Photooxidation of Soybean Oils as Affected by Triacylglycerol Composition and Structure[1]

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The photooxidation of soybean oil was determined and correlated with triacylglycerol composition and structure. Purified triacylglycerols were photooxidized at room temperature under fluorescent light. Rates of peroxide formation and total headspace volatiles were related positively ($P < 0.5$ significance) to oxidizability ($r = 0.75$, $r = 0.76$); content of linolenic acid ($r = 0.80$, $r = 0.85$) and linoleic acid ($r = 0.61$, $r = 0.57$); linoleic acid on carbon 2 ($r = 0.64$, $r = 0.64$); and average number of double bonds ($r = 0.76$, $r = 0.76$). Negative correlations were observed with respect to oleic acid ($r = -0.70$, $r = -0.70$). Soybean oil stability was decreased by linolenic acid-containing triacylglycerols and increased by oleic acid-containing triacylglycerols. Trilinoleoylglycerol and dilinoleoyl-oleoylglycerol were the most important oxidation product precursors. However, for high-linolenic acid soybean oil, dilinoleoyl-linolenoylglycerol and trilinoleoylglycerol were the most important oxidation product precursors. The most abundant volatile produced from thermal decomposition at 140°C of photooxidized triacylglycerols was 2-heptenal, except for high-linolenic acid oils, where the most abundant volatile was propanal. The photooxidative stability of soybean oil triacylglycerols with respect to composition and structure is of interest for the development of soybean varieties with oils of improved odor and flavor stability.

KEY WORDS: Fluorescent light, oxidative stability, peroxide value, photooxidative stability, soybean oil photooxidation, stereospecific analysis, total volatiles, triacylglycerols.

Oxidative deterioration of fats and oils can be initiated by metals, heat, light and prooxidation sensitizers, which can be activated by light (1,2). The resulting oxidation reactions produce free radicals that react with oxygen to form oxidation products, which include hydroperoxides and cyclic peroxides. The oxidation products can decompose under the influence of metals, heat, light and free radicals, to produce a variety of volatile products. These products can produce undesirable flavors and odors in oils, fats and fat products (1–5). How a fat resists oxidation depends on the triacylglycerol (TAG) composition and positional structure (6) and the non-TAG components like tocopherols, carotenoids, chlorophyll, free fatty acids and sterols, which may promote or retard oxidation (1,2,7–11).

We previously investigated the oxidative stability of purified TAG from soybean oils (SBO) oxidized in air in the dark at 60°C (6), and we showed that oxidative stability in the dark correlated positively with increased oleic (O) and decreased linoleic (L) and linolenic (Ln) acid contents of SBO TAG (6). There is continuing interest in how light influences oxidation of vegetable and animal fats. A recent review by Bekbölet on light-influenced catalyzed changes in dairy, meat, fat and oil products cited 176 references (12). No previous studies reported the photooxidative stability of purified SBO TAG as reported here.

EXPERIMENTAL PROCEDURES

Materials. Soybeans [*Glycine max* (L.) Merr.] were commercial cultivars obtained from the U.S. Department of Agriculture Germplasm Collection (University of Illinois, Urbana, IL), which included plant introductions selected on the basis of fatty acid composition and experimental varieties obtained from the U.S. Department of Agriculture Germplasm Collection (North Carolina State University, Raleigh, NC). All other required materials were described previously (6).

Methods. Oil extraction, TAG purification, peroxide value (PV), static headspace-gas chromatography, TAG composition by reversed-phase high-performance liquid chromatography (HPLC), TAG structure by lipolysis, fatty acid analysis by gas chromatography (GC) and statistical methods were described previously (6).

Photooxidation of purified TAG. Four purified TAG samples (225 mg each) were placed in capped vials with oxygen in the headspace, including three samples from the same SBO variety—one wrapped with aluminum foil to exclude light, plus one control SBO and photooxidized at 25.0 ± 1.0°C in a photochemical reactor (Model RPR - 100, The Southern New England Ultraviolet Co., Hamden, CT). Two fluorescent lamps (Sylvania Cool White F8T5/CW, 8 watts, GTE Sylvania Inc., Danvers, MA) were placed 180° apart in the reactor. Light intensity was 545 foot candles (FC) at the surface of the sample vials. Vials were placed on an electrically driven turntable (5 revolutions per min) to allow equal irradiation of all samples.

