Effects of Processing on the Oxidative Stability of Soybean Oil Produced in Mexico

L.A. Medina-Juárez[a,]*, P. González-Díaz[b], N. Gámez-Meza[a], J. Ortega-García[a], A.B. Moreno-Varela[a], L. Bringas-Alvarado[a], and O. Angulo-Guerrero[c]

[a]Departamento de Investigaciones Científicas y Tecnológicas de la Universidad de Sonora, Hermosillo, Sonora, México, [b]Asociación Americana de Soya, D.F., México, and [c]Departamento de Ing. Química y Bioquímica, Instituto Tecnológico de Veracruz, Veracruz, México

ABSTRACT: The stability parameters of 22 samples of soybean oil produced in Mexico were determined. Samples were analyzed for moisture, color, free fatty acids, peroxide value, *p*-anisidine value, fatty acid profile, metals, flavor, and Rancimat test for oxidative stability. Results obtained were compared with the stability parameters of soybean oils produced in the United States and Costa Rica. The fatty acid profile in all samples analyzed corresponded to the expected profile for a 100% soybean oil. Sixty-four percent of the oils had oxidative stabilities similar to those reported for soybean oils from the United States and Costa Rica. This suggests that in spite of the good quality, the soybean oil production process in Mexico needs further improvement. Especially important is maintaining appropriate control during the degumming and bleaching steps. Special consideration should be given to preserving the natural antioxidants present in the oil.

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KEY WORDS: Oxidative stability, quality parameters, Rancimat, soybean oil produced in Mexico.

Soybean is the most important oilseed in the world market. During 1995–1996, the breakdown of 245 million metric tons of worldwide oilseed production was soybean, 51%; rapeseed, 14.3%; cottonseed, 13.9%; peanut, 10.6%; and sunflower 10.5% (1). Factors that contribute to soybean's importance worldwide are the high demand for soy flakes and oil. The consumption of soybean oil in the United States is higher than for any other vegetable oil. During 1992, 77% of the total fats and oils consumed in the United States was soybean oil (2).

The high polyunsaturated fatty acid (PUFA) content in soybean oil is very attractive for meeting the essential fatty acid requirements in human nutrition (3). The PUFA in soybean oil, however, are susceptible to oxidative reactions. Therefore, appropriate processing conditions should be used to eliminate or reduce impurities such as phospholipids, gums, metals, free fatty acids (FFA), oxidation products, and pigments, in order to ensure the best oil quality attributes. The impurities are eliminated through degumming (4–7), caustic refining (8), bleaching (9–11), and deodorization (12,13). The purpose of the present study was to analyze the oxidative stability of 22 soybean oil samples (M1–M22) produced in 18 refining factories in Mexico (60% of total refining factories). The stability parameters analyzed were moisture, color, FFA, peroxide value (PV), *p*-anisidine value (AV), flavor, phosphorus, trace minerals, oxidative stability, and fatty acid profile. The results were compared to those found in soybean oils produced in the United States (E1, E2) and Costa Rica (C1).

EXPERIMENTAL PROCEDURES

Oil sample collection. Oil samples from the local markets in Mexico and Costa Rica were collected by the American Soybean Association-Mexico. Reference oil samples were purchased in the United States of America.

Quality and stability parameters. Quality parameters were checked in all samples immediately after arrival at the laboratory. In order to test for oxidative stability, all samples were stored in closed clear plastic containers and exposed to light at room temperature (27–30°C) continuously for 180 d. Certain analyses were performed at arrival and on a monthly basis: moisture (Ca 2d-25), color (Cc 13e-92), FFA (Ca 5a-40), PV (Cd 8-53), AV (Cd 18-90), flavor (Cg 2-83), and phosphorus (Ca 12-55). The analyses were performed according to standard methods of the AOCS (14). Copper, calcium, magnesium, and iron were determined with atomic absorption spectrophotometry (Perkin-Elmer 3100; Perkin-Elmer de Mexico, Mexico, D.F.). The oil stability index was determined using the Totox (AV + 2PV), (15,16) (M1–M15) and with Metrohm Rancimat (Metrohm 679; Herisau, Switzerland) (M16–M22). The oil sample size was 3.0 g, the air flow rate was 20 L/h, and the temperature was set at 110°C (17,18). Fatty acids from oil samples were analyzed as methyl esters (AOCS Ce 2-66) by gas chromatography in a Varian 6000 chromatograph. A flame-ionization detector and a 6 ft × 1/8″ stainless steel packed column of GP 3% SP-2310/2% SP-2300 as packing material (Chromosorb W AW; Supelco Inc., Bellefonte, PA) were used. The initial oven temperature was 190°C for 2 min.; this was increased to 220°C at 2°C/min. The carrier gas was nitrogen with a flow rate of 20 mL/min. Retention times and peak areas were processed by a computing integrator Varian CDS 401 Varian de Mexico, Mexico, D.F. Identification and quantitation were done by com-

