Composition and Sensory Qualities of Minimum-Refined Soybean Oils

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ABSTRACT: Commodity (normal) and high-oleic soybean oils extracted by extrusion-expelling (E-E) were minimally processed using water degumming and adsorptive deacidification to produce edible oil. Degummed and deacidified oils were deodorized at 150°C for 1 h by purging with N_2, CO_2, or steam. They were also conventionally deodorized for quality comparisons. Generally, the oxidative stability of the properly gas-purged commodity oils was better than that of the conventionally deodorized oils. Total tocopherols, FFA contents, and colors of the deodorized oils were not significantly different among the treatments. Sensory analysis of the oils showed that the toasty/nutty flavors of the gas-purged oils, especially for the degummed oils, were more intense than those of the conventionally deodorized oils. The beany flavors of gas-purged oils were not significantly different from those of conventionally deodorized oils, although the flavor intensities tended to be slightly higher in gas-purged oils. The overall flavor intensities of the gas-purged oils were similar to those of conventionally deodorized oils. Therefore, E-E soybean oil has the potential to be minimally refined to produce edible oil with good compositional and sensory qualities.

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KEY WORDS: Deodorization, extrusion-expelling, gas purging, minimum refining, sensory quality, soybean oil.

Most soybean oil is recovered by extracting with hexane, but mechanical extraction, particularly extrusion-expelling (E-E), is gaining popularity. Compared with traditional solvent extraction, E-E processing is simple, requires low capital investment, and eliminates the use of a flammable solvent. Crude E-E soybean oil has low contents of phosphorus and FFA and also a pleasant toasty flavor (1,2). The unusually high quality of crude soybean oil achieved by E-E processing makes it suitable for minimum (low-cost) refining (2). Conventional soybean oil refining involves degumming, neutralizing, bleaching, and deodorizing. Some of these procedures are harsh and costly. The oil may be subjected to hydrolysis, loss of natural antioxidants and healthy phytochemicals, thermal decomposition, and *trans* isomerization of PUFA (3,4). A simpler, milder, and lower-cost means of refining needs to be developed for E-E oil so that small E-E processors can obtain niche market opportunities. Water degumming and adsorbent deacidification have been shown to be feasible (5), but the flavors of such treated oils need to be improved.

Recently, N_2 has been used as stripping gas for deodorizing olive, sunflower, and soybean oils (4,6,7). There are certain advantages to using N_2 gas vs. steam, e.g., recovery of high-quality deodorizer distillates (8). Carbon dioxide also may be used as stripping gas, but its effectiveness is unknown. The dipole nature of the CO_2 molecule may allow it to interact more extensively with the relatively polar ketone and aldehyde off-flavor compounds, thus making them more easily removed. Therefore, the objective of this study was to evaluate the feasibility of mild deodorization, i.e., gas purging using N_2, CO_2, and steam at relatively low temperature, to minimally process commodity (CO) and high-oleic (HO) soybean oils recovered by E-E processing. E-E is considered a suitable means for processing identity-preserved soybeans, such as HO seeds. HO oil is believed to be more stable to lipid oxidation and off-flavor formation than CO oil. It would be important to study whether different types of oil behave differently under our minimal refining conditions.

EXPERIMENTAL PROCEDURES

Minimum-refining soybean oil. CO and HO soybean oils were obtained from Iowa Soy Specialties (Vinton, IA), and they were extracted by using E-E processing. The crude oils were allowed to settle in a refrigerator to remove meal fines and any hydrated gums. The oils were then degummed by adding 3% distilled water at 60°C and mixing for 1 h. The gums were removed by centrifuging at 12,000 × *g* for 10 min. The degummed CO and HO oils were each divided into two lots. One lot of each oil was retained for direct gas purging and conventional deodorization without deacidifying, and the other lot was treated with 3% Magnesol (Dallas Group of America, Jeffersonville, IN) at 85–90°C in a rotary evaporator at 150 rpm and 23 mm Hg for 20 min, following methods modified from Wang and Johnson (2) to remove FFA. The Magnesol-treated oil was filtered using Whatman No. 4 filter paper to remove the adsorbent, and the oil was then deodorized by gas purging and conventional deodorizing, using the experimental methods described below. Scheme 1 summarizes the processing steps and treatments.

