples subjected to ambient and sunlight storage reached the level of 1.77, 2.90 % and 20.52, 41.89 meq/kg of oil, respectively. The initial values of RI (40°C) (1.4630), *p*-anisidine (1.10), conjugated dienes (0.08) and conjugated trienes (0.04) rose to the point of 1.4647, 1.4659; 36.13, 50.40; 23.97, 41.49 and 13.81, 19.35, respectively. Whereas, the iodine value (g of I /100 g of oil) decreased from 138.00 to 126.18 and 118.04, respectively. At the end of storage period, the overall order, indicative of the oxidative changes in RI, FFA, IV, color (red + yellow), PV, *P*-anisidine, conjugated dienes and conjugated trienes of the SBO subjected to ambient and sunlight storage was as follows: 1.001:1.002, 1.00:1.65, 0.91:0.86, 0.80:0.60 + 0.75:0.50, 1.00:2.04, 1.00:1.39, 1.00:1.73 and 1.00:1.40, respectively. The results of various parameters investigated in the present study demonstrated the magnitude of oxidative deterioration of the SBO samples exposed to sunlight to be significantly ($P < 0.05$) pronounced as compared with that of ambient.

KEY-WORDS: Conjugated oxidation products – Oxidation parameters – Peroxide value- Storage-Soybean oil-

1. INTRODUCTION

Lipid oxidation is considered a principal mean of deterioration in the quality of foodstuffs. It not only imparts rancid and undesirable flavors to fat products, but also it generates reactive oxygen species, which are linked to carcinogensis, inflammation, aging and cardiovascular disorders (Pezzuto and Park, 2002; Siddhuraju and Becker, 2003; Min, 1998). Lipid oxidation also influences the chemical, sensory, and nutritional properties of edible oils and fatty foods and thus plays an important role in determining their use and shelf-life (Dobarganes and Ruiz, 2003; Anwar *et al.*, 2003).

It is an established fact that different variables involved in oil shelf-life, such as processing, storage conditions, light exposure, type of packaging material, availability of oxygen, and addition of antioxidants do affect the quality and characteristics of vegetable oils/ fats and lipid containing products. However, studies on shelf-life or storage of edible oils at room temperature, which may approximate real storage conditions, are inadequate when compared to investigations on accelerated oxidative conditions. The practical studies under ambient conditions require prolonged experiments and there are also difficulties in drawing general conclusions from limited numbers and specific composition and quality of the oils tested (Polvillo *et al.,* 2004).

Auto-oxidation through the free radical chain reaction via the attack on the alpha methylene of the carbon double bonds of the unsaturated fatty acids is a slow process and requires considerable time to produce a sufficient quantity of peroxides (the main initial product of auto -oxidation) and develop unpleasant flavors in lipid containing products (Naz *et al.,* 2004; Lawson, 1995; Shahidi and Wanasundara, 1997). On the other hand, photo-oxidation which involves the direct attack of the extremely electrophilic singlet oxygen on the unsaturated fatty acids, resulting in the generation of peroxy radicals and, ultimately, hydroperoxides is a very fast reaction. The reaction rate of the photo-oxidation also known as singlet oxygen oxidation is at least 1000-1500 times faster than that of common triplet oxygen oxidation (Cuppett *et al.,* 1997). Photosensitized oxidation during food processing and preservation has been demonstrated to display highly detrimental effects on quality of foods due to an accelerated rate of reaction. The susceptibility of vegetable oils or fats and lipid containing products to auto-, and photo-oxidation generally increases due to inadequate means of processing, packing and storage (Xiangqing *et al,* 2004).

