Flavor Stability and Quality of High-Oleate and Regular Soybean Oil Blends During Frying

Caiping Su and Pamela White*

Department of Food Science and Human Nutrition and Center for Crops Utilization Research, Iowa State University, Ames, Iowa 50011

ABSTRACT: The percentages of oleate (18:1), linoleate (18:2), and linolenate (18:3) in blended soybean oils (SBO) were evaluated for their impact on flavor stability and quality in fried foods. Six SBO treatments, including a control (conventional SBO, 21.5% 18:1) and a high-18:1 SBO (HO, 79% 18:1), were tested. In addition, these two oils were mixed in different ratios to make three blended oils containing 36.9, 50.7, and 64.7% 18:1, abbreviated as 37%OA, 51%OA, and 65%OA, respectively. Also, a low-18:3 (LL) SBO containing 1.4% 18:3 and 25.3% 18:1 was tested. Bread cubes (8.19 cm^3) were fried in each of 18 oils (6 treatments × 3 replicates). The fresh and stored bread cubes fried in 79%OA were second to the cubes fried in LL in overall flavor quality, were the weakest in intensity of stale, grassy, fishy, cardboard, and burnt flavors by sensory evaluation, and contained the least amounts of hexanal, hexenal, *t*-2-heptenal, *t,t*-2,4-nonadienal, and *t,t*-2,4-decadienal in volatile analysis. Other treatments were intermediate in these sensory and instrumental evaluations, as related to their 18:1, 18:2, and 18:3 concentrations. In general, the results suggested that the overall flavor stability and eating quality of foods fried in the six oil treatments from the best to the poorest would be: LL ≥ 79%OA, 65%OA, 51%OA, 37%OA, and control.

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KEY WORDS: Fried bread cubes, frying oil stability, high-oleate soybean oil, low-linolenate soybean oil, sensory evaluation, volatile compound analysis.

Although soybean oil (SBO) has a good nutritional profile, it has poor oxidative stability and is prone to flavor deterioration because of its high proportion of unsaturated FA. The FA linoleate (18:2) and, especially, linolenate (18:3) in SBO oxidize quickly and are the major contributors to the poor flavor stability of SBO (1). Hydroperoxides formed by the oxidation of 18:3 can break down to many undesirable flavor compounds, such as 2,4-heptadienal, 2-butylfuran, 2- and/or 3-hexenal, 2-pentenal, and butanal (2). Hydroperoxides formed by the oxidation of 18:2 can break down to undesirable flavor compounds, such as hexanal, under mild conditions and 2,4-decadienal at high temperatures (2).

To improve oxidative and flavor stability, SBO may be hydrogenated to reduce the concentration of PUFA (and increase the saturated FA); however, *trans* FA (*t*FA) are formed during this process. Because of health concerns over the presence of *t*FA in our diets (3), lowering the 18:3 content to a level similar to that obtained by partial hydrogenation, but without *trans* formation, has been an objective of plant breeders.

Various SBO with lowered levels of 18:3 have been developed and studied (4,5). The flavor stabilities of SBO containing as low as 1.0% and 2.2% 18:3 were characterized by using a specialized program involving Chernoff faces, which involves the application of multivariate analysis to visualize sensory perception (5). The results showed that the oil containing 1.0% 18:3 was more stable than the oil containing 2.2% 18:3. However, 18:3 is an EFA belonging to a group called ω-3 (or n-3) FA, which have been shown to reduce or help prevent certain chronic diseases (6); thus, reducing 18:3 to a minimal level may diminish the health benefits of SBO. Therefore, there may be reasons to maintain as much 18:3 as possible in edible vegetable oils. Also important to oxidation is that the oxidation rate of oleate (18:1) is much slower than that of the PUFA 18:2 and 18:3 (7). At the same time, a diet high in monounsaturated FA may help to reduce raised levels of total plasma cholesterol without reducing the HDL-cholesterol level (8). Therefore, developing SBO with both enhanced stability and health benefits and having low but not minimal 18:3, elevated 18:1, no *t*FA, and minimal saturated FA would be very desirable.