Gas-purging deodorization. Four minimally processed oils (degummed CO, degummed HO, Magnesol-treated CO, and Magnesol-treated HO) were purged using N_2, CO_2, or steam

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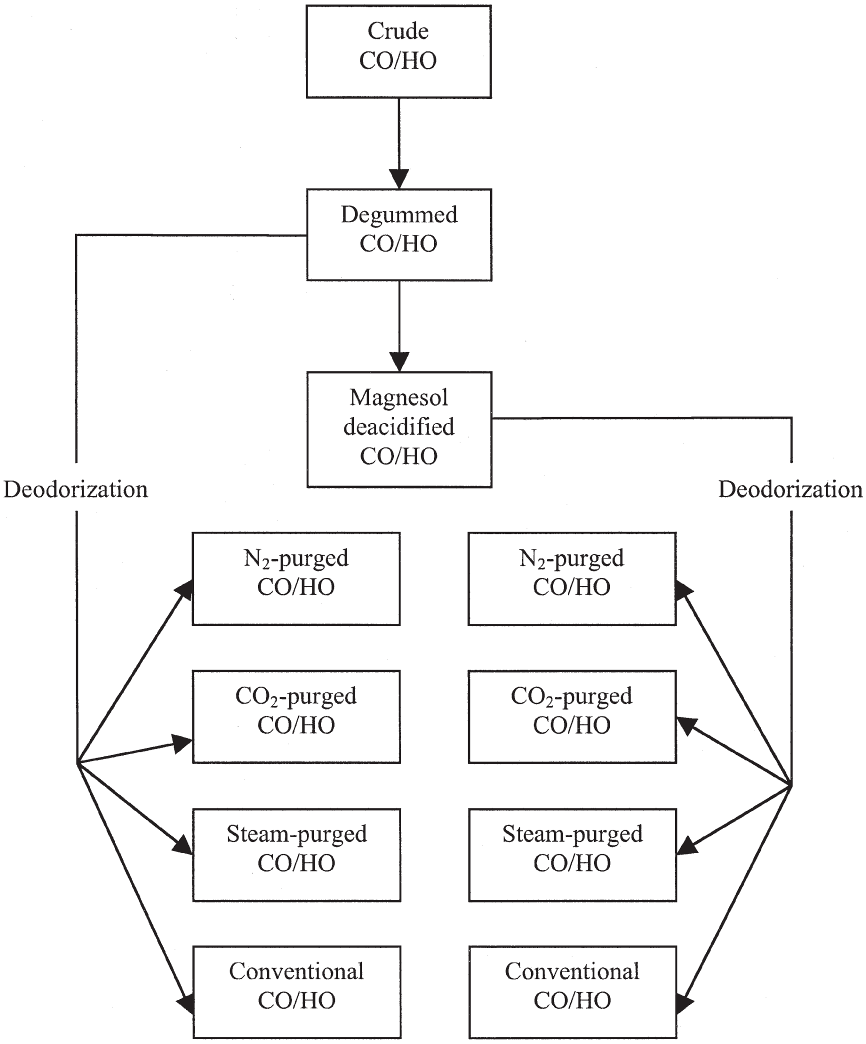

SCHEME 1

at 150°C for 1 h with the apparatus shown in Figure 1. About 250 g of oil was introduced into the round-bottomed, three-necked flask. Gas or steam was introduced at 1.5 mL/min flow rate, and the flask was subjected to vacuum. A 1000-mL trap immersed in an ice bath was connected between the oil flask and the vacuum source to collect any carryover, due to potential operational problems (e.g., foaming), and condensed materials produced during purging. The oil flask was immersed in hot glycerin, used as the heating medium, and the temperature was maintained at 150°C. After the gas-purging treatment, the oil flask was cooled to room temperature, and the oil was stored in a refrigerator before quality analyses and sensory evaluation. To test the effect of vacuum level on deodorization, the four different oils also were purged using N_2 under vacuum produced by a water aspirator, which generated 23–25 mm Hg of vacuum. Duplicate deodorization trials were done with each type of oil.

