Flavor and Oxidative Stability of Hydrogenated and Unhydrogenated Soybean Oils. Efficacy of Plastic Packaging

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ABSTRACT

Soybean oils were packaged in polyvinylchloride, acrylonitrile, clear glass and amber glass bottles and their flavor stabilities were evaluated by a trained sensory panel. Hydrogenated and unhyrdogenated oils showed similar patterns of flavor deterioration regardless of container or type of aging. In accelerated light-exposure tests with air in the headspace, oils in plastic bottles showed flavor and oxidative stability equivalent to the same oils in clear glass bottles. Packaging in the amber glass bottle provided, as expected, significantly improved oil stability during light-exposure tests. In accelerated storage tests at 60 C with air in the headspace, sensory evaluation and peroxide determination showed no significant differences in oils packaged in clear glass and PVC, but sometimes oils received lower scores in glass compared with those in acrylonitrile bottles. During long-term storage, oils in plastic bottles with nitrogen in the headspace had flavor and oxidative stabilities equal to oils in glass bottles with nitrogen. These investigations indicate that packaging soybean oils in polyvinylchloride or acrylonitrile bottles is a viable alternative to packaging in clear glass bottles.

INTRODUCTION

Recently, the use of translucent plastic bottles for vegetable oils in domestic markets has grown significantly; processors in foreign countries have used this type of packaging for many years. Research conducted by scientists at the Northern Regional Research Center and by others has demonstrated that the most effective method of maintaining the quality of liquid soybean oil is the use of amber glass containers to reduce light exposure and of nitrogen packaging to minimize the oxidation of the oil (1). Several investigators have studied the effect of various packaging materials to control light-induced flavor deterioration in milk (2-4), vegetable oils (5-8) and foods containing fat (9). This research has led to significant changes in packaging materials, resulting in the improved light stability of foods. In the past, the amber bottle was adopted for a significant portion of the vegetable oil market, but now clear glass and plastic bottles are being used by edible oil processors. Sattar et al. (6) concluded that relatively simple and inexpensive changes in packaging materials could greatly reduce light transmittance to improve the flavor quality of oils. Milk in polyethylene containers exposed to fluorescent light (2152 lux or 200 ft candles, 8 hr) developed a strong "light-activated" flavor (4). Yellow lamps and yellow and green lamp filters protected the milk from developing an off-flavor. Milk packaged in blow-molded, unpigmented containers exposed to fluorescent light (1076 lux (100 ft candles), 12 hr) had lower hedonic flavor scores than milk packaged in various pigmented paperboard containers (2). Properties such as oxygen permeability, impact resistance, clarity and flavor transmission from the bottle material to the food have also been considered (10). Plastic bottles for oils in use at the time of this study were made with polyvinylchloride (PVC) or with acrylonitrile (AN) resins. The AN copolymer bottles have been used for ca. 30 years in a variety of food-contact applications, such as food-packaging films, vegetable-oil bottles and beverage containers (11). The increasing use of plastic bottles for oils in domestic and foreign markets motivated the present study to compare the effects of light, temperature and nitrogen sparging on the stability of soybean oils and hydrogenated soybean oils in plastic and glass containers.

EXPERIMENTAL PROCEDURES

Materials

Two samples each of soybean oil (SBO) and hydrogenated winterized soybean oil (HWSBO) were obtained commercially as refined, bleached, deodorized and citrated oils. Fatty acid compositions were determined by gas chromatographic methods (Table I). Amber glass, clear glass, PVC and 2 types of AN plastic bottles (32-oz size) were used. The AN resins were Barex 210, produced by Vistron Corporation (Cleveland, OH), and Cycopac 920, manufactured by Borg-Warner (Parkersburg, WV). The AN bottles were obtained from IMCO Container Co. (Vandalia, IL), and the PVC bottles were obtained from Humko Inc. (Memphis, TN). All of the materials have FDA approval for use as packaging for vegetable oils. Of particular importance to the processor is the permeability of the material to water, oxygen and oil (10). The materials used in these studies are reported to have low to very low permeability to these elements. Light-transmittance characteristics of 4 mm X 1 mm strips of the packaging materials were measured with a Beckman spectrophotometer over a wavelength range of 250 nm to 640 nm (Table II). Glass and plastic bottles were both clear and had similar transmittance characteristics, except at 360 nm, whereas amber glass excludes light at wavelengths of 460 nm and below. Anderson showed that the exclusion of light below approximately 490 nm is necessary to protect milk from light deterioration (12). Work by Sattar and others demonstrated