The objectives of this study were to evaluate the impact on flavor stability and eating quality of fried foods caused by altering the percentages of 18:1, 18:2, and 18:3 by blending SBO with oils having different FA compositions. Considering that blended oils often are thought to be only as stable as the "poorest" oil present, a secondary objective was to determine the impact on the flavor and eating quality of the fried food of blending a poor-stability control SBO, having a typical FA composition, with a high-stability, high-18:1 SBO.

MATERIALS AND METHODS

SBO and design. Soybeans (*Glycine max*) with high-18:1 [oleic acid (OA) (79%OA)], low-linolenate (LL, 1.4% with 25.3% 18:1), and conventional (control, 21.3% 18:1) FA compositions, were grown in summer 1998 in Iowa (weather zone 4). The soybeans were crushed and the oils were hexane-extracted, in triplicate, in the Pilot Plant of the Center for Crops Utilization Research, Iowa State University (ISU), Ames, Iowa, by following a previously published method (9). All the oils were

*To whom correspondence should be addressed at 2312 Food Sciences Bldg., Iowa State University, Ames, IA 50011-1060.
E-mail: pjwhite@iastate.edu

refined and bleached as described in AOCS Official Methods Ca 9a-52 and Cc 8a-52, respectively (10), and deodorized by following the procedure described by Stone and Hammond (11). Triplicate sets of each oil were refined, bleached, and deodorized separately. Citric acid (100 ppm) was added to the oils during the cool-down stage of deodorization before placement in high-density polyethylene plastic bottles. The bottles were sparged with nitrogen, then sealed and stored at −10°C until used for testing.

Six SBO treatments were evaluated during frying, including the three SBO just mentioned (control, LL, and 79%OA), plus three oil blends prepared as follows: (i) 75% of the control (by weight) and 25% of the 79%OA (37%OA), (ii) 50% of the control and 50% of the 79%OA (51%OA), and (iii) 25% of the control and 75% of the 79%OA (65%OA).

Frying (Table 1). Eighteen frying sessions, three per day, were carried out with six oil treatments being evaluated in triplicate (6 × 3 = 18). Frying was completed in 3 wk, with two frying days in a week (2 × 3 × 3 = 18). At each frying session, 220 g of an oil treatment was weighed into a Teflon-coated 473-mL electric baby fryer (National Presto Industries Inc., Eau Claire, WI), and the oil was then heated to 185°C within 10 min. The oil was heated at 185 ± 5°C for 2.5 h before frying. Eight 5-piece batches of crust-free bread cubes (2.54 × 2.54 × 1.27 cm) were fried for 1 min per batch at 3-min intervals. Therefore, the actual frying of the cubes for one oil treatment was completed within 0.5 h. The fried bread cubes were then drained and cooled to room temperature. Half of the bread cubes was used immediately for testing, including evaluation of flavor characteristics by a trained sensory panel and instrumental volatile analysis by the GC-solid-phase microextraction (SPME) method. The other half of the bread cubes was stored, loosely covered, at 60°C in the dark for 3 d before sensory evaluation and volatile analysis by the same procedures used on the freshly fried bread cubes. The oil remaining in the fryer was maintained at 185 ± 5°C for another 7 h for a total of 10 h heating on day 1, then cooled to 25°C. The oil was heated at 185 ± 5°C for another 10 h on day 2.

TABLE 1
Design of Frying Sessions

	Week	Day	Session	Treatment[a]	Replicate
1	Monday	1	1	79%	I
			2	Control	I
			3	LL	I
	Tuesday	2	4	79%OA	II
			5	Control	II
			6	LL	II
2	Monday	3	7	79%OA	III
			8	Control	III
			9	LL	III
	Tuesday	4	10	65%OA	I
			11	51%OA	I
			12	37%OA	I
3	Monday	5	13	65%OA	II
			14	51%OA	II
			15	37%OA	II
	Tuesday	6	16	65%OA	III
			17	51%OA	III
			18	37%OA	III

[a]79%OA = high oleate (OA) soybean oil (SBO). The terms 65%OA, 51%OA, and 37%OA = three blends containing % of OA indicated. Control = conventional SBO. LL = low-linolenate SBO.