Conventional deodorization. The degummed and deacidified CO and HO oils were deodorized at 265°C with a laboratory continuous deodorizer as described previously by Wang and Johnson (5). Steam was used as stripping gas, and the vacuum was maintained between 2 and 6 mm Hg. The oil flow rate was 10 mL/min, which was equivalent to a 9-min residence time. Duplicate deodorizations were performed.

Oil quality analyses. The oil samples were analyzed by using standard AOCS methods (9) for PV (AOCS Cd 8-53), anisidine value (*p*-AV, AOCS Cd 18-90), FFA content (AOCS Ca Sa-40), phosphorus content (AOCS Ca 12-55), oxidative stability index (OSI, AOCS Cd 12b-92), and color (AOCS Cc 13b-45). All analyses were done in duplicate.

Tocopherol analyses. Tocopherol contents (α, δ, and γ) of the oil samples were quantified by using an HPLC method modified from the standard AOCS method (9; AOCS Ce 8-89). The Beckman Gold System HPLC (System Gold 126 Solvent Module, System Gold 168 Detector) with a microparticulate silica-packed column (250 × 4 mm) was used. The mobile phase was 2-propanol/hexane (1.5:98.5 vol/vol), at 0.4 mL/min flow rate.

Sensory evaluation. Each oil sample was randomly chosen from the replicates and evaluated by nine trained panelists. Three 40-min training sessions were conducted. Panelists, sitting around a table, were provided with a broad selection of

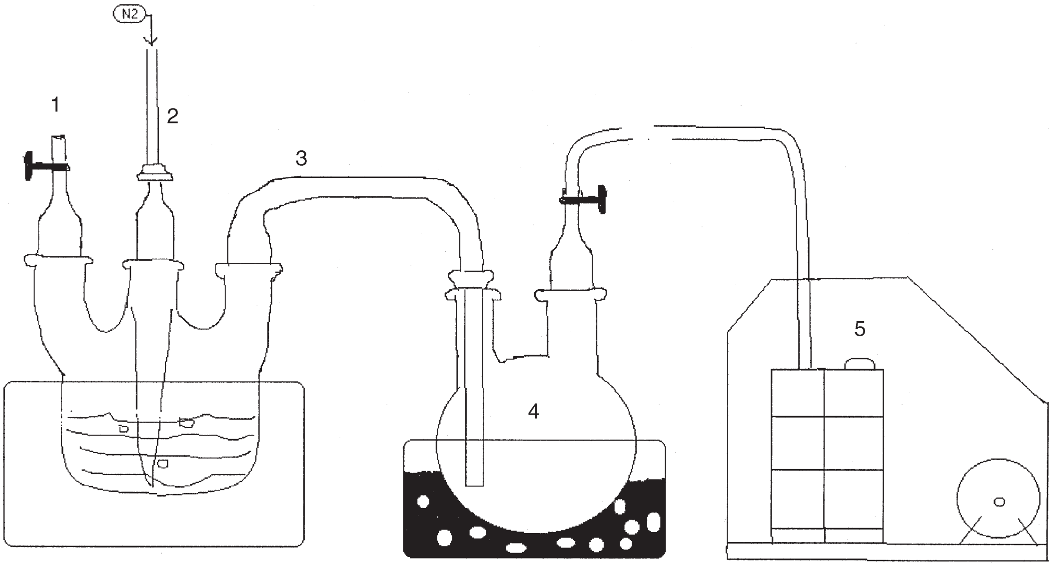

FIG. 1. Gas-purging apparatus (1, vacuum break; 2, gas inlet; 3, gas outlet; 4, trap; 5, vacuum pump).

reference samples (five oils plus a fresh commercial soybean oil) representing the quality range of our products. Panelists developed and defined the common terminologies, as well as the intensity scores to be used by the entire panel. The five reference samples were selected from various processing stages, and they represented the wide range of flavor and intensity. For sensory evaluation, four oil samples and a commercial oil (as reference) were provided for each session. The standard AOCS method (Cg 2-83) was used as the evaluation guide. A line scale or graphic-rating scale (15 cm long) was used to rate each oil for toasty/nutty flavor, buttery flavor, beany/grassy flavor, overall flavor intensity, and desirability. The graphic line was directed from left to right for increasing intensity. For flavor, the range (left to right) was from "bland" to "extremely strong," and for desirability, the range was from "like extremely" to "dislike very much." The panelists placed a vertical line at the position that best reflected the intensity of that characteristic. The distance from the left end to the vertical line was used to quantify the response (10). The desirability evaluation was considered a preliminary test of consumer preference and acceptance.