The aluminum foil-wrapped vial was included to determine the differences between photooxidation and autoxidation for the same SBO variety at the same temperature (25°C). Analytical samples were removed from each TAG at 24, 48 and 72 h of reaction, *i.e.,* three 15-mg samples for PV determination by the colorimetric ferric thiocyanate method, two 50-mg samples for volatile headspace analysis (HS-GC) and one 50-mg sample for oxidation product analysis by reverse-phase high-performance liquid chromatography (RP-HPLC) and, after derivatization to methyl esters, by capillary GC (6).

TAG oxidation product analysis. RP-HPLC of the oxidized TAGs (TAG-OOH) was modified from the previous procedure (6). HPLC conditions were: 5 μ Vydac ODS column, 25 × 0.46 cm (The Separations Group, Hesperia, CA); mobile phase was methylene chloride/methanol/acetonitrile (5:5:90, vol/vol/vol) at a flow rate of 0.8 mL/min; ultraviolet (UV) detector was set at 235 nm for conjugated diene functionality of oxidized fatty acid (FA) with

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sensitivity set at 0.4 absorbance units. Sample size was 10 μL of a solution of 52 mg TAG-OOH per 100 μL hexane. The formation of oxidation products from Ln_2L, LnL_2, L_3, LnLO, LnLP (P, palmitic acid), L_2O, L_2P, LO_2, L_2S (S, stearic acid) and LOP was monitored. Less polar TAG-OOH were not eluted by the isocratic mobile phase and were removed by methylene chloride stripping of the column before the hext injection. The TAG-OOH that were eluted were derived from about 90% of the oxidation percursor TAG in the SBO. The remaining 10% TAG are highly saturated, *i.e.,* PLP or LOS, each less than 1.0% of the total TAG mixture and do not contribute significantly to TAG-OOH. Identification of TAG-OOH was made by matching HPLC retention times with UV detection at 235 nm with standard TAG-OOH as described previously (6).

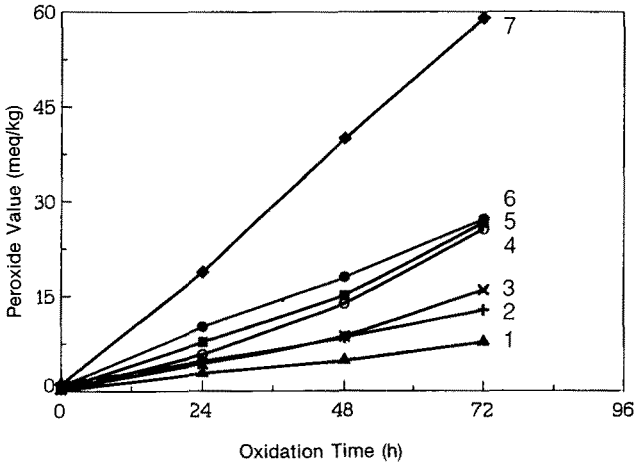

FIG. 1. Photooxidation of soybean oil triacylglycerols. Samples 1–7 as per Table 1.

RESULTS AND DISCUSSION

The oxidation apparatus described above was employed for light-influenced oxidation of purified TAG to levels typical of flavor deterioration of SBO under mild storage conditions while exposed to fluorescent light (5,12). Oxidation levels for TAG oxidized under fluorescent light (545 FC), measured by PV, ranged from 2.8 to 18.9 at 24 h, 4.9 to 32.7 at 48 h and 6.9 to 58.7 meg/kg at 72 h depending on oil composition. Oxidation was definitely light-promoted, because the same oils at 25°C in the dark in the same apparatus showed little oxidation, *i.e.,* PVs ranged from 0.5 to 2.4 at 24 h, 0.9 to 3.3 at 48 h and 1.0 to 4.7 meg/kg at 72 h depending on oil composition.

Correlation of PV and ΔPV with TAG structure. The unsaturated fatty acid composition and location at the glycerol carbons of the TAG, isolated from seven soybean varieties, are presented in Table 1. Significant differences in the composition of O, L and Ln permitted valid comparison of oil oxidative stability with respect to FA composition. Samples are listed in increasing order of calculated oxidizability (OX), which is based on unsaturated FA composition (13).