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*To whom correspondence should be addressed at Departamento de Investigaciones Científicas y Tecnológicas de la Universidad de Sonora. Apartado Postal #1819, 83000, Hermosillo, Sonora, México.
E-mail: amedina@guayacan.uson.mx

TABLE 1
Moisture and Color in Soybean Oil Samples

Soybean oil	Moisture (%)[a]	Color (Lovibond)
E1	0.08 ± 0.02^{c}	2.0Y 0.1R
E2	0.08 ± 0.01^{c}	2.0Y 0.3R
C1	0.12 ± 0.01^{d}	9.0Y 0.7R
M1	0.12 ± 0.01^{d}	8.0Y 0.7R
M2	0.08 ± 0.01^{c}	9.0Y 0.7R
M3	0.13 ± 0.01^{d}	20.0Y 0.1R
M4	0.04 ± 0.01^{b}	20.0Y 0.1R
M5	0.10 ± 0.01^{d}	8.0Y 0.1R
M6	0.07 ± 0.00^{c}	8.0Y 0.2R
M7	0.09 ± 0.00^{d}	20.0Y 1.0R
M8	0.07 ± 0.00^{c}	20.0Y 0.9R
M9	0.05 ± 0.01^{b}	20.0Y 1.1R
M10	0.04 ± 0.00^{b}	20.0Y 1.0R
M11	0.06 ± 0.01^{b}	20.0Y 0.9R
M12	0.13 ± 0.01^{d}	9.0Y 0.7R
M13	0.10 ± 0.01^{d}	2.0Y 0.1R
M14	0.12 ± 0.01^{d}	1.7Y 0.1R
M15	0.11 ± 0.01^{d}	9.9Y 0.5R
M16	0.05 ± 0.00^{b}	5.0Y 0.2R
M17	0.10 ± 0.00^{d}	3.0Y 0.1R
M18	0.09 ± 0.01^{d}	6.0Y 0.7R
M19	0.13 ± 0.01^{d}	7.0Y 0.1R
M20	0.09 ± 0.01^{d}	3.1Y 0.1R
M21	0.08 ± 0.01^{c}	6.0Y 0.2R
M22	0.06 ± 0.01^{b}	8.0Y 0.5R

[a] Values with different superscripts ($^{b-d}$) are significantly ($P < 0.05$) different. Y = Yellow, R = Red.

parison with the retention times and peak areas of known standards (Sigma, St. Louis, MO).

Statistical analysis. Data obtained were subjected to one-way analysis of variance and Tukey's test analysis. Significance was declared at $P < 0.05$. Chart control was also prepared to detect any trend in quality oil behavior by using statgraphic software (Statistical Graphics Corp., Rockville, MD).

RESULTS AND DISCUSSION

Samples are presented beginning with the initial letter of each country (samples from Mexico are represented as M1–M22, samples from the United States as E1 and E2, and the sample from Costa Rica as C). C1 samples from the United States are named as reference samples. Results are expressed as the mean of two replicates and standard deviation.

Moisture. Soybean oils from Mexico (45%) presented acceptable moisture levels (average moisture 0.08%), when compared with the values obtained from reference oils E1 and E2 (0.08%) (Table 1).

Color. Reference oils, and samples M13 and M14 had the lowest color intensity. All oils, however, achieved the color criteria established by the Official Mexican Norm (19), 20Y 3R (Table 1).