Statistical analysis. The data were analyzed by ANOVA and general linear model (GLM), and the least significant differences (LSD) were calculated to compare treatment means (11). A factorial experimental design with two or three main factors, each at two to five treatment levels, was used for the experiment. All refining processes were conducted in duplicate. The analyses of each sample were performed in duplicate.

RESULTS AND DISCUSSION

Effects of degumming and adsorbent treatment on oil quality. Data presented in Table 1 show that oil type significantly affected PV, tocopherol content, FFA, and color. OSI data were collected before HO reached its OSI, so oil type was not considered as a factor for OSI. Processing step significantly

TABLE 1
Quality Characteristics of Different Soybean Oil Types and at Different Refining Steps[a]

		Oil quality characteristics						
Oil type	Processing step	PV (meq/kg)	*p*-AV	OSI (h)	Toco (ppm)	FFA (%)	Color (red)	Phosphorus[b] (ppm)
CO	Crude	0.73^{b}	0.32^{a}	27.1^{a}	960^{b}	0.13^{d}	11.5^{a}	216
	Degummed	0.86^{a}	0.14^{c}	14.0^{b}	961^{b}	0.02^{e}	8.3^{b}	0
	Deacidified	0.22^{f}	0.14^{c}	13.2^{b}	951^{b}	0.01^{e}	$7.6^{d,e}$	0
HO	Crude	0.29^{e}	0.24^{b}	>60.0	1113^{a}	0.59^{a}	7.9^{c}	318
	Degummed	0.44^{c}	0.16^{c}	>60.0	1089^{a}	0.53^{b}	7.7^{d}	0
	Deacidified	0.39^{d}	0.21^{b}	>60.0	1098^{a}	0.34^{c}	7.6^{e}	0
$LSD_{0.05}$		0.04	0.03	2.4	91	0.03	0.1	

[a] Mean values with different superscripts in the same column are significantly different ($P < 0.05$).
[b] Data not analyzed by SAS (Cary, NC). HO, high-oleic soybean oil; CO, commodity soybean oil; *p*-AV, *p*-anisidine value; OSI, oxidative stability index; Toco, tocopherols ($\alpha + \gamma + \delta$).

TABLE 2
Oxidative Quality of Oils After Various Deodorization Treatments[a]

		No deodorization	N_2	CO_2	Steam	Conventional deodorization
PV (meq/kg), $LSD_{0.05}$ = 0.13						
CO	Degummed	0.86	0.86	0.71	0.82	0.39
	Deacidified	0.22	0.37	0.49	0.39	0.36
HO	Degummed	0.44	0.52	0.44	0.71	0.30
	Deacidified	0.39	0.32	0.38	0.74	0.16
p-AV, $LSD_{0.05}$ = 0.08						
CO	Degummed	0.14	0.23	0.38	0.25	0.22
	Deacidified	0.14	0.25	0.18	0.25	0.25
HO	Degummed	0.16	0.16	0.14	0.50	0.17
	Deacidified	0.21	0.25	0.17	0.53	0.18
OSI (h, at 100°C), $LSD_{0.05}$ = 1.19						
CO	Degummed	14.0	13.5	12.8	9.9	11.4
	Deacidified	13.2	13.0	11.9	10.0	11.1
HO	Degummed	>70.0	>70.0	>70.0	>70.0	>70.0
	Deacidified	>70.0	>70.0	>70.0	>70.0	>70.0

[a]For abbreviations see Table 1.

affected PV, *p*-AV, OSI, FFA, and color, but not tocopherol contents. There were significant interactions ($P < 0.05$) between oil type (CO and HO) and processing step (degumming and adsorbent treatment) for PV, *p*-AV, FFA, and color, but not for tocopherol contents.