Plots of PV with oxidation time are presented in Figure 1 for the photooxidation of seven different purified SBO TAG samples. The slopes, obtained by linear regression analysis (6), of the PV *vs.* time plots are a measure of the oil oxidative stability or experimental OX (ΔPV) and are also presented in Table 1. The ΔPV for photooxidation increased in the same order as OX.

Peroxide values determined at 24, 48 and 72 h and ΔPV for each of the TAG studied are correlated by statistical procedures (6) with FA composition and glycerol position in Table 2. The ΔPV and PV at each oxidation time correlated positively with OX and degree of unsaturation for each TAG. The negative correlation of ΔPV and PV with O content showed that O strongly improved oxidative stability. On the other hand, Ln content showed a strong positive correlation, indicating that Ln decreased oxidative stability. Content of L, compared to Ln, showed less of a positive correlation for reduction of TAG stability.

Correlation with glycerol position indicated that the positioning of O or Ln on the internal, compared to the external, carbons apparently has little influence on ΔPV. However, the difference in the correlation coefficients for L positioned on the internal glycerol carbon is significant

TABLE 1

Fatty Acid Composition, Composition at Glycerol Carbons[a] of Triacylglycerol, Oxidizability (OX) and Photooxidative Stability of Soybean Oil Triacylglycerols

Sample number	Variety[b] number	Fatty acid composition (%)			Fatty acid composition (%) 2-position			Fatty acid composition (%) 1,3-position			OX[d]	ΔPV[c] Light[e]
		O	L	Ln	O	L	Ln	O	L	Ln		
1	N 85-2176	50.5	34.4	2.8	51.9	44.6	2.6	49.8	29.3	2.9	0.4101	0.1032
2	N 89-2009	30.2	51.7	3.6	29.7	65.0	3.4	30.4	45.1	3.8	0.5950	0.1591
3	N 83-375	28.1	50.2	6.4	29.1	64.7	5.6	27.9	42.6	6.9	0.6360	0.2133
4	Hardin-90	24.5	53.6	8.0	24.3	67.9	6.5	24.6	46.5	8.7	0.7009	0.3494
5	326.580	16.5	55.4	11.7	15.2	73.8	10.2	17.1	46.2	12.5	0.7913	0.3584
6	291.277	15.3	56.8	11.9	11.6	76.5	11.2	17.1	47.0	12.3	0.8090	0.3628
7	401.418	15.4	56.2	12.5	14.9	73.9	10.4	15.7	46.7	13.1	0.8151	0.7982

[a]Composition of glyceride carbon atoms determined by lipolysis procedure (6). O, oleic; L, linoleic; Ln, linolenic; PV, peroxide value.
[b]Sample varieties 1–3 and 4–7 from germplasm collections at North Carolina State University and University of Illinois, respectively.
[c]Slope obtained by linear regression plot of peroxide value *vs.* time.
[d]OX = (0.02 [0%] + [L%] + 2 [Ln%])/100 (13).
[e]Triacylglycerols oxidized at 25°C in oxygen under 545 foot candles fluorescent light.

TABLE 2

Correlation of Δ Peroxide Value (ΔPV)[a] and PV[b] with Oxidizability,[c] Degree of Unsaturation, Unsaturated Fatty Acid Content and Position at Glyceride Carbons[d]

	Correlation coefficients[e]			
		PV		
Factor	ΔPV	24 h	48 h	72 h
Oxidizability	0.75	0.73	0.72	0.75
Degree of unsaturation	0.76	0.73	0.72	0.76
Oleic acid	−0.70	−0.68	−0.67	−0.71
Linoleic acid	0.61	0.58	0.58	0.62
Linolenic acid	0.80	0.78	0.77	0.80
Oleic acid/carbon 2	−0.68	−0.67	−0.65	−0.68
Oleic acid/carbon 1,3	−0.72	−0.69	−0.68	−0.72
Linoleic acid/carbon 2	0.64	0.63	0.61	0.64
Linoleic acid/carbon 1,3	0.55	0.51	0.51	0.55
Linolenic acid/carbon 2	0.74	0.75	0.72	0.74
Linolenic acid/carbon 1,3	0.80	0.77	0.76	0.79

[a] Slope obtained by linear regression plot of PV *vs.* time.

[b] PV procedure (6).

[c] Oxidizability = (0.02 [0%] + [L%] + 2 [Ln%])/100 (13); O = oleic acid; L, linoleic acid; LN, linolenic acid.