In Pakistan, there are a huge number of shopkeepers and retail whole-sellers who intentionally keep their oils and fats (packed in tin containers, polyethylene terephthalate (PET) bottles and PET bags etc.,) outside their shops, thus directly exposing them to sunlight, for the purposes of advertising or due to insufficient space in their shops. Such lack of control in the practice for storage and shipping of vegetable oils and fats prompts the commencement of photo-oxidation in a silent way. It is, therefore, important to evaluate and quantify the effects of sunlight on the extent of oxidative degradation affecting the quality of oils and fats. The present study was planned with the primary objective of investigating and evaluating the extent of oxidative deterioration and the shelf-life of soybean oil stored under ambient and sunlight conditions. Efforts were also made to compare and correlate the oxidative alterations of the oil investigated under both sets of storage conditions by establishing orderly relationships between the results of different indicative parameters.

2. EXPERIMENTAL

2.1. Materials

Samples of freshly prepared refined, bleached and deodorized (RBD) soybean oil (SBO) were obtained from the "Deodorization Unit" of United Industries Limited, Kashmir Road, Faisalabad, Pakistan. The samples were collected in 150 mL translucent polyethylene terephthalate (PET) bottles, carefully sealed and immediately transferred to the experimental Lab. and kept under refrigeration (4 °C), until used for trial. All the chemicals and reagents (analytical grade) used were from Merck (Darmstadt, Germany), or Sigma-Aldrich Chemical Co. (St. Louis, MO), unless stated otherwise.

2.2. Storage of samples

Two sets of soybean oil samples (packed in 150 mL translucent PET bottles), each of 12 in duplicate were separately stored under ambient (room temperature, in the dark in a cupboard) and sunlight (only during the day), for a period of six months through April to September, 2005. The mean values for maximum and minimum temperature (°C) for the months April, May, June, July, August, and September were 35.1 ± 3.4, 18.2 ± 3.0 (average 26.6); 38.1 ± 3.0, 23.4 ± 2.3 (average 30.8); 43.3 ± 3.2, 28.7 ± 2.9 (average 36.0); 37.1 ± 3.2, 28.3 ± 2.1 (average 32.7); 39.2 ± 2.2, 28.6 ± 1.6 (average 33.9); 37.4 ± 3.1, 26.0 ± 2.2 (average 31.7), respectively.

2.3. Analysis of the stored samples

The magnitude of oxidative alterations taking place in the soybean oil samples subjected to ambient and sunlight storage was determined by the measurement of changes in the refractive index (RI), color, free fatty acid contents (FFA), peroxide value (PV), iodine value (IV), *para*- anisidine (*p*-anisidine) value, conjugated diene and triene contents. Analyses were carried out periodically after every 15 days (Anwar *et al.,* 2003). A fresh soybean oil sample (storage period 0 days) was also analyzed for the above mentioned physico-chemical characteristics, selected as indicative of oxidative deterioration.

2.3.1. Determination of RI, IV, PV, FFA and color

Determination of RI, IV, PV, and FFA was made following the AOCS official methods Cc 7-25, Cd 1-25, Cd 8-53 and F 9a-44, respectively (AOCS, 1989). RI was measured at 40°C, using a Refractometer (Bellingham and Stanley Ltd. London, United Kingdom). The color of the oil was measured by a Lovibond Tintometer (Tintometer Ltd., Salisbury, Wiltshire, United Kingdom), using 1-in. cell.

2.3.2. Determination of conjugated dienes and trienes

Conjugated dienes and trienes, in terms of the measurement of specific extinctions at 232 and 268 nm were determined using spectrophotometer (U- 2001, Hitachi Instrument Inc. Tokyo, Japan). Oil samples were diluted with *iso*-octane to bring the absorbance within limits (0.2-0.8) and $\varepsilon^{1\%}_{1cm}$, was calculated following an IUPAC method (IUPAC, 1987).

2.3.3. Determination of p-anisidine value

The determination of *p*-anisidine value of the oil samples was carried out following an IUPAC method (IUPAC, 1987). The oil samples dissolved in *iso*-octane were allowed to react with *p*-anisidine solution in acetic acid (0.25% w/v) for 10 minutes to produce a colored complex and the absorbance value was noted at 350 nm by using spectrophotometer (U-2001, Hitachi Instruments Inc. Tokyo, Japan).