Degumming by adding 3% water at 60°C and mixing for 1 h effectively removed phosphorus in both CO and HO (Table 1). Furthermore, degumming significantly decreased *p*-AV, FFA, and color. This reduction was probably due to absorption of secondary oxidation compounds, FFA, and carotenoids by the hydrated gum. Degumming increased PV for both types of oil. The increased PV was attributed to the heating during degumming, which promotes lipid oxidation. Because of the increased PV and reduced phospholipids after degumming, the stability of degummed CO significantly decreased compared with crude CO (14 vs. 27 h at 100°C). Because of the high stability of HO, no differences in OSI due to processing step were observed.

Deacidifying by treating oil with Magnesol significantly decreased FFA content of HO but did not significantly decrease FFA content of CO because of the low FFA content after degumming. Adsorptive deacidification also significantly decreased PV and color because of the adsorptive activity of Magnesol. Such deacidification treatment appears not to affect the PV of HO oil as much as does that of CO oil. *p*-AV slightly, but statistically significantly, increased for HO and decreased for CO during adsorptive deacidification. The other chemical characteristics, i.e., OSI and tocopherol contents, did not significantly change with adsorptive deacidification. The deacidified HO had much higher OSI and FFA and tocopherol contents than did CO because of the differences in their initial compositions.

Effect of deodorization on oil quality. Qualities of oil after various deodorization treatments are presented in Tables 2 and 3. Oil type (CO and HO), extent of processing (degumming and deacidifying), and deodorization treatment had sig-

TABLE 3
Tocopherol, FFA, and Color of Oils After Various Deodorization Treatments[a]

Oil type	Extent of processing	No deodorization	N_2	CO_2	Steam	Conventional deodorization
Total tocopherol (ppm), $LSD_{0.05}$ = 86						
CO	Degummed	961	963	1004	1029	892
	Deacidified	951	953	956	946	948
HO	Degummed	1089	1143	1148	1171	1161
	Deacidified	1098	1115	1078	1132	1081
FFA (%), $LSD_{0.05}$ = 0.05						
CO	Degummed	0.02	0.02	0.19	0.03	0.02
	Deacidified	0.01	0.01	0.15	0.01	0.01
HO	Degummed	0.53	0.47	0.50	0.52	0.53
	Deacidified	0.34	0.32	0.66	0.32	0.32
Color (red), $LSD_{0.05}$ = 0.99						
CO	Degummed	8.3	7.8	7.8	7.6	7.6
	Deacidified	7.6	7.6	7.6	7.0	7.6
HO	Degummed	7.7	7.0	7.0	6.5	6.5
	Deacidified	7.6	6.8	5.1	5.5	5.0

[a]For abbreviations see Table 1.

nificant interactions ($P < 0.05$) for PV and p-AV. Each factor significantly affected PV ($LSD_{0.05} = 0.13$), and only deodorization treatment significantly affected p-AV ($LSD_{0.05} = 0.08$). Extent of processing and deodorization treatment significantly affected OSI ($LSD_{0.05} = 1.19$) of CO.

After various deodorization treatments, all oil samples had acceptable PV values, although the values were not as low as with conventional deodorization. The deacidified and deodorized oils had lower PV than the degummed and deodorized oils owing to the initial lower PV. Conventional deodorization uses higher temperatures, which result in a greater degree of peroxide decomposition. All p-AV values were about 0.2, except for the HO oils purged with steam. It is interesting to note that deodorization using steam as the stripping gas significantly increased PV and p-AV of HO oils. HO oil is expected to be more resistant to oxidation, and its high OSI value supports this. It is unknown if HO soybean oil has a different mechanism of oxidation and peroxide decomposition than that of the common soybean oil. Differences in flavor profile were also noticed during sensory evaluation of the two oils. There were no significant differences in OSI between degummed or deacidified CO under the same deodorization treatments, although the deacidified oils tended to have lower stability. The stability of N_2-purged oils was similar to that of the undeodorized oils, and they were both more stable than the conventionally deodorized oils. The CO_2-purged oils had stabilities in between that of the N_2-purged and conventionally deodorized oils. HO had much higher OSI than CO because of its low PUFA content.

A certain problem is inherent with using steam at relatively low temperature (150°C). Steam generated in the described apparatus tended to condense at the steam inlet, and the stripped components and steam also recondensed on the headspace wall of the oil flask, resulting in difficulty in achieving effectively deodorized oil. The stronger vacuum (due to the steam condensation) compared with using other gases may draw air into the deodorization apparatus through the steam generator, resulting in a certain degree of lipid oxidation.