[d] Composition at glyceride carbon atoms determined by lipolysis procedure (6).

[e] Statistical procedure (6).

TABLE 3

Correlation of Δ Peroxide Value (ΔPV)[a] and Total Selected Volatiles (TV)[b] with Triacylglycerol Molecular Species (TAG-MS)[c]

	Content[d]		Correlation coefficients[e]	
TAG-MS	Average (%)	Range (%)	ΔPV	ΔTV
LnLnL	—	0.0–2.4	0.77	0.91
LnLL	7.2	1.5–12.0	0.79	0.87
LLL	15.4	7.2–21.1	0.48, NS[f]	0.49, NS
LnLO	4.7	2.6–7.2	0.67	0.67
LnLP	3.8	0.7–6.8	0.81	0.86
LLO	14.9	11.7–19.5	−0.57	−0.68
LLP	13.1	7.5–17.9	0.65	0.71
LOO	8.6	3.6–16.5	−0.73	−0.80
LLS	3.5	2.2–4.5	0.80	0.77
LOP	8.8	6.6–10.2	−0.70	−0.91
PLP	2.1	0.9–2.9	0.73	0.72
OOO	4.8	0.8–18.3	−0.58	−0.53
LOS	2.8	1.6–4.2	−0.79	−0.89
POO	3.3	0.8–8.9	−0.67	−0.65
SOO	1.1	0.2–2.9	−0.65	−0.65

[a] Slope obtained by linear regression plot of PV *vs.* time.

[b] Slope of linear regression plot of TV *vs.* time.

[c] Composition obtained by reversed-phase high-performance liquid chromatography with flame-ionization detection (6). Individual triglyceride, *i.e.*, LnL_2 triglyceride with one linolenic and two linoleic acids. Abbreviations as in Table 2, footnote c.

[d] Range of content of TAG-MS in the seven soybean varieties.

[e] Statistical procedure (6).

[f] NS = not significant; ($P > 0.05$; <95% confidence level).

and indicates that L positioned on the internal glycerol carbon reduced oxidative stability.

Correlation of PV and ΔPV with TAG species. Quantitative analyses of SBO TAG as determined by RP-HPLC are presented in Table 3. These analyses detected 18 to 23 TAG species, in agreement with previous studies (6,14). The 15 predominant TAG species are listed in Table 3. The major TAG species present in most SBO are LnLL, LLL, LLO, LLP, LOO and LOP (6,15,16). Sample 1, however, also contains OOO as a major TAG species. The range in composition of the major TAG species allowed correlation of oil oxidative stabilities with TAG species composition.

Correlations of the percent compositions of TAG species with ΔPV are presented in Table 3. Correlation of ΔPV is strongly positive for most L- and Ln-containing TAG. While no significant correlation of ΔPV with LLL was observed, replacement of one L of LLL with O, as in LLO, increased oxidative stability, *i.e.*, negative correlation (−0.57) with ΔPV. Replacement of 2 L of LLL with 2O, as in LOO, increased stability somewhat compared to LLO. Unexpectedly, replacement of one L of LLL with P decreased oxidative stability with respect to LLO. Moreover, a greater decrease in oxidative stability was observed for replacement of one L of LLL with S compared to LLP (r = 0.65 to 0.80). Oxidative stability increased sequentially with TAG species OOO, SOO, POO, LOP, LOO and LOS (r = −0.58 to −0.79).

A three-principal component analysis (PC) (6) was performed on the correlations of ΔPV to evaluate the interaction of TAG species with respect to photooxidative stability. The PC analysis shown in Figure 2 illustrates TAG groupings clustered in similar patterns with respect to ΔPV. It was found that the LLnLn, LLLn, LnLO, LnLP, LLP and LLS species had reduced photooxidative stability (*i.e.*, greater ΔPV). On the other hand, OOO, LOO, POO, SOO, LOS, LOP had increased photooxidative stability (*i.e.*, lower ΔPV). The TAG species LLL did not fit any group with respect to ΔPV.

Correlation of volatiles with TAG composition and structure. A GC chromatogram of volatiles generated by thermal decomposition of photooxidized TAG (PV 26.4) is presented in Figure 3. Pentane, propanal, pentanal, hexanal, 2-heptenal and 2,4-heptadienal were the major volatiles. These have been identified previously by GC and GC-mass spectrometry (MS) of oxidized SBO and related to retention and mass spectra of authentic compounds (17–19). Other volatiles in Figure 3 were 2-pentenal, octanal, nonanal, 2-decenal and 2-pentylfuran.