2.4. Statistical analysis

Duplicate samples of soybean oil for each treatment/period were taken. Each sample was analyzed individually in triplicate. The data are reported as mean (n = 2 $\times$ 3) ± SD (n = 2 $\times$ 3). Statistical analyses of the data were performed by Analysis of Variance (ANOVA) using STATISTICA 5.5 (Stat Soft Inc, Tulsa, Oklahoma, USA) software. A probability value of $P \leq 0.05$ was considered to denote the statistically significant differences.

3. RESULTS AND DISCUSSION

Table 1 shows the changes in the refractive index (RI) and colour of the SBO samples subjected to ambient and sunlight storage. The RI values of the SBO investigated increased very slowly under both sets of conditions during the early storage period of 75 days. Later on, there was a more pronounced increase in the RI of samples stored under sunlight as compared with its counterpart and this change was noted to become more distinct during the ending weeks of storage. However, both the storage conditions did not exhibit any significant ($P > 0.05$) effect on the RI values of soybean oils. At the end of the storage period i.e., 180 days, the overall increase in RI of SBO stored under ambient and sunlight conditions followed an order of 1.001:1.002, respectively.

The color values of the SBO samples subjected to ambient and sunlight storage decreased slowly with the passage of time, but, data did not show any significant ($P > 0.05$) differences in discoloration of oil during the preliminary period of storage (*ca.* up to 105 days). However, with time , the changes in colour values of SBO became significant ($P < 0.05$). At the end of the experimental period of storage i.e., 180 days, the overall decrease in color (red + yellow) of SBO stored under ambient and sunlight conditions followed an order of 0.80:0.60 + 0.75:0.50, respectively. Literature revealed that oxidation may lead to the discoloration of color and an increase in RI of the oils due to oxidative deterioration and increased conjugation (Sherwin, 1978; McGinely, 1991).

Table 2 shows the extent of changes in free fatty acid (FFA) contents (% as oleic acid) and iodine value (IV) of the SBO samples subjected to ambient and sunlight storage. In the SBO investigated, FFA, which are mainly the product of hydrolysis, often parallel to oxidative damage (McGinely, 1991), increased in a typical fashion under both storage conditions. However, the increase was more pronounced in case of the SBO samples being exposed to sunlight as compared with those stored at ambient. After 180 days of storage , the FFA contents of SBO samples subjected to ambient and sunlight storage was noted to be increased from 0.02% (initial value) to a level of 1.77 and 2.91%, respectively. The statistical analysis of the data demonstrated the variations in FFA contents of SBO under both conditions to be significant ($P < 0.05$). At the end of 180 days of storage, the overall order of increase in FFA of SBO subjected to ambient and sunlight storage was 1.00:1.65, respectively. Higher values of FFA for SBO

Table 1
Relative change in refractive index and color of soybean oil (SBO) subjected to ambient and sunlight storage