Total tocopherol and FFA contents and color are summarized in Table 3. Oil type, processing stage, and deodorization significantly affected FFA content and color. Only oil type significantly affected tocopherol content. HO oil contained more tocopherol than did CO because of the initial higher content. It was expected that the conventional deodorization would significantly reduce tocopherol content of the oil as a result of the high temperature and vacuum used in the commercial operation. However, our laboratory-scale deodorization did not change the tocopherol content significantly. The reason may be that the residence time of the oil in the column was relatively short (9 min).

There was no significant change in FFA after mild deodorization with nitrogen or steam as stripping forces or with conventional deodorization. FFA increased in CO_2-purged oils, possibly because the CO_2 dissolved in the oil during the

TABLE 4
Sensory Evaluation of Refined Soybean Oils

Oil type	Extent of processing	No deodorization	N_2	CO_2	Steam	Conventional deodorization
Toasty/nutty flavor, $LSD_{0.05} = 2.0$						
CO	Degummed	9.5	4.4	2.7	7.8	1.7
	Deacidified	N/A[a]	1.5	1.0	3.4	1.5
HO	Degummed	4.3	2.8	1.8	4.9	2.7
	Deacidified	N/A	1.8	1.7	2.5	1.5
Buttery flavor, $LSD_{0.05} = 1.6$						
CO	Degummed	1.9	2.7	3.3	1.6	2.6
	Deacidified	N/A	1.9	1.4	1.8	1.9
HO	Degummed	1.2	2.8	2.2	0.8	2.8
	Deacidified	N/A	1.9	2.3	1.5	2.4
Beany flavor, $LSD_{0.05} = 1.9$						
CO	Degummed	3.3	1.1	1.6	4.0	1.7
	Deacidified	N/A	1.5	2.4	3.4	1.1
HO	Degummed	6.9	3.8	3.0	8.0	4.8
	Deacidified	N/A	2.8	1.5	6.9	1.3
Overall flavor intensity, $LSD_{0.05} = 2.0$						
CO	Degummed	11.1	5.4	4.5	8.6	3.4
	Deacidified	N/A	2.5	2.6	5.4	2.2
HO	Degummed	10.2	5.3	4.5	10.2	5.1
	Deacidified	N/A	4.0	3.0	7.6	2.4
Desirability, $LSD_{0.05} = 2.0$						
CO	Degummed	8.7	5.4	6.3	9.6	4.3
	Deacidified	N/A	4.1	5.1	7.0	3.8
HO	Degummed	10.8	7.9	6.4	11.1	8.3
	Deacidified	N/A	6.4	4.3	9.0	3.1

[a] N/A, samples had a strong unpleasant flavor and were not included in sensory evaluation. For other abbreviations see Table 1.

purging treatment resulted in increased apparent FFA content. The red oil color decreased during deodorization or any heat treatment. The carotenoids are the main source of yellow/red color of the oil, and they are susceptible to heat destruction. Carotenoids were destroyed by heating during deodorization, which resulted in decreased red color.

Sensory evaluation. The results from sensory analysis are summarized in Table 4. Each of the main factors, i.e., oil type, processing step, and deodorization treatment, significantly affected toasty/nutty flavors of the oils. All four deodorization treatments significantly decreased toasty/nutty flavors (Table 4). Among the four deodorization treatments, conventional deodorization and gas purging with N_2 and CO_2 were much more effective in removing toasty/nutty flavors than was steam purging because of the problem with the gas purging apparatus described above. Compared with N_2, CO_2 seemed more effective in removing the toasty/nutty flavor. For the two oils at different processing steps, the deodorized degummed oil always had stronger flavor than did the deodorized Magnesol-treated oil, because of adsorption and removal of off-flavor compounds by Magnesol.

Among the three main factors, only deodorization treatment significantly affected buttery flavor. After gas-purging deodorization, buttery flavor tended to increase for all but the steam-treated oil samples. The change in this flavor was opposite to the toasty/nutty flavor, possibly because the strong toasty/nutty flavor masked the buttery flavors of the untreated samples. Therefore, the buttery flavor was relatively stronger compared with the toasty/nutty flavor after deodorization.

