Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 102 (2007) 827–833
Food Chemistry
www.elsevier.com/locate/foodchem

Trans-free Iranian vanaspati through enzymatic and chemical transesterification of triple blends of fully hydrogenated soybean, rapeseed and sunflower oils

Jamshid Farmani [a,*], Manouchehr Hamedi [a], Mohammad Safari [a], Ashkan Madadlou [b]

[a] Department of Food Science and Engineering, Faculty of Agricultural Biosystem Engineering, University of Tehran, Karaj, Iran
[b] Department of Food Science and Technology, Faculty of Agriculture, University of Urmia, Urmia, Iran

Received 21 December 2005; received in revised form 29 May 2006; accepted 8 June 2006

Abstract

Production of trans-free Iranian vanaspati through enzymatic and chemical transesterification of triple blends of fully hydrogenated soybean (FHSBO), rapeseed (RSO) and sunflower (SFO) oils was investigated. The slip melting point (SMP), solid fat content (SFC) at 10–40 °C and induction period of oxidation at 120 °C (IP_{120}) of the transesterified and initial blends were evaluated. Results indicated that all the enzymatically and chemically transesterified blends had lower SMP, SFC and IP_{120} than their initial blends. No significant differences ($P < 0.05$) were observed between the SMP of enzymatically and chemically transesterified blends. Some enzyme treated blends had higher SFC at some temperatures than chemically transesterified ones. Enzymatically transesterified blends had higher IP_{120} than those prepared by chemical transesterification. Correlation between SFC at 20 °C and saturated fatty acid (SFA) content, and between SMP and SFA of transesterified blends indicated that the SFA must be between 27.2% and 36.6% for enzymatic and 28.4% and 37.8% for chemical transesterification to obtain transesterified fats suitable for use as vanaspati.

Keywords: Transesterification; Trans-free; Vanaspati; Fully hydrogenated soybean oil; Rapeseed oil; Sunflower oil

1. Introduction

Vanaspati or vegetable ghee (a substitute for natural ghee) is the major fat product consumed in Iran. It is produced by partial hydrogenation of vegetable oils such as soybean, cottonseed, sunflower and rapeseed oils. Due to adverse health effects of the trans fatty acids produced during partial hydrogenation of vegetable oils (Hayakawa, Linko, & Linko, 2000; Mensink, Plat, & Temme, 2002) there are some trends to produce trans-free products. Contrary to hydrogenation, transesterification causes no trans unsaturation and rearrangement of fatty acids in the triacylglycerol (TAG) molecules leads to modification of TAG composition and consequently, of physical properties. Such methods allow the possibility of producing a trans-free product to suit a particular food application. Transesterification can be carried out either chemically or enzymatically. Chemical transesterification by chemical catalysts produces a complete positional randomization of acyl groups in TAG molecules while transesterification by 1,3-specific lipase does not affect the *sn-2* position of TAG molecules and so produces a more natural product. Enzymatic process requires less severe reaction conditions and produces less waste than the chemical process. However, chemical catalysts are much less expensive than lipases (Konishi, Neff, & Mounts, 1999).

Production of trans-free margarines and shortenings through transesterification has been widely studied (List, Mounts, Orthoefer, & Neff, 1995; List, Pelloso, Orthoefer, Chrysam, & Mounts, 1995; Ming, Ghazali, & Let, 1999; Petrauskaite, De Greyt, Kellens, & Huyghebaert, 1998; Seriburi & Akoh, 1998; Schmidt et al., 1996; Zhang

* Corresponding author. Tel.: +98 912 5780936; fax: +98 261 2248804.
E-mail address: jamshid_farmani@yahoo.com (J. Farmani).

0308-8146/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2006.06.015

et al., 2001). There are few studies on the production of trans-free vanaspati through transesterification. Majumdar and Bhattacharyya (1986a) studied production of trans-free vanaspati by transesterification of palm stearin and some vegetable oil blends. Ray and Bhattacharyya (1996) studied the nutritional quality of physical blends of palm stearin and some vegetable oils and Majumdar and Bhattacharyya (1986b) studied the nutritional quality of the blends after transesterification. They also compared the nutritional quality of the blends with a vanaspati made by partial hydrogenation. In all the studies, no distinct fatty acid composition was considered. In the present study, triple blends of fully hydrogenated soybean (FHSBO), rapeseed (RSO) and sunflower (SFO) oils were subjected to enzymatic and chemical transesterification. Some physicochemical properties of enzymatically and chemically transesterified fat blends were compared with together and those of a commercial low trans Iranian vanaspati. The SFA content of transesterified fats were correlated with their SMP and SFC at 20 °C. The objective of the study was to choose proper formulation to produce trans-free fat suitable for use as Iranian vanaspati.