FA composition by GC; tocopherol contents by HPLC. The FA compositions of SBO before frying were determined according to a method described by Hammond (12). The GC conditions were the same as described by Shen *et al.* (9). Tocopherol contents were determined according to AOCS Official Method Ce 8-89 (10). The HPLC conditions were the same as described elsewhere (4).

Sensory evaluations of the fried bread cubes. Sensory evaluations were conducted according to AOCS Recommended Practice Cg 2-83 (10). A 12-member trained descriptive panel was used to evaluate overall flavor quality and individual flavor and off-flavor intensities of the fried bread cubes. All panelist candidates (17 members) were trained during four 1-h sessions. During training, panelists were given definitions for 10 flavor descriptors, including fried food, cardboard, waxy, stale, grassy, burnt, acrid, fishy, rancid, and painty flavors (13). Standards for these 10 flavors, respectively, included fresh french fries from a local fast-food restaurant, water with cardboard soaked in it for 1 h, melted paraffin oil, potato chips aged 2 wk at room temperature, fresh-cut green grass, burned fried bread cubes, canola oil heated to 240°C for 5 min, canola oil heated to 190°C for 3 min, SBO with a PV of 18 mequiv/kg, and canola oil kept at room temperature for 3 yr (13). Candidates were asked to smell or taste the standards and to assign an intensity score. Also, candidates were given fresh SBO, SBO with a PV of 18 mequiv/kg, and canola oil kept at room temperature for 3 yr to smell and rank in order of painty intensity. Candidates who incorrectly ordered the intensity of painty flavor in these samples or could not detect flavors from the 10 standards, after training, were omitted (5 out of 17 people) as panelists.

For the actual tests, in each session, three bread cubes from three different treatments were presented to each panelist. The cubes were presented on paper plates, labeled with random, three-digit codes, and presented in random order to panelists. Panelists were asked to smell the cubes first, and then bite into the bread to taste. To avoid tasting fatigue and flavor carryover, panelists were given only three samples per session, and were asked to expectorate the sample after tasting and to rinse their mouths with distilled water between tasting samples. Evaluations were conducted in 12 individual, lighted booths. The breads were evaluated for overall flavor quality on a 10-point scale (10 = excellent quality, 9 and 8 = good, 7 and 6 = fair, 5 and 4 = poor, 3, 2, and 1 = very poor) and for intensity of the 10 individual flavors listed in the previous paragraph on a 10-point scale (10 = bland, 9 = trace, 8 = faint, 7 = slight, 6 = mild, 5 = moderate, 4 = definite, 3 = strong, 2 = very strong, 1 = extreme). Overall flavor quality scores were calculated as the average of all overall quality scores given by the panelists. Intensity of a flavor was calculated as the average of the intensity scores by the panelists who detected the flavor in the sample.

Volatile profile of the bread cubes by GC-SPME. The procedures by Jelen *et al.* (14) were followed with some modifications as described. About 3.0 g bread (finely ground with a spatula) from each sample was placed in a 20-mL vial and sealed. A 2-cm 50/30 μm divinylbenzene/Carboxen/polydimethylsiloxane StableFlex fiber (Supelco, Bellefonte, PA) was inserted through the Teflon seal to trap the volatile compounds. The sealed sample was held at 40°C for 60 min, with the temperature maintained by a water bath on a hot plate. The fiber was then removed from the vial and inserted into the injection port of a Hewlett-Packard 5890 Series II gas chromatograph equipped with an HP-5 30 m × 0.32 mm × 0.25 μm column. The gas chromatograph was programmed as follows: injection temperature 250°C, detector temperature 270°C, initial temperature 30°C, initial hold time 3 min, rate 4°C/min until reaching 100°C, then 8°C/min until reaching a final temperature of 220°C, which was held for 5 min. After injection, the fiber remained in the injection port for desorption for 10 min before being used for the next extraction. Individual external standards were used to identify retention times for each flavor compound found in the bread cubes. For this procedure, a volume of 0.5 μL of standard was injected into the fried bread cube (about 3.0 g, ground as previously described) with a syringe inserted through the Teflon seal. The vial was shaken and the rest of the steps were the same as just described.