All three main factors significantly affected beany flavor. Oil type and processing step significantly interacted for beany flavor, and oil type and deodorization treatment significantly interacted as well. Degummed HO had much greater beany flavor than did commodity oil. Conventional deodorization and gas purging significantly decreased the beany flavor except for the steam treatment, for the same reasons as previously discussed. The beany flavors of oils treated by conventional or gas-purging deodorization were not statistically different, indicating that simple gas purging at lower temperature produced good-quality oil. The flavor difference between HO and CO may be due to the differences in their FA compositions. The unique composition of HO may make it a good precursor of certain volatiles that are responsible for the flavor we observed.

All three main factors significantly affected overall flavor intensity. Conventional deodorization and gas purging significantly reduced overall flavor intensity except for deodorization using steam. Deodorized Magnesol-treated oil had lower flavor intensity than did deodorized degummed oil because of the adsorption of flavors by Magnesol. Gas purging was as effective as conventional deodorization in achieving overall flavor intensity and quality.

All three main factors significantly affected desirability. Various deodorization treatments significantly increased the desirability (decreased the score) except for steam treatment. Magnesol-treated oil had higher desirability than the corresponding degummed oil after deodorization, although Magnesol-treated oil had a stronger unpleasant flavor before deodorization than

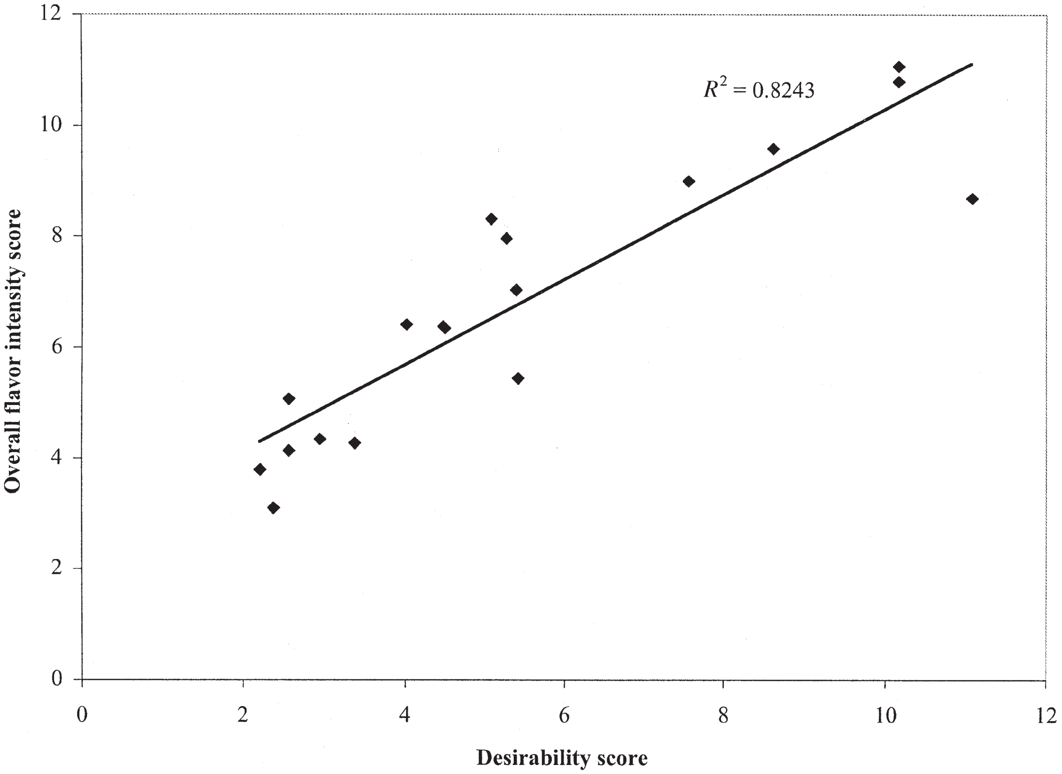

FIG. 2. Correlation between desirability and overall flavor intensity scores of soybean oils refined by various means.