2. Materials and methods

2.1. Materials

Fully hydrogenated soybean oil (FHSBO) was obtained from Faravard Co. (Fariman, Iran) and refined, bleached and deodorized rapeseed oil (RSO) (low erucic acid), and sunflower oil (SFO) were purchased from Behshahr Industrial Co. (Tehran, Iran). Commercial low trans Iranian vanaspati was purchased from a local market. Commercial immobilized 1,3-specific lipase from *Thermomyces lanuginosa*, Lipozyme TL IM, was kindly donated by Novo Nordisk (A. S., Denmark). Sodium methoxide (dry powder) was purchased from Merck (Darmstadt, Germany). Fatty acid methyl ester standards (C12:0, C14:0, C16:0, C18:0, C18:1 9c, C18:1 9tr, C18:2 9c 12c and C18:3 9c 12c 15c) were purchased from Chrompack (Middelburg, The Netherlands). All other chemicals were analytical grade and from Merck (Darmstadt, Germany).

2.2. Preparation of blends

FHSBO was melted at 80 °C and triple blends of FHSBO:RSO:SFO in the mass ratio of 15:25:60, 20:25:55, 25:25:50, 30:25:45, 35:25:40 and 40:25:35 were prepared. Prior to transesterification, all blends were dried at 110 °C under vacuum (0.3 bar abs) for 40 min to remove traces of water.

2.3. Enzymatic transesterification

Lipozyme TL has equilibrium water content of approximately 5% (w/w). The content of water has to be reduced prior to carrying out the experiments to lessen free fatty acid, mono- and diacylglycerol formation caused by hydrolysis of fat. Water removal from the enzyme was performed in a batch glass stirred tank reactor. Three volumes (300 g) of rapeseed oil were transesterified for 30 min at 70 °C to reduce the water content of enzyme by consuming water in hydrolytic side reactions as well as by stripping the water dissolved in the reaction mixture. Lipozyme TL was then quickly washed with the blend to be studied to remove rapeseed oil (Zhang, Pedersen, Kristensen, Adler-Nissen, & Holm, 2004). A given blend (300 g) was then transesterified with an enzyme load of 6% by weight for 4 h in the same reactor. In all experiments a stream of pure nitrogen was passed through the mixture to inhibit fat oxidation. Before sampling, stirring was stopped and the enzyme was allowed to fully settle to the bottom where it remained while products were withdrawn from the top. Transesterified fats were immediately filtered under vacuum through wattman No. 4 filter paper to remove fine enzyme particles remained in it.

2.4. Chemical transesterification

Dried blends (300 g) were charged into a flask and brought to 70 °C. Dry sodium methoxide, 0.5% by weight, was added and vigorous magnet stirring (300 rpm) was continued for 30 min at 70 °C. The catalyst was inactivated by addition of 2% (w/w) aqueous citric acid (20% (w/w) concentration). The mixture was stirred for an additional 15 min; 1% (w/w) filter aid (Celite Hyflo Super Cel filter aid, Fisher Scientific Co., Pittsburgh, PA) was stirred into the reaction mixture and it was filtered under vacuum through wattman No. 4 filter paper to remove soaps (List, Mounts, et al., 1995).

2.5. Removal of free fatty acids and partial acylglycerols

Removal of free fatty acids (FFA) and partial acylglycerols was performed according to Rousseau and Marangoni (1999) with some modifications. Transesterified fat blends were liquefied and subsequently mixed with an equal volume of 96% ethanol (40–50 °C) in a separatory funnel. The ethanol phase was then extracted and the procedure repeated five times. Traces of ethanol were removed by passing a stream of pure nitrogen through fats at 90 °C for 40 min. Dried fats were then filtered under vacuum through wattman No. 4 filter paper to remove any fine particles remaining in the fat.

2.6. Fatty acid composition

Fatty acid methyl esters were prepared according to the American Oil Chemists' Society (AOCS) method Ce 2-66 (AOCS, 1996). Identification and quantification of trans and other fatty acid methyl esters was performed according to the AOCS method Ce 1e-91 (AOCS, 1996). A Chrompack CP 9002 gas chromatograph (Middleburg, The Netherlands) equipped with a flame ionization detector was

used. Capillary chromatographic column CP Sil 88 (100 m, 0.25 mm id and 0.2 μm film thickness; Chrompack, Middleburg, The Netherlands) was used to analyze fatty acid methyl esters. The split ratio was 1:100 and the detector and injector temperature was 250 °C. The column was run isothermally at 175 °C, the carrier gas was nitrogen and the column head pressure was 230 kPa.