The composition of the major volatiles generated from photooxidized TAG are in Table 4. The relative composition of each volatile did not change significantly with oxidation time; therefore, the values presented are an average of the composition of the 24-, 48- and 72- h samples. The Ln-derived volatiles, propanal and 2,4-heptadienal, in general, increased with increased Ln content of the TAG. However, L-derived volatiles, hexanal and 2-heptenal, decreased with increased L content. The ratio of L/Ln decreased from sample 2 through 7 (Table 1). Sample 1 had a lower L/Ln ratio than sample 2, due to low L (34.4%) content. Therefore, sample 1 had a greater ratio of total selected Ln volatiles to L volatiles than did sample 2. However, the Ln/L volatile ratio increased with increased Ln and decreased L/Ln ratio for samples 2 to 7. With the exception of high Ln (12%)-containing SBO samples, which had propanal as the major volatile, 2-heptenal was the major volatile for photooxidized TAG.

Plots of total selected volatiles generated from photooxidized TAG *vs.* oxidation time are presented in Figure 4.

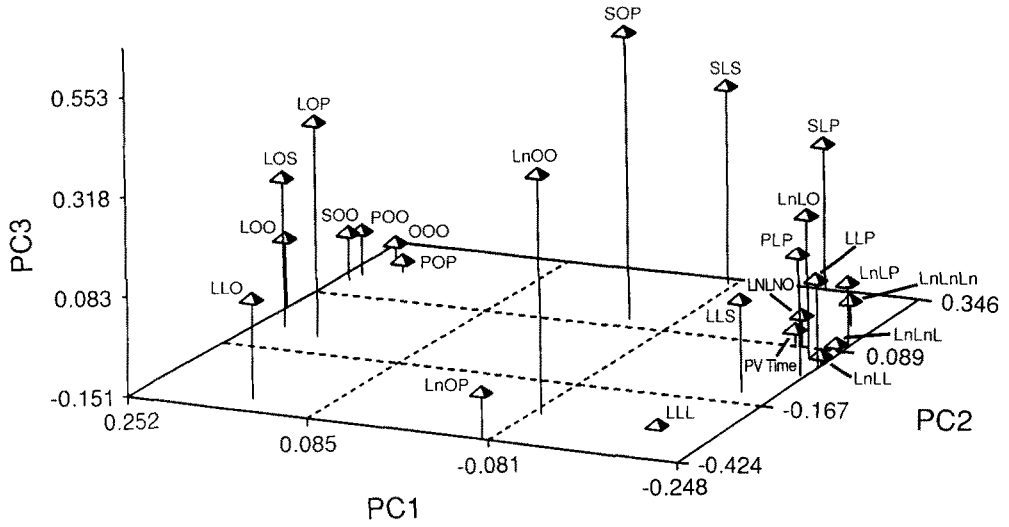

FIG. 2. Principal-component analysis (PC) (6) of influence of the interaction of 23 individual triacylglycerol species from seven soybean varieties on Δ peroxide value. PC-1, assignment to each molecular species with most obvious positive and negative correlations of oxidative stability with other molecular species, accounts for 57% of similarities and differences among the species; PC-2, assignment of correlations left over after effects of PC-1 considered, 19% of total variation explained; PC-3, assignment of effects not considered by PC-1 and -2, 16% of total variation explained. Numbers assigned to each triacylglycerol species by the three PCs are shown. Triacylglycerol composition by reversed phase-high-performance liquid chromatography (6). L, linoleic acid; Ln, linolenic acid; O, oleic acid; P, palmitic acid; S, stearic acid.