TABLE 5
Comparison of N_2 Purging Under Partial Vacuum (23 mm Hg) and Full Vacuum (2 mm Hg)

			Chemical composition[a]					
Oil type	Extent of processing	Vacuum	PV (meq/kg)	*p*-AV	OSI (h)	Toco (ppm)	FFA (%)	Color (red)
CO	Degummed	Full vacuum	0.85	0.23	14.0	963	0.02	7.8
		Partial vacuum	0.92	0.26	13.8	984	0.03	7.7
	Deacidified	Full vacuum	0.37	0.25	13.0	953	0.01	7.6
		Partial vacuum	0.40	0.23	11.1	939	0.01	6.5
HO	Degummed	Full vacuum	0.52	0.16	>70.0	1143	0.45	7.0
		Partial vacuum	0.48	0.25	>70.0	1140	0.52	7.6
	Deacidified	Full vacuum	0.32	0.25	>70.0	1115	0.32	6.8
		Partial vacuum	0.33	0.23	>70.0	1111	0.31	6.5
	$LSD_{0.05}$		0.29	0.09	0.62	78.83	0.06	1.52

			Sensory evaluation				
Oil type	Extent of processing	Vacuum	Toasty	Buttery	Beany	Overall intensity	Desirability
CO	Degummed	Full vacuum	4.4	2.7	1.1	5.4	5.4
		Partial vacuum	3.2	2.0	1.3	4.5	6.2
	Deacidified	Full vacuum	1.5	1.9	1.5	2.5	4.1
		Partial vacuum	1.3	2.0	1.7	3.0	5.2
HO	Degummed	Full vacuum	2.8	2.8	3.8	5.3	7.9
		Partial vacuum	3.1	2.2	4.1	5.6	7.8
	Deacidified	Full vacuum	1.8	1.9	2.8	4.0	6.4
		Partial vacuum	3.3	2.3	3.3	4.7	6.0
	$LSD_{0.05}$		2.0	1.6	1.8	1.9	2.2

[a] For abbreviations see Table 1.

did degummed oil. Magnesol treatment not only removed FFA but also improved the flavors of the deodorized oils. Generally, there were no significant differences in overall desirability scores between gas-purged and conventionally deodorized oils.

The correlation between desirability and overall flavor intensity showed that there was high correlation between overall flavor intensity and desirability ($r = 0.91$). The higher the flavor intensity score, the lower the desirability (higher score) (Fig. 2). Although the preliminary desirability test showed the results we anticipated, we recognize the limit of this test. Usually, a quantitative preference and/or acceptance test needs a large group of panelists/consumers (50 to several hundred) (12); we used only nine trained panelists. Therefore, our result on desirability should be considered preliminary. Further consumer sensory evaluation will be conducted in the future.

Deodorization under two vacuum conditions. There were no significant differences in oil quality (PV, *p*-AV, OSI, color, and tocopherol and FFA contents) between N_2 purging under partial vacuum (about 23 mm Hg, generated by water aspirator) and full vacuum (about 2 mm Hg, gnerated by vaccum pump) (Table 5), indicating that a partial vacuum, such as the level achieved by a common water aspirator, could be used effectively for deodorizing by gas purging.

There were no significant differences in flavor qualities of oils deodorized under different vacuum levels (Table 5). Therefore, a water-aspirator vacuum could be used in the gas-purge deodorization, which should reduce capital and operating costs.

The purpose of deodorization is to remove any unpleasant flavor compounds, thus producing oils with acceptable flavors. The off-flavor compounds of soybean oil come from the low-M.W. ketones or aldehydes. The thresholds for these compounds are so low that sometimes they cannot be accurately quantified. However, they can be quantified by sensory analysis. Sensory evaluation and chemical analyses demonstrated the feasibility of minimal refining. The critical temperature was 150°C for gas purging using either N_2 or CO_2. These two gases had similar efficiency in removing off-flavor compounds. This research also showed that absorptive treatment, such as with Magnesol, is necessary for removing the primary and secondary oxidation compounds if a bland-tasting oil is desired after gas-purging deodorization.

In summary, the compositional and sensory qualities of the minimally refined E-E soybean oils were very comparable to those of conventionally refined oils. Therefore, E-E soybean oils have the potential to be minimally refined to produce unique products.

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