2.7. Iodine value

Iodine value (IV) was calculated from fatty acid composition according to AOCS method Cd 1c-85 (AOCS, 1996).

2.8. Solid fat content

A minispec mq 20 pulsed nuclear magnetic resonance spectroscope (Bruker Corporation, Hamburg, Germany) was used to measure solid fat content (SFC) in samples at 10, 20, 25, 30, 35 and 40 °C according to AOCS Cd 16b-93 direct serial measurement method (AOCS, 1996).

2.9. Slip melting point

Slip melting point (SMP) was determined in accordance with AOCS Cc 3-25 open tube melting point (AOCS, 1996). Capillary tubes filled with samples were stored in a refrigerator (6 °C) overnight before the measurements.

2.10. Oxidative stability by Rancimat and oxidizability

The induction periods (IP) for oxidation of fat blends studied were measured according to AOCS method Cd 12b-92 using a Metrohm Rancimat instrument model 743 (Herisau, Switzerland) (AOCS, 1996). Measurements were done at 120 °C, with 2.5 g sample and air flow rate of 2.5 ml/s. Oxidizability was calculated from the contents of C18:1, C18:2, C18:3. The formula was [0.02(C18:1%) + C18:2% + 2(C18:3%)]/100 (Cosgrove, Church, & Pryor, 1987).

2.11. Statistical analysis

Experiments were performed in triplicate in a complete randomized block design and data were analyzed for analysis of variances (ANOVA) and significant differences between means by MSTATC at the significance level of $P < 0.01$ or $P < 0.05$.

3. Results and discussion

3.1. Fatty acid composition

Table 1 reports the fatty acid composition of FHSBO, RSO and SFO and their blends in various ratios. Fatty acid composition of Iranian vanaspati must be as follow: sum of C12:0, C14:0, C16:0 and C18:0 (SFA) ⩽25%, C18:2 9c 12c ⩾7% and C18:3 9c 12c 15c ⩽2% (Institute of Standards and Industrial research of Iran [ISIRI], 1997). All blends, had contents of C18:2 and C18:3 equal to or lower than 2% and higher than 7%, respectively; but only blend composed of 15% FHSBO had SFA lower than 25%. Due to the presence of about 8% C18:3 in RSO, its maximum usage in formulation was 25%. Source stocks contained small amounts of trans fatty acids (up to 0.7%), which were mainly formed during hydrogenation of soybean oil and deodorization of RSO and SFO. Compared with commercial low trans vanaspati, blends studied in the present work had little trans (0.5–0.6% against 7.7%) but more polyunsaturated fatty acids (PUFA) (29.6–45.7% against 29.1%).

3.2. Iodine value

Iodine value (IV) of source stocks and blends is given in Table 2. Iranian vanaspati must have IV greater than 75 (ISIRI, 1997). All blends except blend composed of 40% FHSBO had IV greater than 75. Blends containing 15%, 20% and 25% FHSBO had higher while; the other three blends had lower IV than the commercial low trans vanaspati.

3.3. Oxidative stability

Induction period at 120 °C (IP_{120}) and oxidizability of source stocks and initial blends are given in Table 2. Due to containing more than 97% SFA, FHSBO had the least oxidizability (0.000). RSO also had a low oxidizability and high IP_{120}, so its application in formulation could improve oxidative stability. However, due to the reason mentioned before, its maximum contribution in formulation was 25%. By increasing FHSBO and decreasing SFO in formulation, oxidizability of blends decreased and IP_{120} of them increased. Only initial blends with 35% and 40% FHSBO had IP_{120} equal to or higher than commercial low trans vanaspati ($P < 0.5$). This was due probably to the presence of more SFA and less unsaturated fatty acids in blends contained 35% and 40% FHSBO.

It is proved that distribution mode of fatty acids in different position of TAG affects its oxidative stability (Hoshina, Endo, & Fujimoto, 2004). Fig. 1 shows IP_{120} of blends before and after transesterification, after FFA and partial acylglycerol removal and after addition of 100 ppm tertiary-butylhydroquinone (TBHQ). Both enzymatic and chemical transesterification reduced IP_{120} of initial blends significantly ($P < 0.01$). IP_{120} of chemically transesterified fats were lower than that of enzymatically transesterified ones ($P < 0.05$). Results obtained in the present study were in accordance with findings of other researchers (Ledochowska & Wilczynska, 1998; Neff, El-Agaimy, & Mounts, 1994). According to the literature, lower IP_{120} of transesterified fat blends was due to formation of FFA and partial acylglycerols and removal of antioxidants present in fat (Kowalski, Tarnowska, Gruczynska, & Bekas, 2004; Ledochowska & Wilczynska, 1998; Moussata & Acoh, 1998)

