Interesterification of Tea Seed Oil and Its Application in Margarine Production

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ABSTRACT: Blends of hydrogenated and nonhydrogenated tea seed oil (Lahijan variety) (30:70, w/w) were chemically interesterified at 60, 90, and 120°C for 30, 60, and 90 min in the presence of 1% (w/w) NaOH. Physicochemical properties of the products were compared with those of the noninteresterified mixture. Statistical comparison of m.p., iodine values (IV), and solid fat contents (SFC) showed that the sample having the highest ranking was interesterified at 120°C for 30 min. The sample was used as a hardstock (40%), with liquid tea seed oil and sunflower oil (ratios of 100:0, 80:20, 60:40, 40:60, 20:80, and 0:100) as a softstock (60%) for production of table margarine, and the properties of these margarines were compared with those of commercial ones. Samples E and D (ratio of 80:20 and 60:40 liquid tea seed oil/sunflower oil, respectively) had the lowest significant differences with commercial table margarine for physicochemical (m.p., IV, and SFC) and organoleptic characteristics, respectively. Generally, based on m.p. and SFC, margarines E and D were classified as soft margarine. The *trans* FA content of E, D, and commercial margarines were 1.8, 1.8, and 2.2%, respectively.

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KEY WORDS: Chemical interesterification, hydrogenation, margarine, oil, tea seed oil.

Tea seed oil is reputed to lower blood pressure and cholesterol, to have a high content of antioxidants, and to be a rich source of emollients for skin care and to minimize signs of aging (1,2). The predominant FA in tea seed oil, as determined by GC/MS, is the monounsaturated FA, oleic acid, followed by the PUFA, linoleic acid (1,2).

Most unmodified vegetable oils have only limited application in their original forms. To widen their use, vegetable oils are modified either chemically, by hydrogenation or interesterification, or physically, by fractionation. Vegetable oils have been modified by hydrogenation for many years (3). However, partial hydrogenation also results in the formation of geometric isomers in the *trans*- rather than the *cis*-configuration found in most vegetable oils (4,5). Several nutritional studies have suggested a direct relationship between *trans* FA consumption and an increased risk for coronary heart disease (3). An alternative to isoselective hydrogenation is random interesterification to obtain fats with desired physical and nutritional properties (3). Interesterification can be viewed as a more "natural" process than hydrogenation because it does not change the acyl groups in the TAG (67). Rather, it modifies the physical properties and crystallizing behavior of fats by altering the original specific TAG composition of the blend components. This fact has made its commercial use an alternative to hydrogenation for producing plastic fats to be used in margarine formulations (8–10). Several studies have investigated chemical interesterification and its influence on physicochemical properties [such as m.p., solid fat content (SFC), and crystallization] of complex fat systems (3,6–12).

In Europe, margarine hard stocks are normally produced from interesterified palm stearine and palm kernel or coconut oil. The selection of oils and fats depends on cost and availability (13). The product range now includes table, bakery and specified puff pastry margarines, which are spreadable at ambient temperature, and tub margarines, which are spreadable at temperatures lower than ambient (5–10°C) and have a lower SFC than solid (block) margarines (14).

The main objectives of this study were (i) to optimize the interesterification reaction conditions of tea seed oil and (ii) to use interesterified tea seed oil in margarine production.

EXPERIMENTAL PROCEDURES

The main material, tea seed (Lahijan variety), was obtained from Iranian farms in Lahijan. Sunflower oil, margarine ingredients [lecithin, potassium sorbate, MAG and DAG, β-carotene solution (3%), citric acid, NaCl, diacetyl essence], and commercial margarine fat base stock were obtained from the Pars vegetable oil-producing factory (Tehran, Iran). Other chemicals used in this study were analytical grade with highest purity available and were purchased from Merck (Darmstadt, Germany).

Five days after collection from the farms (located in the north of Iran) and transfer to the laboratory in baskets at ambient conditions, the tea seeds (*Camellia sinensis*) were oven-dried at 102°C (moisture = 15%) (13). After the tea seeds were ground, oil was extracted by the solvent method and the extracted oil was clarified by passage through fine cheesecloth (2).