SP (days)	Refractive index (40 °C)				Color (1- in. cell)							
	SBO-AS	SBO-SS	ANOVA		SBO-AS	SBO-SS	ANOVA		SBO-AS	SBO-SS	ANOVA	
			F	*P*	Yellow	Yellow	F	*P*	Red	Red	F	*P*
0	1.4630 ± 0.002	1.4630 ± 0.002	0.00NS	1.00	20.00 ±1.00	20.00 ±1.00	0.00NS	1.00	2.00 ±0.05	2.00 ±0.05	0.00NS	1.00
15	1.4630 ± 0.002	1.4631 ± 0.001	0.00NS	0.99	20.00 ± 0.60	20.00 ± 1.00	0.00NS	1.00	2.00 ± 0.10	2.00 ± 0.06	0.00NS	1.00
30	1.4633 ± 0.003	1.4635 ± 0.003	0.01NS	0.94	20.00 ± 0.53	19.00 ± 0.50	5.65NS	0.07	2.00 ± 0.07	1.90 ± 0.05	4.05NS	0.11
45	1.4635 ± 0.004	1.4638 ± 0.004	0.01NS	0.93	19.00 ± 0.63	17.00 ± 0.81	11.4*	0.03	2.00 ± 0.10	1.90 ± 0.04	2.59NS	0.18
60	1.4636 ± 0.004	1.4641 ± 0.003	0.03NS	0.87	18.00 ± 0.55	18.00 ± 0.50	0.00NS	1.00	1.90 ± 0.06	1.80 ± 0.05	4.92NS	0.09
75	1.4638 ± 0.003	1.4643 ± 0.004	0.03NS	0.87	17.00 ± 0.52	17.00 ± 0.40	0.00NS	1.00	1.90 ± 0.10	1.90 ± 0.06	0.00NS	1.00
90	1.4640 ± 0.004	1.4646 ± 0.002	0.05NS	0.83	17.00 ± 0.43	16.00 ± 0.35	9.76*	0.03	1.90 ± 0.07	1.80 ± 0.04	4.62NS	0.10
105	1.4641 ± 0.004	1.4649 ± 0.003	0.08NS	0.79	16.00 ± 0.55	16.00 ± 0.53	0.00NS	1.00	1.80 ± 0.06	1.70 ± 0.10	2.21NS	0.21
120	1.4642 ± 0.004	1.4651 ± 0.004	0.08NS	0.80	16.00 ± 0.60	14.00 ± 0.41	22.70*	0.01	1.80 ± 0.09	1.50 ± 0.06	23.08*	0.01
135	1.4643 ± 0.003	1.4653 ± 0.004	0.12NS	0.75	16.00 ± 0.70	13.00 ± 0.25	48.92*	0.00	1.70 ± 0.06	1.30 ± 0.05	78.09*	0.00
150	1.4645 ± 0.004	1.4655 ± 0.002	0.15NS	0.72	15.00 ± 0.63	13.00 ± 0.45	20.01*	0.01	1.70 ± 0.05	1.40 ± 0.04	65.85*	0.00
165	1.4646 ± 0.004	1.4657 ± 0.003	0.15NS	0.72	15.00 ± 0.41	11.00 ± 0.32	177.4*	0.00	1.60 ± 0.10	1.20 ± 0.08	29.27*	0.01
180	1.4647 ± 0.003	1.4659 ± 0.004	0.17NS	0.70	15.00 ± 0.50	10.00 ± 0.50	150.0*	0.00	1.60 ± 0.08	1.20 ± 0.11	25.45*	0.01
	Order of change 1.001 : 1.002				Order of change 0.75 : 0.50				Order of change 0.80 : 0.60			

Values are mean ± SD for two SBO samples, analyzed individually in triplicate
NS: Non significant
*Significant
SP: Storage period
SBO-AS: Soybean oil subjected to ambient storage
SBO-SS: Soybean oil subjected to sunlight storage

Table 2
Relative change in free fatty acid contents and iodine value of soybean oil (SBO) subjected to ambient and sunlight storage