Table 1
Fatty acid composition (% of area) of base stocks and blends

Stock/blend	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3	SFA	TFA
Base stocks									
FHSBO	0.0	0.1 ± 0.02	11.5 ± 0.35	85.6 ± 0.38	1.2 ± 0.18	0.0	0.0	97.2	0.7
RSO	0.0	0.1 ± 0.03	5.2 ± 0.31	2.4 ± 0.20	61.3 ± 0.36	20.0 ± 0.33	7.9 ± 0.23	7.7	0.5
SFO	0.0	0.1 ± 0.02	6.3 ± 0.21	4.1 ± 0.26	23.5 ± 0.41	64.1 ± 0.34	0.4 ± 0.06	10.5	0.4
LTV	0.1 ± 0.02	0.4 ± 0.05	17.3 ± 0.22	6.0 ± 0.24	45.6 ± 0.28	26.8 ± 0.30	2.3 ± 0.17	23.7	7.7
Blends (FHSBO:RSO:SFO)									
15:25:60	0.0	0.1 ± 0.02	6.8 ± 0.24	15.9 ± 0.33	29.5 ± 0.26	43.6 ± 0.44	2.1 ± 0.19	22.7	0.5
20:25:55	0.0	0.1 ± 0.02	7.1 ± 0.25	20.0 ± 0.32	28.6 ± 0.31	40.2 ± 0.38	2.0 ± 0.20	27.2	0.5
25:25:50	0.0	0.1 ± 0.03	7.2 ± 0.24	24.2 ± 0.37	27.5 ± 0.29	37.2 ± 0.40	2.1 ± 0.19	31.3	0.5
30:25:45	0.0	0.1 ± 0.01	7.6 ± 0.26	28.1 ± 0.25	26.4 ± 0.25	33.9 ± 0.31	2.1 ± 0.15	35.7	0.5
35:25:40	0.0	0.1 ± 0.02	7.9 ± 0.31	32.2 ± 0.27	25.2 ± 0.39	30.8 ± 0.22	2.0 ± 0.21	40.3	0.6
40:25:35	0.0	0.1 ± 0.02	8.0 ± 0.30	36.4 ± 0.29	24.2 ± 0.36	27.6 ± 0.36	2.0 ± 0.23	44.5	0.6

Values are shown as mean ± standard deviation; FHSBO, fully hydrogenated soybean oil; RSO, rapeseed oil; SFO, sunflower oil; LTV, commercial low trans vanaspati; SFA, saturated fatty acids (sum of C12:0, C14:0, C16:0 and C18:0); TFA, trans fatty acids.

Table 2
Calculated iodine value (Calc. IV), oxidizability (Ox) and induction periods at 120 °C (IP_{120}) of base stocks and initial blends

Stock/blend	Calc. IV	Ox	IP_{120} (h)
Base stocks			
FHSBO	1.0	0.000	–
RSO	109.5	0.370	10.1 ± 0.35
SFO	132.5	0.654	3.3 ± 0.33
LTV	92.0	0.322	7.3 ± 0.43
Blends (FHSBO:RSO:SFO)			
15:25:60	106.9	0.484	5.5 ± 0.24
20:25:55	100.2	0.450	5.8 ± 0.27
25:25:50	93.8	0.418	6.1 ± 0.40
30:25:45	87.4	0.386	7.0 ± 0.35
35:25:40	81.0	0.355	7.3 ± 0.26
40:25:35	74.3	0.321	7.9 ± 0.21

Values of IP_{120} are shown as mean ± standard deviation; FHSBO, fully hydrogenated soybean oil; RSO, rapeseed oil; SFO, sunflower oil; LTV, commercial low trans vanaspati.