Hydrogenation of tea seed oil in the laboratory was carried out in a reactor having a 2-L capacity. Operating conditions were as follows: temperature = 170–180°C, mixing rate = 300–400 rpm, Ni catalyst = 0.4% by weight of oil.

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Chemical interesterification of hydrogenated and nonhydrogenated tea seed oil blends in a 30:70 ratio (w/w) were done in rotary evaporator (Heidolph, Schwabach, Germany) at 60, 90, and 120°C for 30, 60, and 90 min, respectively, in the presence of 1% (w/w) sodium hydroxide catalyst. Tea seed oil blends included: 60°C for 30, 60, and 90 min (I–III); 90°C for 30, 60, and 90 min (IV–VI); 120°C for 30, 60, and 90 min (VII–IX); and the control was noninteresterified tea seed oil. Each fat blend was placed into a clean, dry, 500-mL round-bottomed flask and then heated under vacuum conditions at 95°C for 45 min to remove any water. After establishing the temperature condition to be used (60, 90, or 120°C), NaOH catalyst was added and reaction was followed under vacuum conditions with continuous stirring for 30, 60, and 90 min. The reaction was then stopped by breaking vacuum, and the catalyst was removed (after having transferred the interesterified blend to a decanter and washing with 100 mL of hot distilled water). Then, the oil blend was held at 4°C for further experiments (9).

All margarines were produced using the experimental conditions just described. Hard stock (40%—optimum interesterified tea seed oil blend) and soft stock [60%—sunflower oil/ tea seed oil in ratios of 100:0 (w/w) (A), 80:20 (B), 60:40 (C), 40:60 (D), 20:80 (E), and 0:100 (F)] as well as commercial table margarine (control) were melted at 50°C. Then, oil-soluble ingredients (soy lecithin emulsifier, 3% β-carotene solution, diacetyl, MAG and DAG), water-soluble ingredients (salt, citric acid, and potassium sorbate), and boiled water (50°C) were mixed separately and then mixed thoroughly together by commercial mixer (Sunny, Japan). The margarine emulsion was crystallized in a cold-water bath (from 18 to 19°C) and stored in a freezer (–18°C) for completion of crystallization.

The following determinations were carried out on the original fat blend, interesterified products, and produced margarines: m.p. was determined by capillary tube method (15), SFC by NMR (NMR spectrometer; Bruker, Karlsruhe, Germany) (15); IV by Hanus method (15); moisture by oven method; and acid value (AV) and PV by AOCS methods (15). FAME were prepared by the following procedure: 50 mg of extracted oil was saponified with 5 mL of methanolic NaOH (2%) solution by refluxing for 10 min at 90°C. After addition of 2.2 mL BF_3-methanolic, the sample was boiled for 5 min. The FAME were extracted from a salt-saturated mixture with hexane. GC was used to determine the FA profile and *trans* isomers; this entailed using a fused-silica capillary column (BPX70; SGE, Melbourne, Australia), with 100 m × 0.25 mm × 0.39 μm film thickness; a split injector (1 μL injection) at 240°C, and a FID at 250°C. Helium was used as carrier gas (pressure of 50 psi). The temperatures of the column and injection port were 190 and 240°C, respectively.

For sensory evaluation of the margarines, consistency, spreading, color, texture, flavor, and odor were evaluated by 30 trained taste panelists (scores were established as 100 for excellent, 75 for good, 50 for fair, 25 for poor, and 0 for terrible). This analysis was conducted using the Hedonic test (16). Statistical analysis was performed using SPSS software. Meaningful differences among treatments were tested using the LSD.