Statistical analysis. There were six treatments times 3 replicates. The SAS general linear models procedure (GLM) was used to analyze the data (15). Differences in mean values among treatments were determined by the least significant difference test at $\alpha = 0.05$, unless listed otherwise.

RESULTS AND DISCUSSION

FA composition (Table 2). The control oil had much greater palmitate (16:0), 18:2, and 18:3 concentrations than did the 79%OA. The blended treatments were intermediate in these FA levels, based on the ratios of each oil percentage present. The LL was similar in FA composition to the control, except for its greatly reduced 18:3 level and slightly increased 18:1 and 18:2 levels.

Tocopherols (Table 2). The concentrations of α-tocopherol of the oil treatments increased as the concentration of 18:1 decreased. The concentrations of δ-tocopherol of the oil treatments decreased as the concentration of 18:1 decreased, except for the LL treatment, which had the lowest concentration of δ-tocopherol even though its 18:1 percentage was intermediate between that of the 37%OA and the control. There were no differences in the concentrations of γ-tocopherol and total tocopherol among 79%OA, control and LL SBO, and any of the blends.

Sensory evaluations of the fried bread cubes (Table 3). The fresh and stored bread cubes of the LL treatment generally had the best overall flavor quality, the 79%OA the second, the control the worst, and the three blended treatments were intermediate, based on their 18:1, 18:2, and 18:3 concentrations. However, there were no significant differences among treatments for sensory evaluation.

Among all fresh fried bread cubes, the 79%OA tended to have the weakest fishy note, was tied with 51%OA and LL for the weakest cardboard flavor, and was tied with LL for the weakest burnt flavor. The 79%OA was second-weakest to LL and the control in stale flavor, and second-weakest behind 65%OA and 37%OA in grassy flavor (Table 3). In general, LL had the weakest rancid, acrid, burnt (tied with 79%OA), and cardboard (tied with 51%OA and 79%OA) flavors, was second-weakest after 65%OA and 37%OA in grassy flavor, was second-weakest to 79%OA in fishy flavor, and second-weakest after 51%OA and 37%OA in painty flavor. In general, the LL fresh fried bread cubes had the best flavor characteristics among all fresh treatments, followed by 79%OA. The control generally had the most intense grassy, fishy, acrid, and burnt flavors.

In general, among the stored fried bread cubes, the 79%OA and control were the weakest in fried food and stale flavors. The 79%OA was weakest in grassy and burnt flavors. The 79%OA and LL were second-weakest behind 51%OA in fishy flavor, and 79%OA was second-weakest behind 65%OA and LL in acrid flavors. The LL had the most intense fried food flavor and the weakest waxy, cardboard (tied with 65%OA), and acrid (tied with 65%OA) flavors. LL and 65%OA were second-weakest behind 79%OA in stale flavor. LL and 79%OA were second-weakest behind 51%OA in fishy flavor. LL tied with the control and 79%OA was the second-weakest behind 65%OA in painty flavor. The control and LL tended to have the most intense grassy and burnt flavors.