TABLE I

Fatty Acid Composition of Soybean Oils (wt %)

Fatty acid	Unhydrogenated oils (SBO)		Hydrogenated oils (HWSBO)	
	A	B	C	D
16:0	10.4	10.3	10.0	10.2
18:0	4.1	3.9	5.5	5.8
18:1	24.4	23.4	46.2	46.2
18:2	54.2	54.2	35.5	34.6
18:3	7.0	8.1	3.1	3.2
Calc. IV	131	134	109	107

TABLE II

Light Transmittance (%) of Packaging Materials at Various Wavelengths

Packaging	250 nm	360 nm	460 nm	640 nm
Amber glass	0	1	2	35
Clear glass	5	84	86	86
Barex (AN)	4	36	59	72
Cycopac (AN)	4	32	69	74
PVC	4	45	74	79

that the rate of light-induced oxidation of edible oils was significantly diminished when wavelengths below 500 nm were excluded (6-8).

Methods

The oils were bottled and aged by the following methods: accelerated light exposure, accelerated high-temperature storage and long-term ambient temperature storage. The oils in the light-exposure and accelerated-temperature series were packaged with air in the headspace, whereas those in the ambient temperature storage series had nitrogen in the headspace. The fluorescent light exposure test consisted of placing the sealed bottles on a revolving platform in the middle of a 17.5-in. diameter stainless steel drum, 17.5 in. high, which contained 6-15 in., 14-watt daylight fluorescent bulbs (5). Light intensity in the drum was 7535 lux (700 ft candles). Exposure time ranged from 4 to 24 hr. The oils for the accelerated-temperature storage tests were bottled and aged in a forced draft oven at 60 C in the dark for 4 and 8 days. Samples for the ambient-temperature storage were bottled and sparged with nitrogen for 1 min, then sealed and aged at 25C for 4, 6, 9 and 12 months.

Sensory Evaluation

The aged oils were evaluated for odor and flavor by a trained, experienced, 15-member panel. The overall intensity of each sample was rated on a 1-10 scale with 10 as bland and 1 as extreme. Individual odor and flavor descriptions were rated as weak, moderate and strong. Odor intensity values (OIV) and flavor intensity values (FIV) for the descriptions, which are weighted averages, were calculated by the following formula:

$$\text{OIV or FIV} = \frac{1 \times \#\,\text{weak responses} + 2 \times \#\,\text{moderate responses} + 3 \times \#\,\text{strong responses}}{\#\,\text{of testers}}$$

In addition to the test by the panel, peroxide values (13) were measured.

Before the storage stability tests, the oils were evaluated for initial odor and flavor. Odor and flavor scores and peroxide values of the light-exposed oils were evaluated statistically by 3-way analysis of variance (AOV) (14). The 3-way AOV tested interactions of bottle type (amber glass, clear glass, PVC, AN-Barex and AN-Cycopac), amount of light exposure (4, 8, 16 and 24 hr) and type of oil (SBO, HWSBO). The oils in the accelerated temperature and ambient storage were evaluated statistically by a 2-way AOV.

RESULTS AND DISCUSSION

Results of initial odor and flavor evaluations by the taste panel and oxidative tests are presented in Table III.

Fluorescent Light Exposure

Results of the sensory evaluation of the oils, which had been aged in the fluorescent light exposure tests in air, are presented in Table IV. The oils packaged in amber glass, clear glass and PVC bottles were evaluated against each other. Oils packaged in clear glass, Barex and Cycopac bottles were evaluated together. As expected, the oils packaged in amber glass showed no light deterioration based on flavor scores and peroxide values. No significant differences were found in the sensory evaluation between the oils packaged in clear glass or PVC bottles or the oils packaged in clear glass, Barex or Cycopac bottles. As the scores of the SBO samples decreased, an increase was noticed in the number of flavor descriptions such as melon, fishy, sour and light struck. The oils packaged in plastic received neither more unusual nor a greater number of off-flavor descriptions than did the oils bottled in glass. A bottle-to-bottle variation existed for SBO samples B packaged in clear glass and exposed to light for 16 hr in separate trials, but for no apparent reason. The HWSBO samples bottled in Barex received the highest score in each trial, and the difference was significant at 4 hr for HWSBO D and at 8 and 24 hr for HWSBO C; however, this significance pattern was not consistent. Off-flavors such as hydrogenated, light struck and metallic in the HWSBO samples increased with time. The peroxide values for the oils bottled in amber glass were significantly lower than for the oils bottled in plastic (Table IV). The PV's for SBO A bottled in clear glass were significantly higher than for the same oil packaged in Barex or Cycopac. The PV's for HWSBO C showed the same pattern after 16 and 24 hr of light exposure.

