High-Temperature Stabilities of Low-Linolenate, High-Stearate and Common Soybean Oils

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Four soybean oils (SBO) with different fatty acid (FA) compositions were tested for stability during intermittent heating and frying of bread cubes. None of the oils was hydrogenated or contained any additives. Two of the oils were from common commercial varieties. The other two oils were from seed developed in a mutation breeding program and included the line A5, which contained 3.5% linolenate, and the line A6, which contained 20% stearate. Each oil (450 g) was heated to 185 C in a minifryer. Bread cubes were fried at the beginning of heating, and half were stored at -10 C to preserve freshness. The second half was stored at 60 C for 14 days. Heating was continued for 10 hr/day for four days. After 40 hr of heating, an additional 30 g of bread cubes were fried. According to sensory evaluations of the fried bread cubes, peroxide values of oil extracted from the cubes and conjugated diene values of the oils, the A5 and A6 oils were more stable than those from the commercial varieties. Small differences occurred in the flavor and oxidative stability of the cubes fried after 40 hr of heating the oils. Large differences between A5 and A6 and the commercial varieties occurred after storage of bread cubes for 14 days.

Deep frying is one of the most common methods for preparation of foods. Many vegetable oils have limited flavor stability and are considered more suitable for use in salad dressings and sauces, in which less stress is placed on the oils than in frying (1-3). Stressed vegetable oils produce characteristic off-flavors. Soybean oil (SBO), which constitutes 80% of US oil production, develops a fishy, painty or rancid odor and flavor (1). It is relatively unstable when compared with other vegetable oils. Huang et al. (2) concluded that corn and sunflower oils were more suitable for cooking or frying because they contained only small amounts of linolenate (18:3), the fatty acid most prone to autoxidation. For this same reason, in 1973, France limited the 18:3 content of deep frying oils to 2% of the total fatty acids (FA) (3).

Hydrogenation improved the stability of SBO used at high and low temperatures (1-6). The increase in stability was attributed to a decrease in the amount of 18:3 in SBO (6). Frankel et al. (4) found that, although hydrogenation of SBO improved the stability as based on instrumental analyses, the flavor quality was not improved. Blumenthal et al. (5) found that a light hydrogenation improved flavor scores, but that generally, unhydrogenated SBO had better flavor than hydrogenated oils.

Another way to reduce the 18:3 content of SBO is through plant breeding. Researchers at Iowa State University (ISU) have produced soybean genotypes with different oil compositions (7). One line, A5, contains 3.5% 18:3, and another line, A6, has a stearate (18:0) content of 20%. Comparisons of oils from these lines with those of normal SBO showed that the new oils were more stable at room or elevated (60 C) temperatures and produced fewer volatiles (8). However, no tests have been done with these oils at frying temperatures. The purpose of this research was to evaluate SBO of different FA compositions (A5, A6 and two commercial varieties) under frying conditions.

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EXPERIMENTAL PROCEDURES

Extraction, refining and deodorization. The oil from four soybean genotypes was extracted, refined and deodorized under laboratory conditions by using a procedure described previously (8). Two of the soybean lines were selected from a mutation breeding program at ISU. One of these lines, A5, had an 18:3 content of 3.5%, and the other, A6, had an 18:0 content of 20%. Oils from two commercial varieties were prepared by using the same methods. None of the oils were hydrogenated or contained any additives.

Heating and frying procedures. Each oil (450 g) was weighed into a Teflon-coated 473-ml electric minifryer (Presto Fry Baby Electric Fryer, National Presto Industries Inc., Eau Claire, Wisconsin) and heated to 185 ± 5 C within 10 min. Two 30-g batches of 2.54-cm^2 crust-free bread cubes (Fastco Enriched White Sandwich Bread) were fried for one min each. The fried bread was drained. One batch was loosely covered and stored at 60 C for 14 days. The other batch was stored at -10 C in double freezer bags with the air pressed out by hand, until needed for sensory evaluation and chemical analysis. Additional bread cubes were fried in A5 oil, stored at -10 C and used as references during sensory evaluation. Heating of the oils was continued for four days at 185 ± 5 C for 10 hr/day. After 40 hr of heating, 30 g of bread cubes were fried one min and frozen as before. A two-g sample of oil was removed from the fryer just before each day of heating. Oil was not replenished or filtered, and at least 300 g of oil remained in the fryer after the last cubes had been fried. Two replications of the heating and frying procedures were conducted on each of the four oils.

Chemical tests. Oils were extracted from bread cubes for chemical tests by two 10-min extractions with distilled hexane. Preliminary tests showed that a third extraction did not recover significant amounts of oil from cubes fried at 0 hr or 40 hr of heating.