The above results of fresh and stored bread cubes demonstrated that the greatly reduced 18:3 in LL SBO tended to

TABLE 2
FA Composition (area %) and Tocopherols of SBO

Oil treatments[a]	FAME[b]					Tocopherols (μg/g)[c]			
	16:0	18:0	18:1	18:2	18:3	α	γ	δ	Total[d]
79%OA	6.9	3.8	79.0	6.5	3.8	113[e]	722[a]	495[a]	1329[a]
65%OA	7.8	3.9	64.7	18.7	4.9	156[d]	722[a]	457[a,b]	1335[a]
51%OA	9.0	4.1	50.7	30.3	6.0	199[c]	722[a]	419[b,c]	1340[a]
37%OA	9.9	4.3	36.9	41.8	7.1	242[b]	723[a]	381[d,c]	1346[a]
Control	11.2	4.4	21.5	54.8	8.0	285[a]	723[a]	343[d]	1352[a]
LL	10.6	4.5	25.3	58.2	1.4	274[a]	731[a]	286[e]	1290[a]

[a]See footnote *a* of Table 1 for oil treatment definitions.
[b]Methyl palmitate (16:0), stearate (18:0), oleate (18:1), linoleate (18:2), and linolenate (18:3).
[c]Tocopherol concentrations in 79%OA, control, and LL SBO were determined. Tocopherol concentrations in the three blended oils were calculated.
[d]Values in the same column for each test followed by the same superscript letter are not statistically significant at $P \leq 0.05$.

TABLE 3
Flavor Characteristics[a] of Fresh and Stored Fried Bread Cubes by Sensory Evaluations[b]

Fried bread cube treatments[c]		Overall flavor quality	Fried food	Stale	Waxy	Grassy	Fishy	Rancid	Painty	Cardboard	Acrid	Burnt
Fresh	79%OA	6.6	4.1	9.7	9.3	9.7	9.3	8.8	9.0	9.5	8.3	9.3
	65%OA	6.1	4.0	9.0	9.0	9.8	9.0	9.3	9.5	9.3	8.4	8.7
	51%OA	6.0	3.8	9.0	9.4	9.5	8.8	8.9	9.6	9.5	9.0	8.6
	37%OA	6.1	3.8	8.7	9.5	9.8	8.6	8.8	9.6	9.3	9.0	8.9
	Control	5.9	4.4	9.8	9.5	9.3	8.4	9.2	9.3	9.4	8.3	8.1
	LL	6.8	4.7	9.8	9.2	9.7	9.1	9.6	9.5	9.5	9.1	9.3
Stored	79%OA	6.5	5.0	9.3	9.3	10.0	9.4	9.0	9.2	8.9	9.5	9.3
	65%OA	6.1	4.2	9.1	9.3	9.9	9.1	9.2	9.4	9.6	9.7	8.1
	51%OA	6.0	4.6	8.8	9.2	9.8	9.8	9.3	9.1	9.5	9.5	8.2
	37%OA	6.3	4.3	8.9	9.3	9.7	9.0	8.9	9.1	9.3	9.3	8.9
	Control	5.8	5.0	9.3	9.5	9.5	9.2	9.2	9.2	9.4	9.4	7.6
	LL	6.6	4.1	9.1	9.7	9.5	9.4	8.9	9.2	9.6	9.7	8.8

[a]Mean values obtained from a 12-member panel. For overall flavor quality, 10 = excellent, 1 = very poor. For the intensity of individual flavors, 10 = bland, 1 = very strong.
[b]Values in the same column for fresh treatments were not significantly different ($P < 0.05$). Values in the same column for stored treatments were not significantly different ($P < 0.05$).
[c]See footnote *a* of Table 1 for treatment abbreviations.

elevate its flavor stability and quality over those of other treatments containing higher percentages of 18:3. The greatly reduced 18:2 and 18:3 contents in 79%OA (greatly increased 18:1) improved its flavor quality over that of other treatments as demonstrated by weaker stale, grassy, fishy, and cardboard flavors of its fried bread cubes compared with those of other treatments; however, this treatment tended to have weaker fried food flavor than the blended oils containing a fair amount of 18:2, the FA proposed to generate fried food flavor during frying (2). The inconsistency in this reasoning is that both the fresh control and the LL treatments, having the greatest amount of 18:2, had even weaker fried food flavor than the 79%OA treatment. After storage, the control continued to have the weakest fried food flavor, but the LL treatment tended to have the strongest fried food flavor among all stored treatments. Perhaps interactions among other flavors when the bread cubes were fresh diminished the fried food flavor. As the control oxidized during storage, its overall flavor deterioration caused by the many volatile compounds may have decreased the intensity of fried food flavor as detected by the panelists.