Accelerated Storage

The results of the accelerated storage testing in air are presented in Table V. No significant differences were found in the flavor scores of the oils bottled in clear glass compared with those packaged in PVC. In several trials, the oils in clear glass were rated significantly lower than those oils in Barex and Cycopac. No unusual descriptions

TABLE III

Initial Odor and Flavor Scores, Peroxide Values and 8-Hour A.O.M. Values and Flavor Intensity Values for SBO and HWSBO

Evaluations	Oils A	B	C	D
Odor score[a]	8.6	9.0	7.5	9.0
Flavor score[a]	7.4 (0.5)[b]	7.8 (0.4)	6.9 (0.0)	8.2 (0.2)
80-hr A.O.M.	9.0	2.6	5.5	2.0
Flavor descriptions				
Buttery	0.7[c]	0.6	0.8	0.7
Beany	0.4	0.3	0.2	0.3
Grassy	0.2	0	0.3	0
Rancid	0.3	0	0.3	0
Other off flavors	0.4	0	0.6	0

[a]Odor and flavor scores are based on a 1-10 scale with 1 as intense and 10 as bland.

[b]Figures in parentheses are peroxide values determined at time of tasting.

[c]Description intensity values are based on scale of 0 = none, 1 = weak, 2 = moderate and 3 = strong intensity.

TABLE IV

Effect of Fluorescent Light Exposure in Air on Packaged Soybean Oils and Hydrogenated Soybean Oils

Accelerated light exposure (hr)	Oil code	Flavor intensity scores: Type of packaging: Glass: Amber	Glass: Clear	Plastic: Barex (AN)	Plastic: Cycopac (AN)	Plastic: PVC
		Soybean oils				
4	A	—[a]	6.2 (2.1)	6.3 (0.9)	6.8 (2.1)	—
	B[b]	7.8c (0.05)[c]	6.5d (1.5)	—	—	6.5d (1.3)
	B	—	6.8 (2.1)	6.6 (2.0)	7.2 (2.2)	—
8	A	—	5.8 (5.2)	6.1 (3.6)	6.2 (3.9)	—
	B[b]	7.8c (0.6)	5.7d (2.3)	—	—	5.9d (2.2)
	B	—	5.8 (2.7)	6.0 (2.1)	6.3 (2.0)	—
16	A	—	5.3 (7.3)	5.5 (5.2)	5.5 (5.3)	—
	B[b]	7.9c (0.6)	5.2d (2.6)	—	—	5.5d (2.5)
	B	—	6.2 (3.2)	6.0 (3.2)	6.0 (3.4)	—
24	A	—	4.9 (9.3)	5.1 (7.6)	5.1 (7.7)	—
	B[b]	7.7c (1.0)	6.0d (3.0)	—	—	5.7d (2.9)
	B	—	5.9 (4.3)	5.9 (3.9)	5.7 (3.9)	—
		Hydrogenated soybean oils				
4	C	—	6.4 (0.9)	6.8 (0.7)	6.4 (0.9)	—
	D[b]	7.6c (0.6)	6.7d (1.4)	—	—	6.8d (1.3)
	D[b]	—	6.3c (1.0)	7.1d (1.4)	5.7c (1.4)	—
8	C[b]	—	5.7c (1.2)	6.5d (0.9)	6.1cd (1.1)	—
	D[b]	7.5c (0.8)	6.3d (1.9)	—	—	6.8d (1.8)
	D	—	6.2 (1.6)	6.5 (1.8)	6.3 (1.5)	—
16	C	—	5.8 (2.4)	6.0 (1.2)	5.9 (1.5)	—
	D[b]	7.4c (0.8)	6.1d (2.5)	—	—	6.1d (2.4)
	D	—	6.0 (3.2)	6.4 (2.3)	6.3 (2.8)	—
24	C[b]	—	5.5c (3.6)	6.4d (2.5)	6.2cd (2.8)	—
	D[b]	7.6c (0.7)	6.1d (2.5)	—	—	6.3d (2.2)
	D	—	6.0 (3.2)	6.2 (3.6)	6.5 (3.5)	—

[a]— = not tested in this trial.

[b]Significant differences at the 1% level were noted in trials indicated; scores with letters in common are not significantly different.

[c]Figures in parentheses are peroxide values determined at the time of tasting.