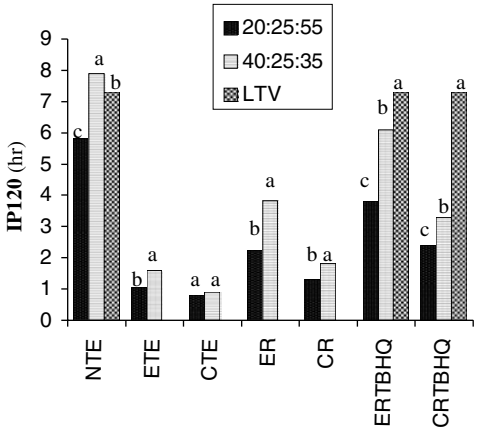

Fig. 1. Effect of transesterification on induction periods at 120 °C (IP_{120}) of blends composed of 20:25:55 and 40:25:35 of fully hydrogenated soybean: rapeseed: sunflower oil (w/w). Bars with different superscripts have significant difference at $P < 0.01$. NTE, not transesterified; ETE, enzymatically transesterified; CTE, chemically transesterified; ER, enzymatically transesterified, after ethanol washing; CR, chemically transesterified, after ethanol washing; ERTBHQ and CRTBHQ, ER and CR after addition of 100 ppm TBHQ; LTV, commercial low trans vanaspati.

besides alteration of fatty acid position in TAGs (Hoshina et al., 2004). Removal of FFA and partial acylglycerols resulted in a significant increase of IP_{120} of transesterified blends ($P < 0.01$). Addition of 100 ppm TBHQ also resulted in a significant increase of IP_{120} of transesterified fats ($P < 0.01$). However, IP_{120} of chemically transesterified fat blends were lower than that of enzymatically transesterified ones and the latter lower than that of initial blends ($P < 0.01$). This issue had previously commented by other researchers. More reduction of IP_{120}s of initial blends by chemical transesterification was due to transferring of PUFA from internal *sn-2* position of TAGs to external positions (*sn-1* and *sn-3*) due to random distribution of fatty acids after chemical transesterification (Ledochowska & Wilczynska, 1998; Neff et al., 1994). It facilitates easier access of oxygen to these acids causing their easier oxidation (Neff et al., 1992; Wada & Koizumi, 1983).

Transesterified fat blends had lower IP_{120} than commercial low trans Iranian vanaspati ($P < 0.05$) due probably to the presence of more PUFAs in them and alteration of fatty acid positions in TAGs.

3.4. Slip melting point

SMP of initial and transesterified fats is given in Table 3. Initial blends had very high SMP (51.4–59.9 °C). According to List, Mounts, et al. (1995), Petrauskaite et al. (1998) and Zeitoun, Neff, List, and Mounts (1993), this was due to the presence of high amounts of trisaturated TAGs originated from FHSBO. Melting point of Iranian vanaspati must not be more than 40 °C (ISIRI, 1997); so initial blends were not suitable for use as vanaspati. Both enzymatically and chemically transesterified fat blends had lower SMP than initial blends ($P < 0.01$). List, Mounts, et al. (1995) and Petrauskaite et al. (1998) had previously commented on this issue. They explained this by the decrease of the higher-melting trisaturated TAGs. No significant differences were observed between chemical and enzymatic treatments ($P < 0.05$). Chemically and enzy-

matically transesterified fats composed of 20% or more FHSBO had higher SMP than commercial low trans vanaspati ($P < 0.01$). Transesterified fat blends composed of 35% and 40% FHSBO had SMP higher than 40 °C ($P < 0.01$). A good linear correlation ($R^2 > 0.98$) was found between SFA and SMP of transesterified fat blends (Fig. 2). According to Fig. 2, SFA content of 36.6% in enzymatically transesterified and of 37.8% in chemically transesterified fats will lead to SMP of 40 °C. Hence, from Fig. 3, which shows linear correlation between the amount of FHSBO and SFA of fat blends, maximum usage of FHSBO in formulation for production of Iranian vanaspati will be 30.9% and 32.3%, for enzymatic and chemical transesterification, respectively.

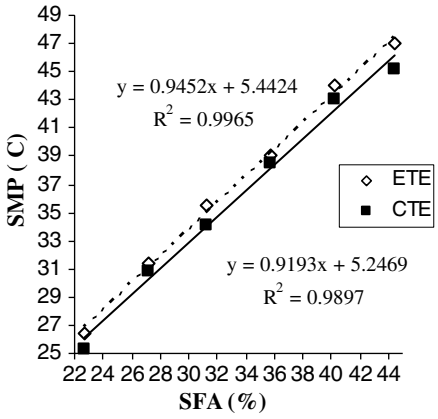

Fig. 2. Linear correlation between amount of saturated fatty acids (SFA) and slip melting point (SMP) of transesterified blends. ETE, enzymatically transesterified; CTE, chemically transesterified.

3.5. Solid fat content

SFC at 10–40 °C of blends before and after transesterification is given in Table 3. Initial blends had wide plastic range and high SFC at 40 °C (higher than body temperature) causing greasiness in mouth; so they were not suitable for use as vanaspati. Both chemical and enzymatic transesterification lowered SFC at all analyzed temperatures ($P < 0.01$) (Table 3). According to the literature, this may be due to a decrease of trisaturated TAGs by transesterification (List, Mounts, et al., 1995; Petrauskaite et al., 1998; Zeitoun et al., 1993).