The trends of overall sensory characteristics among treatments of stored fried bread cubes were generally the same as those among fresh fried bread cubes. The LL and 79%OA still were similar in overall sensory perception. The 65%OA, 51%OA, and 37%OA were similar to each other, and the control was most different from other treatments in overall sensory perception.

Volatile profiles of the fried bread cubes by GC-SPME. Both the fresh and stored fried cubes fried in 79%OA had significantly less hexenal and less (although not significantly) *t,t*-2,4-heptadienal than did those fried in the control. The three blends were intermediate between the 79%OA and the control and were generally not different from each other in the concentration of these two volatiles. When fresh, the LL bread had significantly less hexenal than did the control, and significantly less *t,t*-2,4-heptadienal than did the other treatments (Fig. 1A). After storage, the LL bread had significantly less hexenal than did the control and 65%OA, and tended to have less *t,t*-2,4-heptadienal than did the other treatments (Fig. 1B). Oxidation of 18:3 is known to produce 2,4-heptadienal and hexenal (2,16). Positive correlations between the amounts of these two compounds in fried bread cubes and the concentration of 18:3 in the corresponding frying oils were found (Table 4). There also was a positive correlation between the amount of hexenal in fresh fried bread cubes and the concentration of 18:2 in the corresponding frying oils. The fresh and stored control and LL bread cubes generally had more hexanal, *t*-2-heptenal, *t,t*-2,4-nonadienal, and *t,t*-2,4-decadienal than did the 79%OA cubes, and the differences were generally significant, except for hexanal (Fig. 1). The fresh and stored bread cubes of the three blends had concentrations of these compounds that were intermediate between 79%OA, the control, and LL and related to the 18:2 concentration of the corresponding frying oil. There were strong positive correlation coefficients between the production of these compounds in the fried bread cubes and the concentration of the 18:2 of the frying oils, except for hexanal (Table 4). This relationship can be explained by the finding that oxidation of 18:2 favors enals and dienals at higher temperatures (17). Although hexanal is a breakdown product of 18:2, its formation is favored under mild conditions; thus, the poor correlations were not surprising (Table 4). The 79%OA tended to produce more nonanal and *t*-2-decenal than did the other treatments, and there were strong positive correlations between the amounts of these two compounds in the fresh and stored fried bread cubes and the initial concentration of 18:1 in the corresponding frying oil (Table 4).

The compounds noted in Figure 1B may play significant roles in the flavor characteristics of foods because of their low thresholds and specific flavor characteristics (18). Previous studies estimated the significance of some volatile compounds