TABLE V

Effect of Accelerated Storage in Air on Packaged Soybean Oils and Hydrogenated Soybean Oils

Days storage at 60 C	Oil code	Flavor intensity scores: Clear glass	Barex	Cycopac	PVC
		Soybean oils			
4	A[a]	5.1[c] (3.6)[b]	6.8d (3.7)	6.1d (4.1)	—[c]
	B	6.7 (1.6)	6.8 (1.4)	7.0 (1.4)	—
	B	6.1 (2.4)	—	—	6.2 (2.8)
8	A[a]	5.0c (17.6)	5.4c (21.0)	6.3d (18.6)	—
	B[a]	4.4c (7.3)	6.5d (7.3)	6.0d (10.5)	—
	B	5.1 (6.0)	—	—	4.8 (9.2)
		Hydrogenated soybean oils			
4	C	5.4 (3.6)	6.0 (6.7)	5.8 (9.9)	—
	D	7.2 (1.3)	6.8 (1.4)	7.2 (1.1)	—
	D	7.0 (2.3)	—	—	7.1 (2.2)
8	C[a]	4.7[c] (18.1)	5.7c (19.3)	5.5d (22.7)	—
	D	6.0 (6.0)	6.5 (6.4)	6.7 (7.7)	—
	D	6.6 (3.3)	—	—	6.4 (4.8)

[a]Significant differences at the 1% level were noted in the trials indicated; scores with letters in common are not significantly different.

[b]Figures in parentheses are peroxide values determined at the time of tasting.

[c]— = not tested in this trial.

TABLE VI

Effect of Long-Term Ambient Temperature Storage with Nitrogen on Packaged Soybean Oil

Months storage at 25 C	Flavor intensity scores			
	Type of packaging			
	Clear glass		PVC	
	SBO B	HWSBO D	SBO B	HWSBO D
4	7.1 (2.7)[a]	–[b]	7.0 (2.3)	–
		7.3 (1.0)		7.2 (1.1)
6	5.7 (13.9)	–	5.1 (33.6)	–
		7.2 (6.0)		7.0 (8.2)
9	5.8 (19.0)	–	6.2 (11.5)	–
		5.7 (21.2)		5.8 (33.7)
12[c]	3.5[d] (6.2)	–	6.2e (6.0)	–
		5.3 (48.0)		5.2 (53.0)

[a]Figures in parentheses are peroxide values determined at the time of tasting.

[b]– = not tested in this trial.

[c]Significant differences at the 1% level were noted in the trials indicated; scores with letters in common are not significantly different.

were reported for the oils aged in plastic. All oils became more rancid and painty with increased storage time.

Ambient Storage

Some doubts have been raised about the effectiveness of nitrogen for the protection of oils packaged in plastic because of the permeability of the plastic material to oxygen. Therefore, the effect of nitrogen in the headspace of oils packaged in clear glass and PVC bottles and aged at ambient conditions for 12 months was investigated with SBO and HWSBO. The results of these evaluations are presented in Table VI. No significant difference was found in the sensory evaluation of the oils aged in the long-term ambient temperature tests regardless of the packaging material used for bottling, except for the 12-month storage test for SBO in clear glass. This sample was given an unusually low flavor score, and the result may be considered untypical.

Based on these results, we can conclude that amber glass prevents oil deterioration from light exposure, whereas clear glass and PVC bottles allow significant but equal decreases in quality for both SBO and HWSBO. Deterioration of SBO is the same in Cycopac and Barex and clear glass bottles, but HWSBO samples, for unknown reasons, have significantly greater stability in Barex bottles than in clear glass. No differences were seen between HWSBO packaged in Cycopac and clear glass in light-exposure studies. Accelerated storage tests of SBO and HWSBO at 4 and 8 days, 60 C, also showed no significant difference between PVC and clear glass. However, in similar comparisons of clear glass, Barex and Cycopac bottles, the oils in plastic containers showed significantly less deterioration than the oils in clear glass in 3 of 6 SBO trials, but only in 1 of 6 HWSBO tests (Table V). Greater differences in oil quality of glass vs plastic are observed after 8 days' storage than after 4-day tests. In long-term ambient temperature studies, HWSBO or SBO show no differences in oil deterioration between glass and PVC packaging. Nitrogen treatment of oils in glass bottles does not increase the flavor stability compared with oils packaged in PVC bottles with nitrogen in the headspace. Therefore, PVC or AN bottles are acceptable alternatives to packaging oils in clear glass.

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