Methyl esters of the FA were prepared by transesterification of the oils with sodium methoxide in methanol (9). FA compositions were determined by gas liquid chromatography (GLC) of methyl esters on a 3.2-mm × 2-m column packed with a moderately polar cyano-silicone phase (10% SP 2330, Supelco Inc., Bellefonte, Pennsylvania) on 100/120 Chromosorb W.

Peroxide values (PV) of the oils were determined according to a method of Hamm et al. (10), and conjugated dienoic acids (CD) were measured using AOCS method Ti la-64 (11). Duplicate analyses of each chemical test were averaged. Separate analyses were done for each of the two heating and frying replications.

Sensory evaluation. Ten trained panelists evaluated the fried bread cubes at room temperature for intensity of oxidized flavor by using the AOCS Flavor Intensity Scale (12). On this scale, 10 is bland, and one is extremely intense flavor. The panelists were trained by judging fresh and stored bread cubes fried in A5 and BSR 101. Four training sessions were conducted to develop agreement on oxidized flavor scores. The samples were presented at room temperature and in random order, and the panelists were instructed to first smell the cubes and then to taste them in approximate order of increasing odor intensity. This reduced the possibility of a strongly oxidized bread cube overwhelming a panelist's ability to discriminate less oxidized cubes before all samples were evaluated. Panelists were instructed to hold the cubes in their mouths and to judge the intensity of the volatiles as well as the flavor. Panelists evaluated each of the three sets of fried cubes from all oils. Panels were repeated two times for each heating and frying replication, resulting in a total of 12 panels with four cubes presented at each.

Statistical analysis. The data were analyzed by Analysis of Variance (ANOVA). Least significant differences were calculated by using the statistical analysis system (13).

RESULTS AND DISCUSSION

Chemical analyses. FA composition of the oils at the beginning (0 hr) and the end (40 hr) of heating and frying are shown in Table 1. The A6 oil had more 18:0 and slightly less 18:3 than oil from the commercial varieties and was semisolid at room temperature. The A5 oil had less 18:3 and 18:2 than normal SBO. Typically, oxidation or heat stress causes an increase in the percentage of saturated FA and a decrease in the percentage of unsaturated FA. After 40 hr of heating and frying, all oils exhibited this pattern.

Stevenson et al. (14) did not find any changes in FA composition after heating partially hydrogenated canola and SBO at 185 ± 2 C for 75 hr. However, oils used in that study (14) contained stabilizers and had lower 18:3 contents than oils used in the present study. Also, Stevenson et al. (14) replenished the frying oils with fresh fat twice daily and conducted more frying, which can protect an oil from deterioration because of the steam generated (15).

The PV is a measure of the amount of peroxides formed in oils through oxidation processes. The peroxides are the initial products of lipid oxidation, which break down to secondary products that contribute to flavor. Therefore, PV should be an indirect measure of flavor. Peroxides do not accumulate in heated oil, so the PV is not a good indicator of actual frying oil deterioration. It can, however, be used to measure deterioration once a fried product has been cooled and/or stored (15, 16).

Shown in Table 2 are the PV of oils extracted from bread cubes fried at 0 hr and 40 hr of heating and from bread cubes fried at 0 hr of heating and stored at 60 C for 14 days. Some significant differences ($P<0.05$) in PV among the oils were noted in fresh cubes fried at 0 hr and 40 hr of heating. Much larger differences were noted in the cubes fried in fresh oil after storage for 14 days. Oil extracted from cubes fried in A5 and A6 had the lowest PV ($P<0.05$) after storage for 14 days, whereas oil extracted from cubes fried in Hardin and stored 14 days had the highest PV ($P<0.05$). The PV of oils extracted from bread cubes fried at the end of heating were similar to PV found by Stevenson et al. (14) for oil extracted from french fries after extended frying. However, Stevenson et al. (14) found no difference in the flavor of french fries cooked in liquid canola oil or SBO with 18:3 content of 1.2% and 2.8%, respectively.

The formation of hydroperoxides normally coincides with the conjugation of double bonds in polyunsaturated FA when oils are stored at room temperature. The conjugated dienes absorb UV light at a wavelength of 233 nm. (15, 16). These values can be used as a relative measure of oxidation, with higher CD values indicating greater degrees of oxidation (15, 16). The CD values of oils heated for up to 40 hr are shown in Table 3. The CD values of A5 and A6 were significantly lower ($P<0.05$) after 10 hr of heating than CD values of the commercial varieties and continued to be so for the remainder of the test. After 30 hr of heating, values

TABLE 1

Fatty Acid Composition (relative area %) of Frying Oils at the Beginning (0 hr) and the End (40 hr) of Heating