FFA. The majority of the Mexican oils tested (73%) and the oil from Costa Rica exhibited FFA levels of between 0.04 and 0.06%. These values corresponded to the upper limit level of FFA recommended for refined oils but not for deodorized oils (4,13). However, there was no significant difference ($P < 0.05$) in FFA between oils from the United States (E1 and E2) and the oils produced in Mexico (M1, M17, M18, M21, and M22). The maximal level of FFA recommended for deodorized edible oil is 0.03% (13), (Table 2). In general, FFA levels did not correlate with the sensory attributes of the oil samples (Fig. 1).

TABLE 2
Free Fatty Acids, Peroxide Value, and *p*-Anisidine Value of Soybean Oil Samples[a]

Soybean oil	Free fatty acids (% oleic acid)	Peroxide (mEq/kg oil)	*p*-Anisidine
E1	0.03^{b}	0.39 ± 0.01^{b}	0.67 ± 0.01^{b}
E2	0.02^{b}	0.49 ± 0.01^{b}	1.59 ± 0.05^{b}
C1	0.04^{c}	0.67 ± 0.07^{b}	0.53 ± 0.00^{b}
M1	0.03^{b}	$1.94 \pm 0.15^{d,e}$	1.87 ± 0.00^{c}
M2	0.05^{d}	1.12 ± 0.07^{c}	0.50 ± 0.07^{b}
M3	0.05^{d}	1.52 ± 0.05^{c}	1.11 ± 0.21^{b}
M4	0.05^{d}	2.11 ± 0.02^{e}	2.32 ± 0.00^{d}
M5	0.06^{e}	1.60 ± 0.19^{d}	1.57 ± 0.09^{b}
M6	0.06^{e}	3.68 ± 0.38^{f}	4.83 ± 0.29^{f}
M7	0.05^{d}	0.32 ± 0.00^{b}	1.73 ± 0.14^{c}
M8	0.04^{c}	0.27 ± 0.00^{b}	1.59 ± 0.38^{b}
M9	0.04^{c}	0.28 ± 0.00^{b}	1.58 ± 0.37^{b}
M10	0.05^{d}	0.69 ± 0.01^{b}	1.41 ± 0.10^{b}
M11	0.04^{c}	1.48 ± 0.00^{c}	1.35 ± 0.24^{b}
M12	0.07^{e}	0.75 ± 0.03^{b}	1.00 ± 0.21^{b}
M13	0.06^{e}	0.36 ± 0.01^{b}	1.55 ± 0.17^{b}
M14	0.06^{e}	0.44 ± 0.02^{b}	0.75 ± 0.09^{b}
M15	0.06^{e}	0.68 ± 0.03^{b}	0.73 ± 0.21^{b}
M16	0.04^{c}	0.64 ± 0.04^{b}	3.90 ± 0.52^{e}
M17	0.03^{b}	0.35 ± 0.09^{b}	1.17 ± 0.18^{b}
M18	0.03^{b}	0.60 ± 0.03^{b}	0.82 ± 0.01^{b}
M19	0.04^{c}	0.60 ± 0.01^{b}	1.00 ± 0.05^{b}
M20	0.04^{c}	0.62 ± 0.02^{b}	0.57 ± 0.16^{b}
M21	0.03^{b}	0.71 ± 0.05^{b}	0.66 ± 0.06^{b}
M22	0.02^{b}	0.69 ± 0.00^{b}	3.61 ± 0.10^{e}

[a] Values in columns with different superscripts ($^{b-f}$) are significantly ($P < 0.05$) different.