In terms of comparison between enzymatic and chemical transesterification, SFC of some enzymatically transesterified fats at some temperatures were higher than that of chemically transesterified ones ($P < 0.05$). The results were in contrast with the findings of other researchers. Alpaslan and Karaali (1998) used sodium methoxide and 1,3-specific *Mucor miehie* lipase for transesterification of blends of partially hydrogenated palm oil and olive oil. Rousseau and Marangoni (1999) used sodium methoxide and 1,3-specific *Rhizupus arrhizus* lipase for transesterification of blends of butterfat and canola oil. In both studies SFC of enzyme treated fat blends were lower than that of chemically transesterified ones. The different results obtained in the present study may be due to the use of different enzymes, source stocks and formation of lower amounts of by-products (such as FFA, mono- and diacylglycerols) during enzymatic transesterification. Because of no need to adjust the water content of reaction medium by adding water and also reducing the water content of the enzyme before

Table 3
Solid fat content and slip melting point (SMP) of blends and commercial low trans vanaspati

Blends		Solid fat content (%)						SMP (°C)
		10 °C	20 °C	25 °C	30 °C	35 °C	40 °C	
FHSBO:RSO:SFO								
15:25:60	NTE	17.9^a	16.2^a	15.0^a	13.8^a	12.3^a	10.2^a	51.4^a
	ETE	12.0^b	5.1^b	3.0^b	2.0^b	0.9^b	0.5^b	26.4^b
	CTE	10.6^c	4.7^b	2.9^b	2.0^b	1.0^b	0.5^b	25.3^b
20:25:55	NTE	23.5^a	21.6^a	20.2^a	18.7^a	16.5^a	14.3^a	55.5^a
	ETE	17.6^b	8.4^b	4.8^b	3.1^b	1.6^b	0.7^b	31.4^b
	CTE	16.2^c	7.8^b	4.3^b	3.0^b	1.6^b	0.7^b	30.8^b
25:25:50	NTE	29.9^a	27.2^a	25.9^a	24.3^a	21.9^a	19.3^a	57.8^a
	ETE	17.9^b	12.8^b	8.5^b	5.3^b	3.5^b	1.9^b	35.5^b
	CTE	16.9^b	12.4^b	7.7^b	5.3^b	2.9^b	1.8^b	34.1^b
30:25:45	NTE	33.5^a	30.9^a	29.2^a	27.5^a	25.1^a	22.4^a	58.8^a
	ETE	21.9^b	17.2^b	12.8^b	8.0^b	5.3^b	3.3^b	39.0^b
	CTE	20.1^c	16.8^b	12.6^b	7.7^b	5.1^b	3.2^b	38.5^b
35:25:40	NTE	39.3^a	37.6^a	35.5^a	33^a	30.9^a	28^a	59.3^a
	ETE	30.5^b	28.4^b	21.7^b	14.7^b	10.6^b	7.0^b	44.0^b
	CTE	29.4^b	27.0^c	21.9^b	13.6^b	9.3^c	6.3^b	43.1^b
40:25:35	NTE	43.7^a	41.7^a	39.9^a	37.4^a	35.1^a	32.4^a	59.9^a
	ETE	37.2^b	35.3^b	29.0^b	20.6^b	14.9^b	10.3^b	47.0^b
	CTE	33.9^c	29.1^c	27.9^b	18.6^c	12.8^c	8.6^c	45.1^b
LTV		22.8	8.9	4.6	1.3	0.0	0.0	28.7

Different superscripts in each temperature-blend represent significant difference at $P < 0.05$. FHSBO, fully hydrogenated soybean oil; RSO, rapeseed oil; SFO, sunflower oil; LTV, commercial low trans vanaspati; NTE, not transesterified; ETE, enzymatically transesterified; CTE, chemically transesterified.

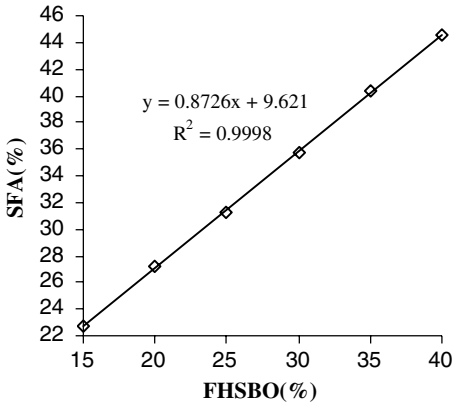

Fig. 3. Linear correlation between portion of fully hydrogenated soybean oil (FHSBO) and corresponding saturated fatty acid (SFA) content of transesterified blends.

transesterification of blends (according to method used in this study), Lipozyme TL IM produces less FFA and mono- and diacylglycerols than other commercial lipases (Zhang et al., 2001). Zhang et al. (2001) showed that FFA or diacylglycerol content in the product can decrease SFC of the product. So less formation of FFA and diacylglycerol during transesterification by Lipozyme TL IM means more SFC in the final product.