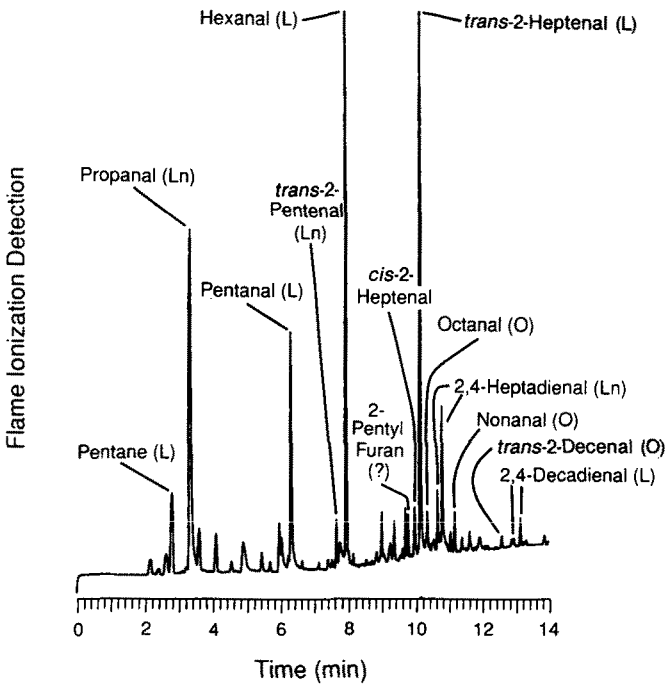

FIG. 3. Resolution of volatiles by capillary gas chromatography from photooxidized soybean oil triacylglycerols thermally decomposed, in the static headspace analyzer (140°C, N_2, 20 min). Gas-liquid chromatography and headspace conditions given previously (6). Abbreviations as in Figure 2.

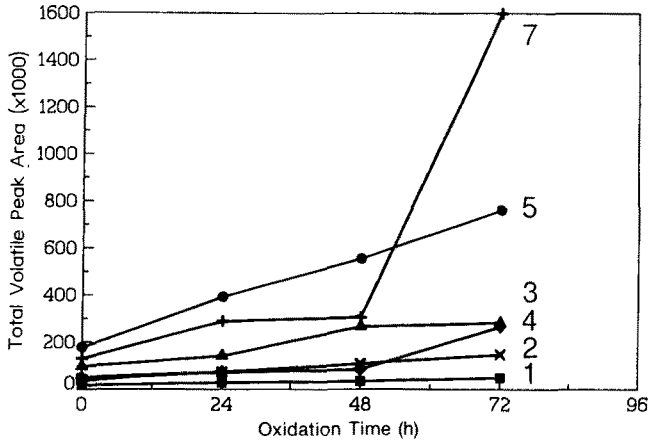

FIG. 4. Total selected volatiles generated from oxidized soybean oil triacylglycerols thermally decomposed in the static headspace analyzer (6) (140°C, 20 min) with respect to photooxidation time.

Sample 7, with highest Ln content, produced the most amount of volatiles, while sample 1, with lowest L and Ln, produced the least. These results were similar to the oxidation levels for the same samples as measured by PV with oxidation time (Fig. 1).

Correlation of rates of formation of total selected volatiles (ΔTV), hexanal (ΔHX), propanal (ΔPR), heptenal (ΔHT), pentane (ΔPANE), pentanal (ΔPAL) and heptadienal (ΔDIENAL) are presented in Table 5. There was a high positive correlation of ΔTV, ΔHX, ΔPR, ΔHT, ΔPANE, ΔPAL and Δ-DIENAL with degree of unsaturation and Ln. Oleic acid correlated with reduced formation of ΔTV, ΔPR, ΔHX and ΔHT. There was a strong positive correlation of ΔHT with L content.

With regard to stereospecific composition, little difference was observed between the specific location of O or Ln on the glycerol carbons for correlation with ΔTV, ΔHX, ΔPR and ΔHT. However, L on the internal glycerol carbon showed significant correlation with increased ΔTV, ΔHX, ΔPR and ΔHT. The ΔPANE, ΔPAL, and ΔDIENAL were similarly correlated.

Correlation of ΔTV with TAG species showed the same positive or negative correlations as ΔPV (Table 3).

TABLE 4

Selected Volatiles[a] from Thermal (140°C) Decomposition of Photooxidized Triacylglycerols (TAGs)[b]

Sample number	Selected volatiles[c] Area percent [average of oxidized soybean oil (SBO) at 24, 48, 72 h]						Volatile ratio[d] Ln/L
	Pentane	Propanal	Pentanal	Light hexanal	Light 2-heptenal	Light 2,4-heptadienal	
1	1.3	18.2	11.9	27.6	34.8	6.3	0.324
2	3.2	19.4	12.2	25.3	37.7	2.2	0.276
3	3.5	23.0	12.1	23.2	33.9	4.3	0.376
4	11.4	22.8	12.0	14.4	29.9	9.6	0.480
5	5.6	28.0	10.3	20.8	27.2	8.2	0.565
7	15.5	27.8	9.0	15.0	20.0	12.7	0.688

[a]Composition obtained by gas-chromatography-mass spectrometry analysis (6).