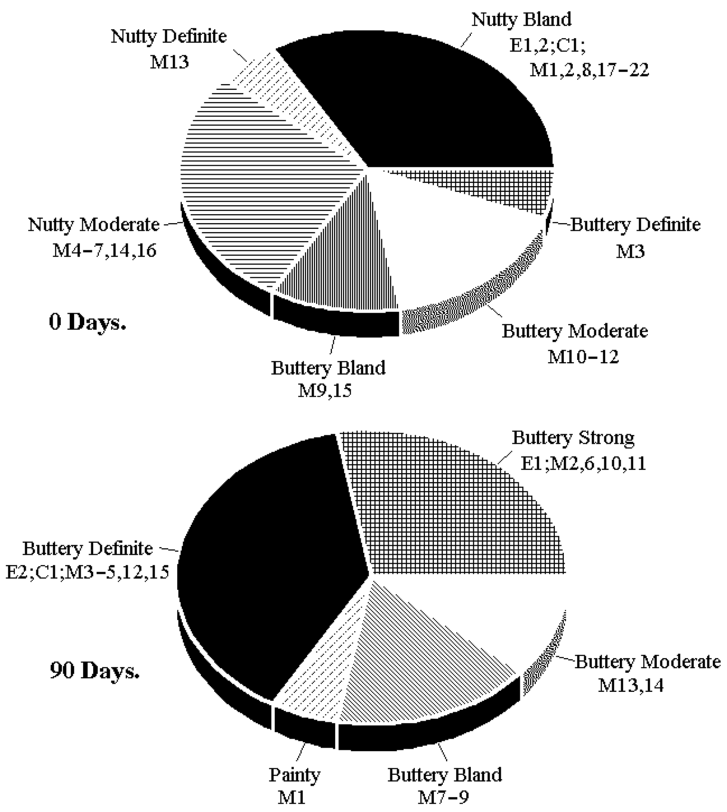

FIG. 1. Soybean oil flavor at the beginning of the experiment and after 90 d of storage.

TABLE 3
Fatty Acid Profile of Soybean Oil Samples

	Fatty acids (%)				
Soybean oil	Palmitic	Stearic	Oleic	Linoleic	Linolenic
E1	10.5	2.8	23.4	54.5	8.7
E2	10.3	2.2	23.2	55.0	8.5
C1	10.2	2.5	36.8	44.4	6.1
M1	7.5	1.6	40.4	41.7	8.7
M2	11.0	2.6	21.6	55.8	9.0
M3	11.2	2.2	22.5	56.3	7.8
M4	10.4	2.6	23.5	55.4	7.5
M5	9.2	2.2	34.0	46.1	8.5
M6	8.5	2.8	18.9	64.7	4.2
M7	10.2	2.7	29.1	51.9	5.4
M8	9.8	2.5	28.8	51.2	6.8
M9	10.2	2.6	28.2	51.0	7.0
M10	10.1	2.7	29.1	51.9	5.4
M11	9.8	2.6	28.8	51.2	6.8
M12	11.1	2.6	22.6	55.7	7.4
M13	11.0	2.7	22.7	54.3	9.4
M14	11.2	2.5	22.3	53.9	9.5
M15	9.8	2.5	23.0	57.2	7.5
M16	10.7	2.5	21.8	54.8	9.7
M17	10.6	3.0	22.4	54.0	9.1
M18	10.7	2.5	22.7	55.5	7.8
M19	10.9	2.7	22.7	55.2	8.0
M20	11.0	2.2	23.7	55.2	7.2
M21	5.4	50.1	28.9	10.9	3.1
M22	5.8	50.1	28.5	11.0	3.1

TABLE 4
Rancimat in Soybean Oil Samples

Soybean oil	Rancimat^{a,b}
E1	8.55 ± 0.05^{c,e,f}
E2	9.12 ± 0.07^{d,f,g}
C1	18.45 ± 0.55^{j}
M16	10.70 ± 0.01^{g,h}
M17	12.25 ± 0.65^{h,i}
M18	23.25 ± 0.45^{k}
M19	9.28 ± 0.30^{d,f,g}
M20	13.65 ± 0.35^{i}
M21	7.45 ± 0.22^{c,e,f}
M22	6.57 ± 0.39^{e}

[a] Time (h) at 110°C.
[b] Values in column with different superscripts ($^{c-k}$) are significantly ($P < 0.05$) different.

PV. Similar PV levels ($P < 0.05$) exhibited the oil from Costa Rica, reference oils and 68% of the oils produced in Mexico (Table 2). Samples M1, M4, M5, and M6 had a high PV; however, only sample M1 developed a painty flavor (Fig. 1). PV was analyzed at 30, 60, 90, and 180 d. Initially, sample C1 had a higher PV than the PV reported for E1 and E2. In spite of this, the PV for this sample was lower than E1 and E2 PV at the end of the storage period.