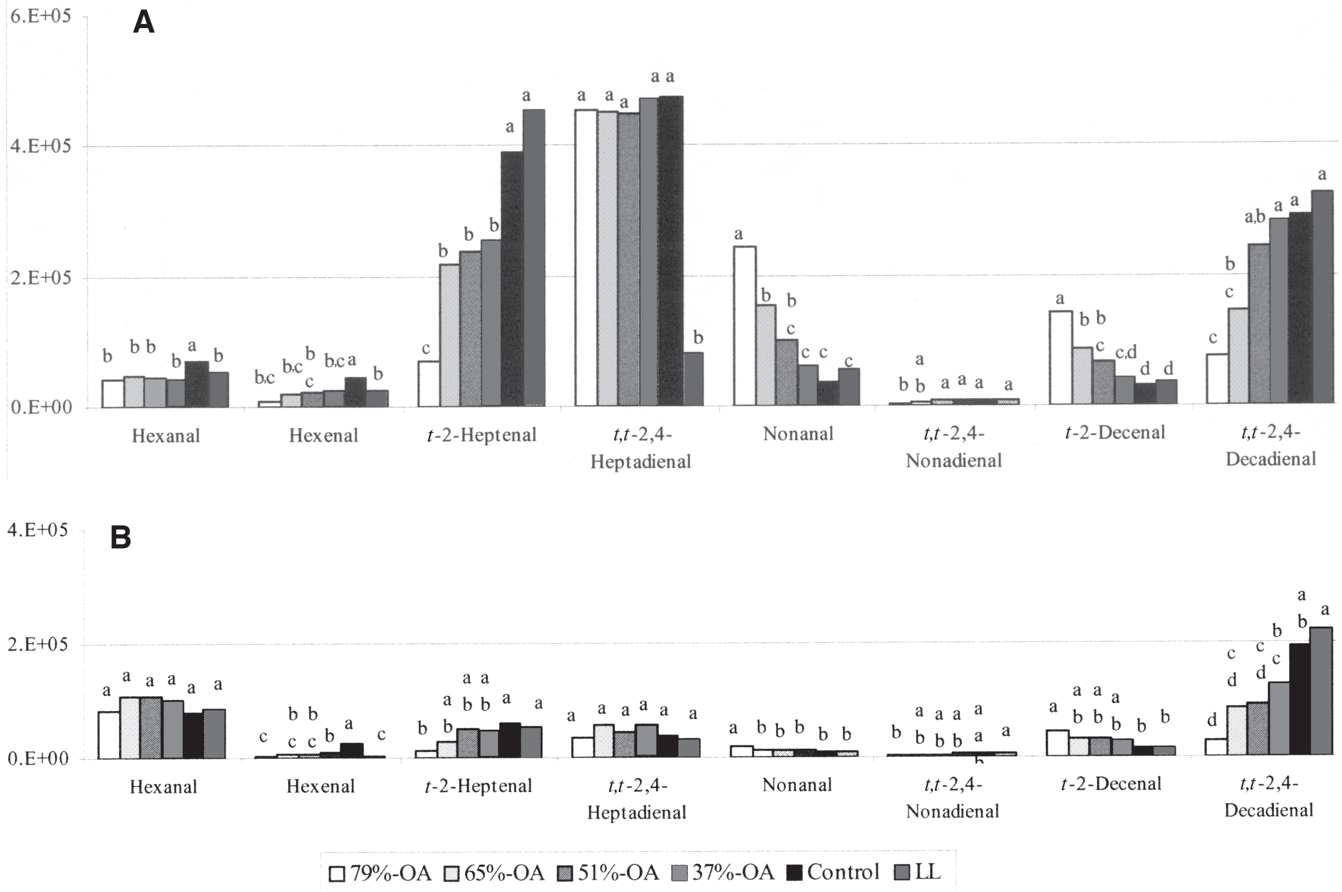

FIG. 1. Volatile compounds from (A) fresh fried bread and (B) stored fried bread. [a]For each volatile compound, values with label letters in common were not significantly different ($P < 0.05$). *Y* axis units: GC area count.

from the oxidation of soybean oil on food flavor, based on their concentrations and threshold values. For example, *t,c*-2,4-decadienal was the most flavorful, followed by *t,t*-2,4-decadienal, *t,c*-2,4-heptadienal, 1-octen-3-ol, *n*-butanal, *n*-hexanal, *t,t*-2,4-heptadienal, 2-heptenal, *n*-heptanal, *n*-nonanal, and 2-hexenal (19). In the current study, the greater amount of hexanal (fresh fried bread cubes), *t,t*-2,4-heptadienal (fresh), and hexenal (fresh and stored fried bread cubes) present in the control may have contributed to its generally stronger grassy and fishy off-flavors. Conversely, the generally low amounts of these compounds may have resulted in generally weaker grassy and fishy off-flavors in 79%OA and LL. The tendency for more *t*-2-heptenal and *t,t*-2,4-decadienal to be present in the control and LL treatments may have caused slightly stronger rancid and fried food flavor in the fresh fried cubes.

