Formulation and pilot scale production of low-trans vanaspati with modified polyunsaturated fatty acids content

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Abstract Pilot scale production of low-trans vanaspati through a combination of techniques including non-selective hydrogenation of palmolein and physical blending of 3 vegetable oils, namely Canola, soybean and sunflower oils was investigated. Six formulations (A-F) of trans-free vanaspati were prepared. The fatty acid composition, peroxide value, acid value, iodine value, slip melting point (SMP), solid fat content (SFC) at 10–40 °C and oil/oxidative stability of the formulations were evaluated. The percentage of trans-fatty acids obtained for vanaspati formulations were within the value recommended by WHO (<4), except for B and D formulations (5.81 and 5.28, respectively). A and E formulations had the lowest trans-fatty acids content. The total saturated fatty acids (SFA) in the vanaspati formulations ranged from 22.96 to 30.11 %. Among the six formulations, A showed the significant percentage of SFA. The highest and the Lowest of linolenic acid contents were obtained for samples E (4.36 %) and F (0.28 %). Percentage of the monounsaturated fatty acids (MUFA) of the vanaspati formulations suggested an order from the highest to lowest as: A > C > E > F > D > B formulations. B formulation had the highest significant percentage of PUFA, followed by D, E, F, C, and A formulations. Only A vanaspati had the induction periods (IP) of higher than commercial low-trans vanaspati, while the lowest stability time belonged to sample B (10.20 h). SMP of all the vanaspati formulations was higher than the commercial low-trans vanaspati, but less than 40 °C. Although A and E formulations contained lower SFA than the commercial low-trans vanaspati,

they indicated higher SFC at 20–40 °C. According to the above information, E and A formulations could be recommended as suitable formulations for further research in a larger scale.

Keyword Vanaspati · Low-trans fatty acids · Stability · Palmolein · Canola oil · Soybean oil · Sunflower oil · Blending

Introduction

Vanaspati, the vegetable alternative for ghee, is an all-purpose cooking fat, which is widely consumed in the Indo-Pakistan subcontinent, Middle Eastern countries, and Southeast Asia. Ghee is made from milk fat from either cow or buffalo; but, its demand has exceeded the supply and raised its price. Hence, a ghee substitute- vegetable ghee or vanaspati has emerged Nor Aini et al. (1999). Initially, vanaspati has been made from a blend of vegetable oils such as soybean, rapeseed, cottonseed, and palm oil which was hydrogenated to make it solid Farmani et al. (2008). However, trans-fatty acids are formed and saturated fatty acids (SFA) are increased during this process. Unfortunately, consumption of a diet high in trans-fatty acids has been reported to raise total and low-density lipoprotein (LDL) cholesterol and lower high-density lipoprotein (HDL) cholesterol levels and a diet having a high ratio of SFA to polyunsaturated fatty acids (PUFA) has been shown to increase serum total cholesterol, all of which are indicators of increased risk for cardiovascular diseases (Mensink and Katan 1990; Su and White 2004). The most common method of substituting hydrogenation is through modifying fatty acid composition of oil, which can be done by several methods; physically by replacing hydrogenated fats with natural solid fats, namely Palmstearin, in vanaspati formulation, and chemically by enzymatic or chemical transesterification (Menaar et al. 2013). But, the problem with the interesterification reaction is that it increases processing costs, which is not

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acceptable in the oil industry of the mentioned countries. Furthermore, it produces SFA (Chu and Kung 1998). Palmstearin is not nutritionally favored in many countries due to consumer concerns about SFA, since it contains approximately 66 % SFA with 60 % palmitic acid (C16:0) (Ray and Bhattacharyya 1996). According to Saadi et al. (2011), Norizzah et al. (2004), and Nor Aini and Miskandar (2007), palmstearin is not used directly for edible purposes due to its high-melting triacylglycerols and exhibits incomplete melting at body temperature. In addition, the difficulty in the transformation of high-melting point palmstearin among industrial tanks limits its application for the vanaspati formulation.