AV. The AV normally accepted is 2 for fresh soybean oil presenting good stability (15). Of the soybean oil samples analyzed in this study, several samples did not meet the AV quality parameter: M4, M6, M16, and M22 (Table 2).

Flavor. At the start of the experiment, 41% of the oils produced in Mexico and the Costa Rica oil had a flavor similar to that reported for the reference samples (Fig. 1). After storage for 90 d, the flavor profile of one Mexican sample (M1) had changed significantly (Fig. 1). The flavor note normally used for fresh oil is nutty and bland, moderate, or definite. The majority of the samples (86%) fell into these categories. Only six Mexican samples were found to have buttery flavor (M3, M9–12, M15). It is interesting that in all samples analyzed the nutty flavor was lost after 90 d of storage. However, samples that initially (day 0) exhibited buttery flavor (M10 and M11) changed from buttery moderate to buttery strong. On the other hand, samples that originally presented a nutty flavor (e.g., E1, E2, C1, and M2) exhibited a substantial flavor change (buttery strong or buttery definite) after 90 d of storage.

Fatty acid profile. The fatty acid profile in all samples corresponded to the expected profile for 100% soybean oil (Table 3). It can be seen from Table 3 that, according to the Official Mexican Norm for Pure Soybean Edible Oil (19), almost all samples analyzed were composed mainly of soybean oil, except two samples (M21 and M22) that had low levels of linoleic and linolenic acids. These samples had nutty blend flavor characteristics at 0 d of storage (Fig. 1) and exhibited Rancimat values similar ($P <$ 0.05) to those of the reference oils E1 and E2 (Table 4).

Minerals. Phosphorus levels in all samples fell between the expected values for samples that have been well degummed (13). However, samples M1–3, M7–10, M12, and M19 were not completely devoid of nonhydrated gums (Table 5). Normally, one finds a good correlation between high trace mineral levels (pro-oxidants) and high PV (4,5); however, our study did not confirm this correlation.

TABLE 5
Minerals in Soybean Oil Samples (ppm)^{a}

Soybean oil	Minerals				
	Iron	Copper	Calcium	Magnesium	Phosphorus
E1	ND	ND	ND	1.71 ± 0.66^{b}	0.02 ± 0.01^{b}
E2	ND	ND	ND	ND	0.01 ± 0.00^{b}
C1	ND	ND	ND	ND	0.04 ± 0.01^{c}
M1	ND	0.64 ± 0.03^{b}	28.4 ± 0.83^{b}	6.21 ± 0.23^{c}	0.01 ± 0.01^{b}
M2	ND	0.72 ± 0.13^{c}	28.5 ± 0.07^{b}	7.66 ± 1.81^{c}	0.01 ± 0.00^{b}
M3	5.47 ± 0.01^{d}	0.35 ± 0.05^{b}	30.2 ± 3.09^{b}	5.28 ± 1.42^{c}	ND
M4	ND	ND	ND	ND	ND
M5	ND	ND	ND	ND	0.02 ± 0.01^{b}
M6	ND	ND	ND	ND	ND
M7	ND	0.78 ± 0.03^{c}	36.26 ± 5.09^{d}	5.97 ± 0.10^{c}	ND
M8	ND	ND	28.56 ± 0.59^{b}	3.39 ± 0.29^{c}	ND
M9	ND	3.39 ± 0.29^{c}	0.32 ± 0.02^{b}	27.09 ± 0.89^{b}	2.80 ± 0.31^{c}
M10	ND	0.17 ± 0.02^{b}	28.53 ± 0.80^{b}	2.94 ± 0.16^{c}	ND
M11	ND	ND	ND	ND	ND
M12	ND	0.15 ± 0.00^{b}	22.36 ± 0.63^{b}	2.05 ± 0.12^{c}	ND
M13	ND	ND	ND	ND	ND
M14	ND	ND	ND	ND	ND
M15	ND	0.20 ± 0.05^{b}	14.82 ± 0.50^{c}	ND	ND
M16	0.24 ± 0.03^{b}	ND	12.42 ± 1.73^{c}	3.55 ± 0.01^{c}	0.01 ± 0.00^{b}
M17	0.31 ± 0.04^{b}	0.14 ± 0.00^{b}	ND	ND	0.01 ± 0.01^{b}
M18	1.50 ± 0.16^{c}	0.49 ± 0.00^{b}	ND	ND	0.01 ± 0.00^{b}
M19	1.58 ± 0.28^{c}	0.72 ± 0.22^{c}	40.01 ± 1.65^{d}	2.39 ± 0.07^{c}	0.01 ± 0.00^{b}
M20	7.84 ± 1.90^{d}	0.58 ± 0.11^{b}	ND	12.26 ± 2.67^{d}	ND
M21	0.09 ± 0.00^{b}	3.43 ± 0.05^{e}	ND	ND	ND
M22	ND	1.44 ± 0.05^{d}	17.43 ± 5.98^{c}	ND	ND