There were strong positive correlations between the amounts of nonanal and *t*-2-decenal and the 18:1 concentration, which may explain the stale, waxy-like off-flavor sometimes associated with high-OA SBO. Nonanal was previously described as tasting fruity and *t*-2 decenal was described as tasting plastic (20). However, which compounds cause what particular flavors in fats and oils is still controversial for two reasons. On one hand, it is difficult to agree on the common terms to describe the same odor or off-flavor by different researchers. On the other hand, little progress has been made in relating flavor descriptors with individual volatile compounds in a natural mixture, such as food, owing to additive and antagonistic interactions between volatile compounds (21).

Overall, the 79%OA had better flavor stability and quality than did the control. But the impact of 18:2 and 18:3 reduction and 18:1 elevation on flavor stability was not as pronounced as that on its oxidative stability, which was reported in a related paper as measured by PV, FFA, conjugated dienoic acid, polar compound percentage, and viscosity of the frying oils (16).

The greatly reduced 18:3 concentration in the LL treatment tended to elevate its flavor stability and quality to be equal to or greater than that of the 79%OA, greater than that of the blends, and greater than that of the control. The impact of reducing the 18:3 concentration on flavor stability was greater than that on the oxidative stability (16), likely because of the significance of the volatile compounds (*t,t*-2,4-heptadienal and hexenal) produced from the breakdown of 18:3. In the oxidative stability tests (16), LL was equivalent only to 37%OA, and not as good as 79%OA, as it tended to be in flavor stability. These findings further demonstrated the importance of 18:3 in flavor instability of SBO.

TABLE 4
Correlations Between the Mean Amounts of Individual Volatile Compounds from Fried Bread Cubes and the Mean Concentrations of the Unsaturated FA of the Frying Oils

		Fresh fried bread cubes		Stored fried bread cubes	
Volatile compound	FA	Correlation coefficient	*P* value	Correlation coefficient	*P* value
	18:3	0.536	0.279	0.779	0.070
Hexenal	18:2	0.785	0.064	0.496	0.317
	18:1	−0.835	0.039	−0.580	0.227
	18:3	0.807	0.051	0.462	0.354
t,t-2,4-Heptadienal	18:2	−0.512	0.299	−0.209	0.693
	18:1	0.408	0.430	0.152	0.773
	18:3	0.269	0.615	0.174	0.742
Hexanal	18:2	0.632	0.176	−0.274	0.601
	18:1	−0.653	0.159	0.251	0.630
	18:3	−0.069	0.887	0.338	0.520
t-2-Heptenal	18:2	0.957	0.003	0.929	0.007
	18:1	−0.932	0.007	−0.953	0.003
	18:3	0.274	0.606	0.062	0.914
t,t-2,4-Nonadienal	18:2	0.904	0.013	0.941	0.005
	18:1	−0.920	0.009	−0.931	0.007
	18:3	0.141	0.797	−0.062	0.899
t,t-2,4-Decadienal	18:2	0.965	0.002	0.973	0.001
	18:1	−0.964	0.002	−0.949	0.004
	18:3	−0.332	0.526	−0.278	0.602
Nonanal	18:2	−0.942	0.005	−0.927	0.008
	18:1	0.964	0.002	0.943	0.005
	18:3	−0.289	0.586	−0.065	0.912
t-2-Decenal	18:2	−0.941	0.005	−0.954	0.003
	18:1	0.958	0.003	0.944	0.005

The impact of blending a poor-stability oil with a high-stability oil on flavor quality and stability of the three blends was two-sided in that the three blends tended to have stronger off-flavors, such as stale, fishy, and burnt, than did 79%OA, but also stronger favorable fried food flavor. This observation may be explained by the fact that 18:2 and 18:3 oxidize to form both favorable and unfavorable flavor compounds. A good balance of all these flavor compounds provides the flavor quality people desire. Therefore, an intermediate FA composition in the blends may result in good flavor quality and characteristics of the blends.

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