[b]TAGs oxidized neat in oxygen at 25°C under fluorescent light (545 foot candles).

[c]These were the major SBO volatiles detected.

[d]Volatile ratio = Ln-derived volatiles: (propanal + 2,4-heptadienal) to L-derived volatiles: (pentane + pentanal + hexanal + 2-heptenal). Ln, linolenic acid; L, linoleic acid.

TABLE 5

Correlation of ΔTV,[a] ΔHX, ΔPR, ΔHT, ΔPANE, ΔPAL and ΔDIENAL[b] with Oxidizability, Degree of Unsaturation, Unsaturated Fatty Acid Content and Position at Glyceride Carbons

Factor	Correlation coefficients[c] ΔTV	ΔHX	ΔPR	ΔHT	ΔPANE	ΔPAL	Δ-DIENAL
Oxidizability[d]	0.76	ND[e]	ND	ND	ND	ND	ND
Degree of unsaturation	0.76	0.77	0.73	0.89	0.60	0.87	0.68
Oleic acid	−0.70	−0.72	−0.67	−0.88	−0.54	−0.86	−0.62
Linoleic acid (L)	0.57	0.58	.53	0.75	0.43 N.S.	0.73	0.49 N.S.
Linolenic acid (Ln)	0.85	0.86	0.83	0.94	0.69	0.92	0.79
Oleic acid/carbon 2	−0.70	−0.71	−0.67	−0.88	−0.53	−0.86	−0.62
Oleic acid/carbon 1,3	−0.71	−0.72	−0.68	−0.88	−0.55	−0.86	−0.63
Linoleic acid/carbon 2	0.64	0.65	0.60	0.83	0.48 N.S.	0.82	0.55
Linoleic acid/carbon 1,3	0.47 N.S.	0.48 N.S.	0.44 N.S.	0.66	0.35 N.S.	0.65	0.40 N.S.
Linolenic acid/carbon 2	0.84	0.86	0.82	0.96	0.67	0.95	0.77
Linolenic acid/carbon 1,3	0.83	0.85	0.81	0.94	0.67	0.93	0.77

[a]Slope of linear regression plot of sum of selected volatiles *vs.* oxidation time.

[b]Slopes of linear regression of gas-liquid chromatography peak areas for ΔHX (hexanal), ΔPR (propanal), ΔHT (2-heptenal), ΔPANE (pentane), ΔPAL (pentanal) and ΔDIENAL (2,4-heptadienal) with oxidation time.

[c]Statistical procedure (6) N.S. = not significant $P > 0.05$; <95% confidence level.

[d]Oxidizability = (0.2 [0%] + [L%] + 2 [Ln%])/100 (13); O = oleic acid.

[e]ND = not determined.

Therefore, it can be concluded that the same interactive effects of FA of a TAG on oxidative stability as measured by ΔPV were operative for oxidative stability as measured by ΔTV. A PC analysis of TAG interaction (Fig. 5) showed the same TAG that acted together to change ΔPV (Fig. 2) also acting together to increase or decrease ΔTV. Oleate-containing TAG tended to interact as a group to reduce ΔTV. Conversely, Ln-containing TAG species tended to interact to increase ΔTV, while LLL was inclined to act alone and to have a less significant effect on ΔTV.

Hydroperoxide formation during photooxidation of SBO TAG. The selected TAG-OOH compositions, as determined by RP-HPLC, of the samples after 72-h photooxidation are presented in Table 6. The most important TAG-OOH precursor is LLL, followed in a generally decreasing order by LLO, LLP, LOL and LOP for samples 1–4. However, with samples 5–7, which have high Ln (11–12%) composition (Table 1), LnLL was as important as LLL as a TAG-OOH precursor. This agreed with the increase in the Ln-derived volatiles, propanal and 2,4-heptadienals, compared to the L-derived volatile, hexanal, for samples 5 and 6 (Table 4).