TABLE 1
Comparison of the Melting Points, Iodine Values (IV), and Solid Fat Contents (SFC) of Interesterified and Noninteresterified Blends

	SFC[b], %											
Ranking[a]	45°C	40°C	35°C	30°C	25°C	20°C	15°C	10°C	5°C	IV[b,c]	mp[b]	Tea seed oil blends[d]
12	7.13 ± 0.17	7.13 ± 0.17	10.06 ± 0.06	15.27 ± 0.26	19.08 ± 0.24	24.52 ± 0.22	30.76 ± 4.63	35.06 ± 3.31	36.47± 0.21	80.08 ± 0.42*	42.42 ± 0.38*	I
11	7.00 ± 0.18	7.00 ± 0.18	10.28 ± 0.19	15.27 ± 0.14	19.20 ± 0.39	24.65 ± 0.53	28.22 ± 0.36	33.52 ± 0.16	36.53 ± 0.31*	76.50 ± 0.21*	42.33 ± 0.58*	II
—	12.15 ± 0.10	12.15 ± 0.10	15.51 ± 0.09	20.34 ± 0.23	23.81 ± 0.30	28.63 ± 0.19	30.49 ± 1.78	24.90 ± 0.39	36.90 ± 0.76	74.44 ± 0.11	44.92 ± 0.38	III
7	6.52 ± 0.32	6.52 ± 0.32	11.81 ± 0.36	15.23 ± 0.58	20.73 ± 0.50	24.45 ± 0.40	29.65 ± 1.49	33.52 ± 1.25	36.72 ± 0.37	76.26 ± 1.25*	42.25 ± 0.25*	IV
13	6.98 ± 0.36	6.98 ± 0.36	12.16 ± 0.33	15.61 ± 0.54	21.37 ± 0.48	25.07 ± 0.52	29.98 ± 0.38	34.00 ± 0.33	37.42 ± 1.00	79.34 ± 0.27*	41.67 ± 0.29*	V
12	6.55 ± 0.22	6.55 ± 0.22	11.62 ± 0.24	15.05 ± 0.03	20.40 ± 0.12	24.16 ± 0.26	29.21 ± 0.14	33.05 ± 0.24	37.04 ± 0.23	78.53 ± 0.30*	41.83 ± 0.29*	VI
14	6.78 ± 0.16	6.78 ± 0.16	9.71 ± 0.16	14.96 ± 0.32	18.82 ± 0.21	24.20 ± 0.04	28.28 ± 0.63	32.87 ± 0.55	36.20 ± 0.91	78.73 ± 0.86*	42.00 ± 0.50*	VII
1	12.02 ± 0.13	12.02 ± 0.13	15.08 ± 0.11	20.29 ± 0.01	23.76 ± 0.17	28.34 ± 0.18	30.22 ± 1.99	34.52 ± 0.99	37.43 ± 0.23	74.23 ± 0.11	44.83 ± 0.58	VIII
—	11.97 ± 0.04	11.96 ± 0.04	15.02 ± 0.18	20.35 ± 0.29	23.63 ± 0.24	28.55 ± 0.11	31.45 ± 0.16	35.48 ± 0.21	37.97 ± 0.24	73.98 ± 0.12*	45.33 ± 0.29	IX
—	12.37 ± 0.01	12.37 ± 0.01	17.72 ± 0.01	20.77 ± 0.01	25.48 ± 0.01	28.94 ± 0.02	32.97 ± 0.21	35.82 ± 0.52	38.48 ± 0.69	75.13 ± 0.59	45.58 ± 1.28	Control[e]

[a]Comparison sum of rank.
[b]Asterisk (*) indicates significant difference from control (nonesterified) sample at a = 0.05.
[c]Hanus method: 1 mL of $Na_2S_2O_3$ (N/10) = 0.01269 I_2.
[d]Tea seed oil blends were interesterified at 60°C for 30, 60, and 90 min (I–III), 90°C for 30, 60, and 90 min (IV–VI), and 120°C for 30, 60, and 90 min (VII–IX).
[e]Noninteresterified sample.