SP (days)	Free fatty acid content (% as O.A)				Iodine value (g of I/100 g of oil)			
	SBO-AS	SBO-SS	ANOVA		SBO-AS	SBO-SS	ANOVA	
			F	*P*			F	*P*
0	0.02 ± 0.01	0.02 ± 0.01	0.00^{NS}	1.00	138.00 ± 2.50	138.00 ± 2.50	0.00^{NS}	1.00
15	0.12 ± 0.02	0.21 ± 0.01	48.60*	0.00	137.50 ± 3.80	137.00 ± 2.20	0.04^{NS}	0.85
30	0.23 ± 0.02	0.41 ± 0.02	121.5*	0.00	136.80 ± 4.90	135.70 ± 1.90	0.13^{NS}	0.74
45	0.35 ± 0.04	0.62 ± 0.05	53.30*	0.00	135.80 ± 3.10	134.00 ± 3.04	0.52^{NS}	0.51
60	0.49 ± 0.03	0.87 ± 0.05	127.4*	0.00	134.77 ± 4.00	132.25 ± 2.78	0.80^{NS}	0.42
75	0.67 ± 0.02	1.16 ± 0.04	360.1*	0.00	133.47 ± 4.10	130.45 ± 2.85	1.10^{NS}	0.35
90	0.84 ± 0.04	1.46 ± 0.06	59.08*	0.00	132.29 ± 3.02	128.55 ± 4.00	1.67^{NS}	0.26
105	1.00 ± 0.03	1.71 ± 0.05	444.8*	0.00	131.28 ± 4.25	126.79 ± 2.78	2.35^{NS}	0.20
120	1.16 ± 0.04	1.97 ± 0.04	615.1*	0.00	130.25 ± 3.10	125.04 ± 2.21	5.62^{NS}	0.07
135	1.33 ± 0.04	2.22 ± 0.07	367.2*	0.00	129.20 ± 3.99	123.30 ± 3.02	4.17^{NS}	0.11
150	1.48 ± 0.05	2.45 ± 0.06	462.7*	0.00	128.22 ± 2.13	121.55 ± 2.99	9.90*	0.03
165	1.64 ± 0.06	2.66 ± 0.05	511.7*	0.00	127.21 ± 3.05	119.79 ± 3.45	7.79*	0.05
180	1.77 ± 0.05	2.91 ± 0.06	639.1*	0.00	126.18 ± 4.01	118.04 ± 3.65	6.76*	0.05
	Order of change				Order of change			
	1.00 :	1.65			0.91 :	0.86		

Values are mean ± SD for two SBO samples, analyzed individually in triplicate
NS: Non significant
*Significant
SP: Storage period
SBO-AS: Soybean oil subjected to ambient storage
SBO-SS: Soybean oil subjected to sunlight storage

subjected to sunlight storage as compared with that of ambient might be attributed to the elevated rate of hydrolysis and photo-oxidation of the oil under accelerated temperatures.

The iodine value (IV) of the SBO samples subjected to ambient and sunlight storage decreased under both conditions, but did not exhibit any significant ($P > 0.05$) difference up to a period of *ca.*135 days. However, during the later storage period (after 135 days), the statistical analysis of the data showed the variations in IV in SBO stored at ambient and sunlight condition to be significant ($P \leq 0.05$). After the storage period of 180 days under ambient and sunlight, the initial level of IV in SBO (138.00 g of I/100 g of oil) was decreased to 126.18 and 118.04 g of I/100 g of oil and the decline in values followed an overall order of 0.91:0.86, respectively. A considerably higher decline in iodine values of the SBO samples subjected to sunlight storage as compared with those at ambient might be attributed to the higher loss of unsaturated fatty acids as a result of the elevated rate of photo-oxidative degradation. Iodine value can be characterized by a decrease in the total unsaturated contents of the oil and thus is looked upon as an important indicator of deterioration of the oils (Naz *et al.*, 2004).

Table 3 depicts the extent of changes in the peroxide value (PV) and *p*-anisidine value of the soybean oil subjected to ambient and sunlight storage. The PV, which measures hydroperoxide products, is a good indicator of the primary oxidation products of the oils (McGinely, 1991). A typical pattern of rise in PV of soybean oil samples stored under both conditions was observed. It was noted that the PV of the SBO samples subjected to sunlight storage increased at a significantly ($P < 0.05$) higher rate as compared with those at ambient. After the completion of the storage period of 180 days, the level of PV for the SBO samples stored under ambient and sunlight reached 20.52 and 41.89 meq /kg of oil, respectively. The overall order of increase in the PV of SBO samples subjected to ambient and sunlight storage was noted to be 1.00:2.04, respectively. Literature reports also revealed a higher rate of formation of primary oxidation products in light-exposed oils (Khan and Shahidi, 2000).