	Fatty acid GLC %				
Oil type	16:0	18:0	18:1	18:2	18:3
A5					
0 hr	9.8	4.2	32.6	49.7	3.5
40 hr	11.8	4.6	37.4	44.2	1.9
A6					
0 hr	8.4	20.2	22.0	43.4	5.9
40 hr	9.7	23.0	23.7	39.2	4.3
Hardin					
0 hr	10.0	4.8	24.1	53.7	6.9
40 hr	14.0	5.8	29.0	47.5	3.7
BSR-101					
0 hr	10.0	5.2	22.2	54.5	8.1
40 hr	12.4	5.9	25.6	50.8	5.3

TABLE 2

Peroxide Values[a] of Oils Extracted from Bread Cubes Fried at 0 hr of Heating, After 40 hr of Heating and from Cubes Stored for 14 Days after Frying in 0 hr Oil

	Heating time of oil		
Soybean oil type	0 hr	40 hr	Cubes stored 14 days
A5	1.0[a]	4.2[b]	83[c,*]
A6	0.8[a,b]	3.8[b]	82[c]
Hardin	0.3[b]	4.5[b]	489[a]
BSR-101	1.1[a]	5.4[a]	263[b]

[a]Values in the same column with different superscript letters are significantly different ($p<0.05$).
*Values from one replication.

TABLE 3

Percentages of Conjugated Dienoic Acid[a] in Oils Heated for Different Lengths of Time

Soybean oil type	Heating time (hr) 0	10	20	30	40
A5	0.13[c]	0.59[c]	1.19[b]	2.09[c]	2.53[c]
A6	0.16[c,b]	0.52[c]	0.98[b]	1.58[d]	2.01[d]
Hardin	0.22[b]	1.37[a]	1.90[a]	2.96[a]	3.37[a]
BSR-101	0.62[a]	1.07[b]	1.58[a]	2.75[b]	3.13[b]

[a]Values in the same column with different superscript letters are significantly different ($p<0.05$).

were significantly different among all oils with A5 <A6 <BSR 101 <Hardin.

Sensory evaluation. It is of interest to known if there are differences in fats and oils used for frying. Several studies have compared the sensory qualities of french fries or bread cubes fried in various types of oils and fats (2–4, 14, 17, 18). Bread cubes were chosen in the present study because of their availability, uniform size and moisture content and lack of antioxidants.

Flavor evaluations of the cubes fried at 0 hr and 40 hr of heating of the oils and after storage of cubes fried at 0 hr are shown in Table 4. The flavor scores of bread cubes fried in A5 oil at 0 hr and at 40 hr of heating were generally higher than the flavor scores of bread cubes fried in the other oils. In some cases, the differences were significant ($P<0.05$). The stored cubes fried in A5 and A6 were significantly blander ($P<0.05$) than those fried in the commercial oils.

The 18:3 content sometimes predicted the relative flavor stabilities of the oils (8). The order of 18:3 content was A5 <A6 <Hardin <BSR 101, whereas flavor scores for cubes fried in oil heated for 40 hr were A5> A6> Hardin = BSR 101, and scores for stored cubes were A6> A5> Hardin = BSR 101. The flavors of fresh cubes fried at 0 hr were not predictable. The final CD values of the heated oils and the PV of the extracted oils did a fairly good job of predicting the relative flavor scores of the stored bread cubes and those fried after 40 hr of heating. Other researchers (18) have noted differences in flavor and stability among unhydrogenated SBO even though their FA compositions were similar. Differences in PV, free FA or mineral content also did not predict the flavor or oxidative stability of these oils (18). Although these factors contribute to flavor, additional unknown factors seem to affect the flavor stability of SBO.

The results of sensory evaluation of fried bread cubes, PV of the oils extracted from the fried cubes and CD values of the heated oils showed that A5 and A6 were generally more stable than the commercial oils. The greatest advantage was seen after storage of the fried bread cubes. These new SBO may offer the advantage of both improved flavor and improved oxidative stability in deep frying.

TABLE 4

Flavor Evaluation[a] of Bread Cubes Fried at 0 hr of Heating, after 40 hr of Heating and of Cubes Stored for 14 Days after Frying in 0 hr Oil

Soybean oil type	Heating time of oil 0 hr	40 hr	Cubes stored 14 days
A5	7.5[a]	5.8[a]	4.2[b,*]
A6	5.8[b]	5.3[a,b]	5.8[a]
Hardin	5.2[b]	4.7[b]	1.2[c]
BSR-101	6.9[a]	4.7[b]	1.2[c]

[a]Values in the same column with different superscript letters are significantly different ($p<0.05$). Flavor intensity scale ranged from 1 (strong) to 10 (bland). Ten trained panelists evaluated the oils.
*Scores from one replication.

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