TABLE 2
Comparison of Some Characteristics of Tea Seed Oil Blend VII (present study) and Other Oil Blends

SFC, %								m.p. (°C)		
After[a]				Before[b]						
40°C	30°C	20°C	10°C	40°C	30°C	20°C	10°C	After[a]	Before[b]	Oil blends
6.78	14.96	24.20	33.04	12.36	20.76	28.94	36.12	41.50	45.20	Blend VII + hydrogenated tea seed oil (70:30) (present study)
2.30	4.80	14.10	27.50	7.10	11.60	23.20	35.00	31.40	40.00	Olive oil + partially hydrogenated palm oil (60:40)[c]
3.00	5.00	8.00	16.00	26.00	30.00	33.00	34.00	38.00	62.00	Fully hydrogenated vegetable oil + vegetable oil (30:70)[d]
5.00	10.00	19.00	35.00	18.00	24.00	30.00	38.00	—	—	Fully hydrogenated soybean oil + soybean oil (40:60)[e]
0.00	3.00	10.00	26.00	0.00	5.00	12.00	32.00	—	—	Butterfat + canola oil (80:20)[f]
0.00	5.00	10.00	30.00	3.00	8.00	15.00	35.00	—	—	Palm oil + soybean oil (70:30)[f]

[a]After interesterification.
[b]Before interesterification.
[c]Reference 8.
[d]Reference 4.
[e]Reference 3.
[f]Reference 9

RESULTS AND DISCUSSION

Moisture, PV, and AV of the original fat blend (blend of noninteresterified and hydrogenated tea seed oil in a ratio 70:30) were 0.009%, 0.02 meq/kg, and 0.04%, respectively. The catalysts for chemical interesterification are extremely sensitive to moisture; therefore fat or oil should contain <0.01% (w/w) water. FFA and peroxides also impair catalyst performance, and their levels should be maintained at <0.05% (w/w) (11).

The m.p., IV and SFC of interesterified and non-interesterified tea seed oil blends are presented in Table 1. The greatest differences were observed between m.p., IV, and SFC of interesterified and noninteresterified (control) blends ($\alpha = 0.05$). To optimize interesterification, the sample blends were ranked based on physicochemical properties (m.p., IV, and SFC). Table 1 shows that sample VII, interesterified at 120°C for 30 min at optimum conditions, had higher differences in comparison with the control, therefore tea seed oil blend VII, which had the highest ranking, was used as a hard stock in margarine production. The results showed that the m.p. and SFC of tea seed oil blend decreased and their IV increased. In contrast the results confirm previously reported research (3,4). Decreases in m.p. and SFC are due to a decrease in the proportion of higher-m.p. TAG (mainly trisaturated TAG) and an increase in mo-

TABLE 3
Comparison of the m.p., IV, and SFC of Margarines

	SFC[b], %							Sample
Ranking[a]	45°C	40°C	35°C	30°C	25°C	IV[b,c]	m.p. °C	margarine
4	0.91 ± 0.01	2.72 ± 0.03	4.10 ± 0.03	6.04 ± 0.03	7.81 ± 0.02	83.12 ± 0.16*	36.33 ± 0.58*	A
8	1.10 ± 0.01	3.00 ± 0.03	4.21 ± 0.03	6.37 ± 0.03	8.12 ± 0.03	102.75 ± 0.17*	31.75 ± 0.25*	B
9	0.91 ± 0.01	2.92 ± 0.03	4.27 ± 0.04	6.55 ± 0.08	7.96 ± 0.03	99.50 ± 0.18	33.00 ± 1.00	C
12	1.10 ± 0.01	2.78 ± 0.03	3.45 ± 0.03	6.02 ± 0.02	7.92 ± 1.73	95.44 ± 0.18*	33.75 ± 0.75	D
15	1.06 ± 0.01	3.11 ± 0.03	3.90 ± 0.03	6.94 ± 0.025	8.80 ± 0.57	91.55 ± 0.16*	34.50 ± 0.50	E
8	0.47 ± 0.01	2.43 ± 0.03	3.62 ± 0.03	5.39 ± 0.03	6.71 ± 0.03	107.14 ± 0.17*	30.5 ± 0.50*	F
—	0.00 ± 0.00	0.00 ± 0.00	1.21 ± 0.03	6.96 ± 0.03	13.28 ± 0.03	83.80 ± 0.16*	33.50 ± 0.50	Control[d]