P-anisidine value, which generally reflects the magnitude of aldehydic secondary oxidation products in oils (McGinely, 1991), for SBO stored at ambient and sunlight conditions changed from 1.10 to a level of 36.13 and 50.40, respectively. The differences in the *p*-anisidine values between the SBO stored under both conditions were statistically significant ($P < 0.05$). After 180 days, the overall order of increase in *p*-anisidine values of SBO samples subjected to ambient and sunlight storage was noted to be 1.00:1.39, respectively. A higher level of *p*-anisidine value for the SBO samples exposed to sunlight as compared with its counterpart might be attributed to the high rate of formation of secondary oxidation products in the former. Literature also revealed a higher extent of formation of secondary oxidation products in light-exposed oils which might be due, in part, to the enhanced rate of oxidative deterioration (Khan and Shahidi, 2002).

Table 3
Relative change in peroxide value and *para*-anisidine value of soybean oil (SBO) subjected to ambient and sunlight storage

SP (days)	Peroxide value (meq/kg of oil)				*Para*- anisidine value			
	SBO-AS	SBO-SS	ANOVA		SBO-AS	SBO-SS	ANOVA	
			F	*P*			F	*P*
0	0.04 ± 0.01	0.04 ± 0.01	0.00^{NS}	1.00	1.10 ± 0.04	1.10 ± 0.04	0.00^{NS}	1.00
15	2.46 ± 0.10	6.50 ± 0.30	489.6*	0.00	3.70 ± 0.10	4.50 ± 0.08	117.1*	0.00
30	4.52 ± 0.30	10.10 ± 0.25	612.5*	0.00	6.68 ± 0.09	8.31 ± 0.20	165.7*	0.00
45	6.85 ± 0.20	13.20 ± 0.32	849.5*	0.00	9.62 ± 0.30	12.20 ± 0.40	79.88*	0.00
60	8.14 ± 0.30	17.20 ± 0.50	724.3*	0.00	12.53 ± 0.54	16.32 ± 0.33	107.6*	0.00
75	11.51 ± 0.50	20.30 ± 0.37	599.1*	0.00	15.50 ± 0.65	22.71 ± 0.57	208.6*	0.00
90	12.80 ± 0.43	23.50 ± 1.00	289.8*	0.00	18.51 ± 0.50	27.32 ± 1.00	186.3*	0.00
105	14.11 ± 0.65	27.10 ± 0.67	580.9*	0.00	21.44 ± 0.73	31.80 ± 0.75	293.9*	0.00
120	15.39 ± 0.70	30.20 ± 1.24	324.5*	0.00	24.37 ± 0.80	35.71 ± 0.52	423.8*	0.00
135	16.67 ± 0.40	33.51 ± 0.85	964.0*	0.00	27.31 ± 1.30	39.42 ± 1.00	163.6*	0.00
150	17.97 ± 0.51	36.60 ± 0.75	1265.8*	0.00	30.29 ± 1.10	43.51 ± 0.90	259.5*	0.00
165	19.25 ± 0.45	39.10 ± 1.20	719.7*	0.00	33.19 ± 0.99	46.73 ± 1.50	170.3*	0.00
180	20.52 ± 0.60	41.89 ± 1.10	872.6*	0.00	36.13 ± 1.40	50.40 ± 1.20	179.7*	0.00
	Order of change				Order of change			
	1.00 :	2. 04			1.00 :	1.39		

Values are mean ± SD for two SBO samples, analyzed individually in triplicate
NS: Non significant
*Significant
SP: Storage period
SBO-AS: Soybean oil subjected to ambient storage
SBO-SS: Soybean oil subjected to sunlight storage

The conjugated diene (CD) and conjugated trienes (CT) contents, measured in terms of specific extinctions at 232 and 268 nm, respectively, for soybean oil samples subjected to ambient and sunlight storage are shown in Table 4. The estimation of CD and CT is a good measure of the oxidative state of oils (McGinely, 1991). The periodical analysis of the SBO samples subjected to both the storage practices revealed a typical pattern of rise in the CD and CT contents. After the

Table 4
Relative change in conjugated diene and conjugated triene contents in soybean oil (SBO) subjected to ambient and sunlight storage