Enzymatically and chemically transesterified fats composed of 20% or more, and 25% or more FHSBO in their formulation, respectively, had SFC values at 20–30 °C equal to or more (better) than commercial low trans vanaspati ($P < 0.05$). A good power correlation ($R^2 > 0.99$) was found between SFA and SFC at 20 °C of transesterified fats (Fig. 4). According to Fig. 4 enzymatically and chemically transesterified fats containing 27.2% and 28.4% SFA, respectively (according to Fig. 1, 20% and 21.5% FHSBO, respectively), will have the same SFC at 20 °C as commercial low trans vanaspati.

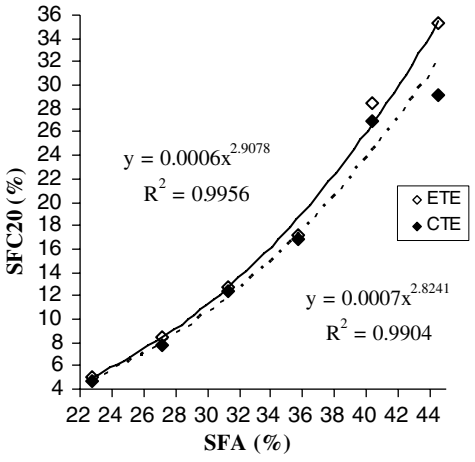

Fig. 4. Power correlation between amount of saturated fatty acids (SFA) and solid fat content (SFC) at 20 °C of transesterified blends. ETE, enzymatically transesterified; CTE, chemically transesterified.

4. Conclusions

Comparison of SFC of transesterified blends with those of the commercial low trans vanaspati showed that the minimum SFA necessary to produce a trans-free fat suitable for use as vanaspati was 27.2% (20% FHSBO) for enzymatic and 28.4% (21.5% FHSBO) for chemical transesterification. On the other hand, to have a SMP lower than 40 °C, content of SFA must be lower than 36.6% (30.9% FHSBO) and 37.8% (32.3% FHSBO) for enzymatic and chemical transesterification, respectively. Transesterification resulted in reduction of IP_{120} of initial blends. However, enzymatically transesterified fats had higher IP_{120} than chemically transesterified ones. Enzymatic transesterification led to less SFA and more oxidatively stable fats than chemical transesterification.

Acknowledgement

Ahmad Motahhari (The Chief Manager of Faravard Oils & Fats Producing Co.) is thanked for financial support.

References

Alpaslan, M., & Karaali, A. (1998). The interesterification-induced changes in olive and palm oil blends. *Food Chemistry, 61*(3), 301–305.

AOCS (1996). *Official methods and recommended practices of the American Oil Chemists' Society* (4th ed., 3rd printing). Champaign, USA: American Oil Chemists' Society Press.

Cosgrove, J. P., Church, D. F., & Pryor, W. A. (1987). Kinetics of the auto-oxidation of polyunsaturated fatty acids. *Lipids, 22*, 299.

Hayakawa, K., Linko, Y. Y., & Linko, P. (2000). The role of trans fatty acids in human nutrition. *Starch/Stärke, 52*, 229–235.

Hoshina, R., Endo, Y., & Fujimoto, K. (2004). Effect of triacylglycerol structure on thermal oxidative stability of edible oil. *Journal of the American Oil Chemists' Society, 81*(5), 461–465.

ISIRI (1997). Hydrogenated edible vegetable oil and fat (vanaspati) (7th ed., 4th rev., Standard No. 144). Tehran, Iran: Institute of Standards and Industrial Researches of Iran.

Konishi, H., Neff, W. E., & Mounts, T. L. (1999). Chemical interesterification with regioselectivity for edible oils. *Journal of the American Oil Chemists' Society, 70*, 411–415.

Kowalski, B., Tarnowska, K., Gruczynska, E., & Bekas, W. (2004). Chemical and enzymatic interesterification of tallow and rapeseed oil equal-weight blend. *European Journal of Lipid Science and Technology, 106*, 655–664.