	20°C	15°C	10°C	5°C	IV[b,c]	m.p. °C	Sample margarine
4	10.58 ± 0.03	12.72 ± 0.03	14.72 ± 0.04	15.26 ± 0.05*	83.12 ± 0.16*	36.33 ± 0.58*	A
8	10.30 ± 0.04	11.98 ± 0.03	13.51 ± 0.01	14.45 ± 0.06*	102.75 ± 0.17*	31.75 ± 0.25*	B
9	10.27 ± 0.19	11.94 ± 0.03	14.26 ± 0.05	15.08 ± 0.05*	99.50 ± 0.18	33.00 ± 1.00	C
12	8.64 ± 1.70	11.80 ± 0.03	13.83 ± 0.03	14.80 ± 0.04*	95.44 ± 0.18*	33.75 ± 0.75	D
15	11.02 ± 0.03	13.31 ± 0.03	16.08 ± 0.02	16.63 ± 0.02*	91.55 ± 0.16*	34.50 ± 0.50	E
8	8.41 ± 0.55	10.24 ± 0.03	12.06 ± 0.03	12.72 ± 0.03*	107.14 ± 0.17*	30.5 ± 0.50*	F
—	23.93 ± 0.03	32.54 ± 0.03	39.86 ± 0.03	42.71 ± 0.025	83.80 ± 0.16*	33.50 ± 0.50	Control[d]

[a]Comparison sum of rank.
[b]Asterisk (*) indicates significant difference from control sample at $\alpha = 0.05$.
[c]Hanus method: 1 mL of $Na_2S_2O_3$ (N/10) = 0.01269 I_2.
[d]Table commercial margarine. For abbreviations see Table 1.

TABLE 4
Organoleptic Properties of Margarines A–F and Control[a]

Margarine samples	Consistency	Spreadability	Color	Texture	Flavor	Odor	Ranking[a]
A	70 ± 11.18	80 ± 11.18	90 ± 13.69	70 ±11.18	50 ± 0.00*	45 ± 11.18*	30
B	45 ± 11.18*	75 ± 17.68	80 ± 11.18	60 ± 13.69*	45 ± 11.18*	50 ± 17.68*	26
C	45 ± 11.80*	75 ± 25.00	75 ± 17.68	65 ± 13.69	40 ± 13.69*	40 ± 13.69*	23
D	70 ± 20.92	90 ± 13.69	80 ± 20.92	75 ± 17.68	55 ± 20.92*	50 ± 17.68*	34
E	60 ± 28.50	75 ± 25.00	80 ± 11.18	70 ± 11.18	50 ± 17.68*	40 ± 22.36*	28
F	70 ± 20.92	90 ± 13.69	65 ± 13.69*	65 ± 22.36	60 ± 13.69*	45 ± 27.38*	32
Control	80 ± 11.18	85 ± 13.69	65 ± 13.69	80 ± 11.18	70 ± 11.18*	70 ± 11.18	—

[a]Asterisk (*)indicates mean comparison between margarines A–F and control margarine are significantly different (a = 0.05).
[b]Comparison sum of rank.

TABLE 5
Comparison of Properties of Margarines D and E with Some Reference Soft and Stick Margarines

	SFC (%)									
Kind of margarine	10°C	20°C	21.1°C	26.7°C	30°C	33.7°C	37.7°C	40°C	m.p. (°C)	IV[a]
E (present study)	16.08	11.02	—	—	6.94	—	—	3.11	34.50	91.55
D (present study)	13.83	9.64	—	—	6.02	—	—	2.78	33.50	95.44
Soft[b]	15.90	10.20	—	—	4.50	—	—	1.40	33.00	—
Soft[c]	11.70	8.10	—	—	4.60	—	—	—	32.50	125.30
Soft[d]	11.00	—	7.00	5.00	—	2.00	0.50	—	—	—
Semisolid[d]	20.00	—	13.00	9.00	—	2.50	0.00	—	—	—
Soybean oil + palm oil (50:50)[e]	15.00	5.00	—	—	2.00	—	—	0.00	—	—
Canola oil + butterfat (20:80)[e]	26.00	10.00	—	—	3.00	—	—	0.00	—	—
Corn oil + milk fat (60:40)[f]	13.00	4.00	—	—	0.00	—	—	0.00	—	—
Olive oil + partially hydrogenated palm oil (60:40)[b]	25.30	8.40	—	—	2.00	—	—	0.00	—	—