[a] Values in columns with different superscripts ($^{b-e}$) are significantly ($P < 0.05$) different. ND = not detected <0.01 ppm.

TABLE 6
Totox in Soybean Oils Samples at the Beginning of the Experiment and After 90 D of Storage[a]

Soybean oil	Totox 0 days	Totox 90 days
E1	1.45 ± 0.02^{b}	33.68 ± 0.76^{d}
E2	2.56 ± 0.03^{c}	36.34 ± 0.11^{d}
C1	1.75 ± 0.26^{b}	18.55 ± 0.24^{b}
M1	5.95 ± 0.50^{e}	152.05 ± 2.80^{h}
M2	2.70 ± 0.22^{c}	60.44 ± 0.71^{g}
M3	4.20 ± 0.32^{d}	40.62 ± 0.41^{e}
M4	6.53 ± 0.04^{f}	26.24 ± 1.02^{c}
M5	5.77 ± 0.49^{e}	45.00 ± 0.81^{f}
M6	12.19 ± 1.04^{g}	$30.66 \pm 2.83^{c,d}$
M7	2.37 ± 0.14^{c}	15.95 ± 0.21^{b}
M8	2.14 ± 0.37^{b}	16.50 ± 0.21^{b}
M9	2.14 ± 0.38^{b}	17.36 ± 0.37^{b}
M10	2.78 ± 0.08^{c}	14.43 ± 0.07^{b}
M11	4.30 ± 0.23^{d}	18.27 ± 0.21^{b}
M12	2.50 ± 0.27^{c}	13.95 ± 0.15^{b}
M13	2.28 ± 0.16^{b}	12.65 ± 0.35^{b}
M14	1.64 ± 0.15^{b}	12.00 ± 1.00^{b}
M15	2.01 ± 0.17^{b}	25.00 ± 1.05^{c}
M16	5.18 ± 0.60^{e}	ND
M17	1.87 ± 0.37^{b}	ND
M18	2.02 ± 0.06^{b}	ND
M19	2.21 ± 0.07^{b}	ND
M20	1.98 ± 0.09^{b}	ND
M21	2.09 ± 0.03^{b}	ND
M22	4.99 ± 0.09^{e}	ND

[a] Values in columns with different superscripts ($^{b-h}$) are significantly ($P < 0.05$) different.
ND, not determined

Oxidative stability. The Totox value was used to validate the oxidative stability of samples. Results showed that 64% of the oil samples from Mexico and the one from Costa Rica presented values similar to those of the reference samples. After 90 d of storage, 11 Mexican oils had lower Totox values than the reference samples. Samples M1–M3 and M5, nevertheless, had the highest Totox value after 90 d of storage (Table 6).

A Rancimat test was also used to probe the oxidative stability in oils (M16–M22). These samples presented acceptable Rancimat values when compared with those obtained from the reference oils E1 and E2 (Table 4). All samples (M16–M22) had a nutty flavor at 0 d of storage (Fig. 1). These samples also exhibited PV levels similar ($P < 0.05$) to those found in the reference oils (Table 2).