Ledochowska, E., & Wilczynska, E. (1998). Comparison of the oxidative stability of chemically and enzymatically interesterified fats. *Fett/Lipid, 100*(8), 343–348.

List, G. R., Mounts, T. L., Orthoefer, F., & Neff, W. E. (1995). Margarine and shortening oils by interesterification of liquid and trisaturated triglycerides. *Journal of the American Oil Chemists' Society, 72*(3), 379–382.

List, G. R., Pelloso, T., Orthoefer, F., Chrysam, M., & Mounts, T. L. (1995). Preparation and properties of zero trans soybean oil margarines. *Journal of the American Oil Chemists' Society, 72*(3), 383–384.

Majumdar, S., & Bhattacharyya, D. K. (1986a). Trans free vanaspati from palm stearin and vegetable oils by interesterification process. *Oleeagineux, 41*, 235–240.

Majumdar, S., & Bhattacharyya, D. K. (1986b). Nutrition of hydrogenated vanaspati and interesterified vanaspati made from palm stearin and selected oils. *Oleeagineux, 41*, 393–399.

Mensink, R. P., Plat, J., & Temme, E. H. M. (2002). Dietary fats and coronary heart disease. In C. C. Akoh & D. B. Min (Eds.), *Food lipids* (pp. 603–636). New York, USA: Marcel Decker.

Ming, L. O., Ghazali, H. M., & Let, C. C. (1999). Use of enzymatic transesterified palm stearin-sunflower oil blends in the preparation of table margarine formulation. *Food Chemistry, 64*, 83–88.

Moussata, C., & Acoh, C. C. (1998). Influence of lipase-catalyzed interesterification on the oxidative stability of melon seed oil triacylglycerols. *Journal of the American Oil Chemists' Society, 75*(9), 1155–1159.

Neff, W. E., El-Agaimy, M. A., & Mounts, T. L. (1994). Oxidative stability of blends and interesterified blends of soybean oil and palm olein. *Journal of the American Oil Chemists' Society, 71*(10), 1111–1115.

Neff, W. E., Selke, E., Mounts, T. L., Rinsch, W., Frankel, E. N., & Zeitoun, M. A. M. (1992). Effect of triacylglycerol composition and structures on oxidative stability of oils from selected soybean germplasm. *Journal of the American Oil Chemists' Society, 69*, 111–118.

Petrauskaite, V., De Greyt, W., Kellens, M., & Huyghebaert, A. (1998). Physical and chemical properties of trans-free fat produced by chemical interesterification of vegetable oil blends. *Journal of the American Oil Chemists' Society, 75*(4), 489–493.

Ray, S., & Bhattacharyya, D. K. (1996). Comparative nutritional quality of palm stearin-liquid oil blend and hydrogenated fat (vanaspati). *Journal of the American Oil Chemists' Society, 73*(5), 617–622.

Rousseau, D., & Marangoni, A. G. (1999). The effect of interesterification on physical and sensory attributes of butterfat and butterfat-canola oil spreads. *Food Research International, 31*(5), 381–388.

Schmidt, S., Hurtová, S., Zemanovič, J., Sekretár, S., Šimon, P., & Ainsworth, P. (1996). Preparation of modified fats from vegetable oils and fully hydrogenated vegetable oil by randomization with alkali catalysts. *Food Chemistry, 55*(4), 343–348.

Seriburi, V., & Akoh, C. (1998). Enzymatic interesterification of lard and high-oleic sunflower oil with Candida Antarctica lipase to produce plastic fats. *Journal of the American Oil Chemists' Society, 75*(10), 1339–1345.

Wada, S., & Koizumi, C. (1983). Influence of the position of unsaturated fatty acid esterified glycerol on the oxidation rate of triglyceride. *Journal of the American Oil Chemists' Society, 60*, 1105–1109.

Zeitoun, M. A. M., Neff, W. E., List, G. R., & Mounts, T. L. (1993). Physical properties of interesterified fat blends. *Journal of the American Oil Chemists' Society, 70*(5), 467–471.

Zhang, H., Pedersen, L. S., Kristensen, D., Adler-Nissen, J., & Holm, H. C. (2004). Modification of margarine fats by enzymatic interesterification: evaluation of solid fat content-based exponential model with two groups of oil blends. *Journal of the American Oil Chemists' Society, 81*(7), 653–658.

Zhang, H., Xu, X., Nilsson, J., Mu, H., Adler-Nissen, J., & Høy, C. (2001). Production of margarine fat by enzymatic interesterification with silica-granulated *Thermomyces lanuginosa* lipase in a large-scale study. *Journal of the American Oil Chemist's Society, 78*(1), 57–64.