[a]Hanus method: 1 mL of $Na_2S_2O_3$ (N/10) = 0.01269 I_2.
[b]Reference 8.
[c]Reference 3.
[d]Reference 17.
[e]Reference 9.
[f]Reference 6.

nounsaturated TAG as a result of interesterification (3,4,7,8). The increase in IV may be due to changes of TAG species having intermediate degrees of unsaturation, crystal habit, crystal morphology, and fat structure (17). Characteristics of tea seed oil blend VII and other oil blends before and after interesterification are compared in Table 2.

Produced margarines A–F and the control (commercial) margarine are compared with respect to m.p., IV, and SFC in Table 3 and to organoleptic properties (consistency, spreadability, color, texture, flavor and odor) in Table 4. The highest differences between m.p., IV, and SFC in margarines A–F and the control were observed ($\alpha = 0.05$). For selection of the best margarine based on physicochemical and organoleptic properties, samples were ranked (Tables 3, 4). Margarines E and D had the highest difference compared with the control group. The differences between SFC, IV, and m.p. in margarines A–F and in the control were significant ($\alpha = 0.05$). As a result the kind of margarine may be important and the margarines presented here should be compared with other researches (18).

Comparison of characteristics of the best margarines (D and E) produced from tea seed oil with soft and stick margarines from other oils is presented in Table 5. Margarines D and E can classified as soft margarines (3,8,19). According to the organoleptic properties, D had the least difference from the control. The highest differences in organoleptic properties between tea seed oil (D or E) and table commercial margarines

TABLE 6
FA Profiles of Margarines D, E, and Control and Two Previously Reported Margarines

Sample	C_{12}	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1(t)}$	$C_{18:1(c)}$	$C_{18:2}$	$C_{18:2(c)}$	C_{20}	$C_{18:3}$	C_{22}
E (present study)	—	—	14.50	—	9.40	1.80	47.70	—	25.50	—	0.40	—
D (present study)	—	—	13.00	—	9.70	1.80	43.80	—	30.70	—	0.35	—
Control	—	—	10.00	—	9.50	2.20	31.10	—	46.30	—	0.36	—
Soft margarine[a]	1.60	1.20	11.30	—	8.20	3.50	21.50	—	52.60	—	—	—
Palm oil + olive oil (40:60)[a]	0.40	0.50	22.30	0.70	6.40	7.50	53.50	0.50	6.30	0.50	0.60	0.10

[a]Reference 8.

were in flavor and odor, which seems normal because the fat portion of the control sample was industrially deodorized but the oil portions of the others (Blends I–IX) were deodorized under experimental conditions. The FA profiles for the best margarines from tea seed oil (D and E) and table commercial soft and stick margarines as determined by GC are presented in Table 6. Margarines E and D are good soft products based on FA profile and *trans* FA content and can be produced under industrial conditions.