As OX increased, ΔPV, ΔTV and ΔTAG-OOH increased (Tables 1,5,6). Thus, as the amount of polyunsaturated FA increase in the TAG, the greater were the rates of oxidation as measured by ΔPV and ΔTAG-OOH. As expected, as ΔTAG-OOH (volatile precursors) increased, the greater became the ΔTV. As the L- and Ln-containing TAG increased in content (sample 7), TAG-OOH were produced 12 times faster than for low L and Ln and high O (sample 1). The ΔTV also was accelerated by ΔTAG-OOH, *i.e.,* ΔTV was about 50 times greater for the higher Ln-containing sample (sample 7) than for the low-Ln and high O (sample 1).

The oxidative-stability results presented here for purified SBO TAG oxidation under light with regard to

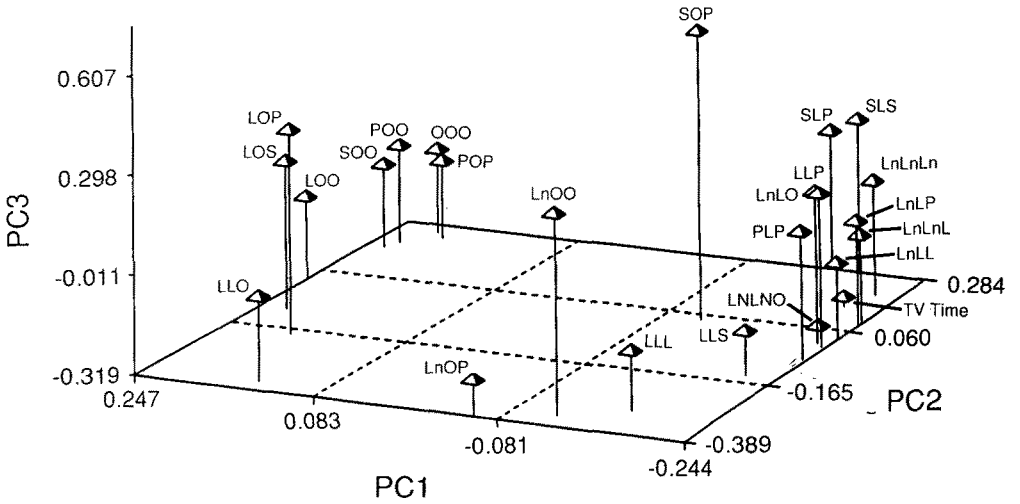

FIG. 5. Principal-component analysis (PC) (6) of influence of interaction of 23 individual triacylglycerol species from six soybean varieties on Δ total selected volatiles (ΔTV). The PC assignments and abbreviations are the same as in Figure 2.

TABLE 6

Selected Triacylglycerol (TAG) Hydroperoxide Composition[a] at 72-h Oxidation Time[b]

Sample number	TAG hydroperoxide (area percent)						
	L_2Ln	L_3	L_2O	L_2P	LO_2	LOP	Δ-OOH
1	5.8	23.9	25.6	11.4	9.8	6.0	5.8
2	6.4	31.8	26.6	10.9	5.3	4.0	7.3
3	9.7	30.1	21.6	12.6	6.3	4.3	11.2
4	9.4	30.9	21.2	10.6	2.4	4.1	14.9
5	29.4	28.4	11.0	13.0	2.0	3.6	12.7
6	28.7	27.9	14.8	8.4	4.1	2.0	10.8
7	22.5	30.1	12.0	15.6	4.2	7.3	73.2

[a] Triacylglycerol hydroperoxide composition obtained by reversed-phase high-performance liquid chromatography with ultraviolet detection, 235 nm.

[b] TAG oxidized at 25°C in oxygen under 545 FC fluorescent light.

[c] Slope of linear regression plot of sum of peak areas for [Ln_2 L-CPO + Ln_2 L-OOH + (LLnL − CPO + LLLn − CPO) + (LLnL-OOH + LLLn-OOH) + L_3-OOH + (LnLO-OOH + LnLP-OOH) + L_2 O-OOH + L_2 P-OOH + LO_2 -OOH) + L_2 S-OOH + LOP-OOH] *vs.* oxidation time. Abbreviations as in Figure 2. OOH, oxidized TAG.

SBO TAG composition, FA location on the TAG glycerol moiety, FA interaction in individual TAG and interaction among TAG species should assist plant breeders in developing genetically improved soybean varieties with oils of improved stability and nutritional value.

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