SP (days)	Conjugated dienes $\varepsilon^{1\%}_{1cm(\lambda 232)}$				Conjugated trienes $\varepsilon^{1\%}_{1cm(\lambda 268)}$			
	SBO-AS	SBO-SS	ANOVA		SBO-AS	SBO-SS	ANOVA	
			F	*P*			F	*P*
0	0.08 ± 0.02	0.08 ± 0.02	0.00^{NS}	1.00	0.04 ± 0.01	0.04 ± 0.01	0.00^{NS}	1.00
15	2.09 ± 0.12	4.70 ± 0.15	553.8*	0.00	1.14 ± 0.08	1.64 ± 0.10	45.73*	0.00
30	4.11 ± 0.15	8.51 ± 0.22	819.2*	0.00	2.35 ± 0.10	3.15 ± 0.15	59.08*	0.00
45	6.10 ± 0.10	11.50 ± 0.19	1897.6*	0.00	3.63 ± 0.10	4.74 ± 0.21	68.32*	0.00
60	8.15 ± 0.35	14.81 ± 0.25	643.6*	0.00	4.59 ± 0.20	6.43 ± 0.30	78.13*	0.00
75	10.22 ± 0.36	21.21 ± 0.50	954.5*	0.00	5.81 ± 0.32	8.03 ± 0.40	56.35*	0.00
90	12.23 ± 0.45	24.70 ± 0.45	1151.8*	0.00	6.93 ± 0.25	9.53 ± 0.25	162.2*	0.00
105	14.30 ± 0.41	27.80 ± 0.70	830.8*	0.00	8.10 ± 0.40	11.23 ± 0.350	104.0*	0.00
120	16.29 ± 0.65	30.71 ± 0.45	998.0*	0.00	9.11 ± 0.35	12.83 ± 0.28	206.6*	0.00
135	18.35 ± 0.50	33.82 ± 1.00	574.4*	0.00	10.41 ± 0.24	14.44 ± 0.35	270.5*	0.00
150	20.34 ± 0.35	36.61 ± 0.72	1239.1*	0.00	11.52 ± 0.40	16.04 ± 0.43	177.7*	0.00
165	22.32 ± 0.68	39.30 ± 0.60	1051.7*	0.00	12.63 ± 0.32	17.75 ± 0.50	223.2*	0.00
180	23.97 ± 0.62	41.49 ± 0.50	1451.5*	0.00	13.81 ± 0.35	19.35 ± 0.85	108.9*	0.00
	Order of change				Order of change			
	1.00 :	1.73			1.00 :	1.40		

Values are mean ± SD for two SBO samples, analyzed individually in triplicate
NS: Non significant
*Significant
SP: Storage period
SBO-AS: Soybean oil subjected to ambient storage
SBO-SS: Soybean oil subjected to sunlight storage

180 day storage period, the initial level of CD (0.08) and CT (0.04) for the SBO subjected to ambient and sunlight storage jumped to the values of 23.97, 41.49 and 13.81, 19.35, respectively. The statistical analysis showed a rise in the CD and CT contents of the SBO, stored under both conditions to be significantly ($P < 0.05$) different. After 180 days, the overall order of increase in CD and CT of SBO samples subjected to ambient and sunlight storage was noted to be 1.00:1.73 and 1.00:1.40, respectively. A higher value of CD and CT in the light-exposed soybean oil samples as compared with those stored at ambient might be attributed to the accelerated rate of photo-oxidation and exposure to sunlight radiations that might speed up the oxidative alterations (Khan and Shahidi, 2002; Pan *et al.,* 2004).

The results of different parameters investigated in the present analysis strongly suggest that photosensitized oxidation of soybean oil proceeds rapidly. It has resulted in a marked increase in the magnitude of oxidative alterations of the oil investigated. Furthermore, it could be predicted from the present findings on soybean oil that the extent of oxidative deterioration with regards to sunlight exposure is more pronounced in terms of generation of FFA, PV and conjugated dienes. The oxidation threat to oils can be minimized by improving packing, shipping, storage, and using effective antioxidants.

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