REFERENCES

1. Wang, X., F. Chen, and J. Chen, Composition and Sensory Evaluation of Tea Seed Oil, presented at the 94th AOCS Annual Meeting and Expo, Kansas City, Missouri, May 4–7, 2003.
2. Sahari, M.A., D. Attaii, and M. Hamedi, Characteristics of Tea Seed Oil in Comparison with Sunflower and Olive Oils And Its Effects as a Natural Antioxidant, *J. Am. Oil Chem. Soc. 81*:585–588 (2004).
3. Petruskaite, V., W. De Garyet, M. Kellenes, and A. Huyghebaert, Physical and Chemical Properties of *trans*-free Fats Produced by Chemical Interesterification of Vegetable Oil Blends, *Ibid. 75*:489–493 (1998).
4. Schmidt, S., S. Hurtová, J. Zemanovič, S. Sekretár, P. Šimon, and P. Ainsworth, Preparation of Modified Fats from Vegetable Oil and Fully Hydrogenated Vegetable Oil by Randomization with Alkali Catalysts, *Food Chem. 55*:343–348 (1996).
5. Chu, B.S., H.M. Ghazali, O.M. Lai, Y.B. Che Man, and S. Yousef, Physical and Chemical Properties of a Lipase Transesterified Palm Stearine/Palm Kernel Olein Blend and Its Isopropanol-Solid and High Melting Triacylglycerol Fractions, *Ibid. 76*:15 –164 (2002).
6. Rodrigues, J.N., and L.A. Gioillie, Chemical Interesterification of Milkfat and Milk Fat-Corn Oil Blends, *Food Res. Int. 75*:489–493 (2003).
7. Norizzah, A.R., C.L. Chong, C.S. Chew, and O. Zaliha, Effects of Chemical Interesterification on Physicochemical Properties of Palm Stearine and Palm Kernel Olein Blends, *Food Chem. 86*:229–235 (2004).
8. Alpaslan, M., and A. Karaali, The Interesterification Induced Changes in Olive and Palm Oil Blends, *Food Chem. 61*:301–305 (1998).
9. Marangoni, A.G., and D. Rousseau, Chemical and Enzymatic Modification of Butterfat and Butterfat-Canola Oil Blends, *Food Res. Int. 31*:595–599 (1998).
10. Klinkesorn, U., A. Kittikun, P. Chinachoti, and P. Sophanodora, Chemical Transesterification of Tuna Oil Enriched Omega-3 Polyunsaturated Fatty Acids, *Food Chem. 87*:415–421 (2004).
11. Marangoni, A.G., and D. Rousseau, Engineering Triacylglycerols: The Role of Interesterification. 1. Melting and Crystallization, *J. Am. Oil Chem. Soc. 75*:329–335 (1995).
12. Marangoni, A.G., and D. Rousseau, The Influence of Chemical Interesterification on the Physicochemical Properties of Complex Fat Systems. ß. Melting and Crystallization, *J. Am. Oil Chem. Soc. 75*:1265–1271 (1998).
13. Zhang, H., P. Smith, and J. Adler-Nissen, Effect of Degree of Enzymatic Interesterification on the Physical Properties of Margarine Fats: Solid Fat Content, Crystallization Behavior, Crystal Morphology and Crystal Network, *J. Agric. Food Chem. 52*:4423–4431 (2004).
14. Laia, O.M., H.M. Ghazali, F. Cho, and C.L. Chong, Physical and Textural Properties of an Experimental Table Margarine Prepared from Lipase-Catalyzed Transesterified Palm Stearin: Palm Kernel Olein Mixture During Storage, *Food Chem. 71*:173–179 (2000).
15. AOCS, *Official Methods and Recommended Practices of the AOCS*, 5th edn., AOCS Press, Champaign, 1997.
16. Meilgaard, M., G. Civille, and B. Carr, *Sensory Evaluation Techniques*, 3rd edn., CRC Press, Boca Raton, Florida, 1999, 387 pp.
17. Akoh, C.C., and D.B. Min, *Food Lipids: Chemistry, Nutrition, and Biotechnology* 2nd edn., Marcel Dekker, New York, 2002, pp. 301–333.
18. Podmore, J., Application of Edible Oils, in *Edible Oil Processing*, edited by W. Hamm and R.J. Hamilton, CRC Press, Boca Raton, Florida, 2000, pp. 190–218.
19. Alexandersen, K.A., Margarine Processing Plants and Equipment, in *Bailey's Industrial Oil and Fat Products*, 5th edn., edited by Y.H. Hui, John Wiley & Sons, New York, Vol. 4, 1996, pp. 491–568.

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