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REFERENCES

1. *Soya Bluebook Plus*, The Annual Directory of the World Oilseed Industry, Soyatech, Inc., Bar Harbor, 1997, p. 290.
2. Asbridge, D.D., Soybean vs. Other Vegetable Oils as a Source of Edible Oil Products, in *Practical Handbook of Soybean Processing and Utilization*, edited by D.R. Erickson, AOCS Press, Champaign, 1995, pp. 3–6.
3. Emken, E.A., Valor Nutricional del Aceite de Soya en Comparación con Otras Grasas y Aceites, in *Boletín de la Asociación Americana de Soya*, México, D.F., 1994, p. 1.
4. Beauregard, L., Producción de Aceite de Soya de Optima Calidad, in *Refinación de Aceites Vegetales*, edited by Universidad de Sonora, Hermosillo, Sonora, México, 1996, pp. 89–93.
5. List, G.R., T.L. Mounts, and A.J. Heakin, Steam-Refined Soybean Oil: II. Effect of Degumming Methods on Removal of Prooxidants and Phospholipids, *J. Am. Oil Chem. Soc. 55*:55–281 (1978).
6. Gupta, M.K., Processing to Improve Soybean Oil Quality, *INFORM 4*:1267 (1993).
7. Carelli, A.A., M.I.V. Brevedan, and G.H. Crapiste, Quantitative Determination of Phospholipids in Sunflower Oil, *J. Am. Oil Chem. Soc. 74*:514 (1997).
8. Hui, Y.H., Edible Oil and Fat Products: Processing Technology, *Bailey's Industrial Oils and Fats Products*, John Wiley & Sons, Inc., Vol. 4, 1996.
9. Bravo, C.A., La Refinación de Aceites y Grasas Antes y Después de Trisyl, in *Extracción y Refinación de Aceites*, edited by Universidad de Sonora, Hermosillo, Sonora, Mexico, 1993, pp. 50–53.
10. Mag, T.K., Bleaching: Theory and Practice, in *World Conference Proceedings Edible Fats and Oils Processing: Basic Principles and Modern Practices*, edited by D.R. Erickson, American Oil Chemists' Society Press, Champaign, 1990, pp. 107–116.
11. Villa, V.M., Operaciones Críticas Durante el Blanqueo, in *Refinación de Aceites Vegetales*, edited by Universidad de Sonora, Hermosillo, Sonora, México, 1996, pp. 96–99.
12. Zehnder, C.T., Deodorization, in *Practical Handbook of Soybean Processing and Utilization*, edited by D.R. Erickson, AOCS Press, Champaign, 1995, pp. 239, 240.
13. Erickson, D.R., Overview of Modern Soybean Processing and Link Between Processes, in *Ibid.*, edited by D.R. Erickson, AOCS Press, Champaign, 1995, pp. 62–64.
14. *Official Methods and Recommended Practices of the American Oil Chemists' Society*, American Oil Chemists' Society, 4th edn., AOCS Press, Champaign, 1994.
15. Lusas, E.W., and, E. Hernandez, Principles of Analysis and Quality Control for Oil Extraction and Processing, in *Vegetable Oils Processing*, edited by E.W. Lusas, E. Hernandez, L.R. Watkins, and, S.C. Doty, Texas A&M University, College Station, 1993, p.22.
16. Henderson, J.H., R.F. Ariansz, D.R. Taylor, and, C.B. Ungermann, Efectos del Blanqueo en los Indices de Peróxido y Anisidina de Aceite de Soya, in *Soybean Extraction and Oil Processing*, edited by S.C. Doty, E.W. Lusas, and L.R. Watkins, Texas A&M, College Station, 1992, p. 11.
17. Matthäus, B.W., Determination of the Oxidative Stability of Vegetable Oils by Rancimat and Conductivity and Chemiluminescence Measurements, *J. Am. Oil Chem. Soc. 73*:1039–1043 (1996).
18. Méndez, E., J. Sanhueza, H. Speisky, and A. Valenzuela, Validation of the Rancimat Test for the Assessment of the Relative Stability of Fish Oils, *Ibid. 73*:1033–1037 (1996).
19. *Norma Oficial Mexicana NOM F 252 1985*, Alimentos Aceite Comestible Puro de Soya, Secretaría de Comercio y Fomento Industrial, México, 1985, p. 5.

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