There are some studies on the production of trans-low vanaspati through the mentioned methods. Nor Aini et al. (1999) investigated the production of trans-free vanaspati by physical blending of Palm Oil–palmstearin–palmolein and Palm Oil–palmstearin–Palm Kernel Olein. Ray and Bhattacharyya (1996) compared the nutritional quality of palmstearin-liquid oil blends and hydrogenated fat (Vanaspati). Farmani et al. (2006, 2007 and 2008) studied the production of trans-free vanaspati through enzymatic and chemical transesterification of vegetable oil blends. The objective of this work was to prepare lower-cost formulation of vanaspati with high nutritional properties. This research introduced some formulations in the pilot scale for producing vanaspati with trans-fatty acids content of below 5 % and high amount of linolenic and oleic acids. To this goal, a combination of techniques including non-selective hydrogenation of palmolein and physical blending of some vegetable oils such as canola (CAO), soybean (SBO) and sunflower (SFO) oils was used. Some physicochemical properties of the formulated fat blends were compared with each other and a commercial low-trans Iranian vanaspati. Finally, suitable formulations recommended for further research in a large scale.

Materials and methods

Materials

Refined, bleached, and deodorized palmolein (POO), CAO, SBO, and SFO with no added antioxidants were supplied by Varamin Factory, Tehran, Iran. Commercial low-trans Iranian vanaspati was purchased from local market. Fatty acid methyl ester (FAME) standards and all the chemicals and solvents used in this study were of analytical reagent grade and supplied by Merck and Sigma Chemical Companies.

Preparing hydrogenated POO as the solid constitute of formulations

Hydrogenated POO (IV=34 and SMP=55 °C) was used as the solid (hard) constitute of *formulations*. 20 kg of refined,

bleached, and deodorized POO was hydrogenated in a pilot converter (Pars Separator Co., Tehran, Iran) under non-selective conditions to decrease trans-isomers. The applied non-selective conditions included the gassing temperature of 135 °C, nickel catalyst concentration of 0.05 % (PRICAT 9910, Germany), maximum reaction temperature of 190 °C, hydrogen pressure of 2.5–3 Bar and 120 rpm agitation rate. The hydrogenation process was continued until IV=34 and SMP=55 °C was obtained.

Preparing the blends

Formulations of vanaspati were prepared by simply blending RBD hydrogenated POO with RBD liquid oils according to the ratios shown in Table 1.

“Approximate position of Table 1”

Then, the blended oils were transferred to a pilot bleacher tank (Pars Separator Co., Tehran, Iran) and 0.2 % bleaching clay and 0.007 % citric acid solution 50 % were added to it. This blend was stirred at 90 °C for 15 min and then passed through a filter press to eliminate the remaining nickel. The nickel-eliminated oils were deodorized in a stainless steel type deodorizer (Pars Separator Co., Tehran, Iran, 20-lit capacity) at 235 °C and under the vacuum of 4 mmHg. 0.012 % TBHQ antioxidant and 0.0015 % beta-carotene suspension of 30 % were added to the deodorized oils at 65 °C and the mixture was stirred thoroughly to form uniform blends. 800g of the prepared oil was packed in PET bottles and stored at room temperature (25±2 °C) for 24 h to form physical solid state and crystallization. Finally, the samples were stored at refrigerator temperature (5±2 °C) until analysis.

Fatty acid composition

Fatty acid composition of the samples was determined by gas–liquid chromatography. Fatty acids were transesterified into

Table 1 Formulations of Vanaspati

	Oil blend ratios	Code
Hydrogenated palmolein (HPO), Palmolein (POO), canola (CAO), soybean (SBO) and sunflower oil (SFO)	HPO/POO/CAO 12 : 13 : 75	A
	HPO/POO/SBO 15 : 2 : 83	B
	HPO/POO/SFO /CAO 13 : 10 : 38.5: 38.5	C
	HPO/POO/SFO/SBO 14 : 4 : 41 : 41	D
	HPO/POO/SFO/SBO 11 : 11 : 39 : 39	E
	HPO/POO/SFO 13 : 7 : 80	F

their corresponding FAMES by vigorous shaking of the oil solution in hexane (0.3g in 7 mL) with 2 mL of 7 N methanolic potassium hydroxide at 50 °C for 10 min. The FAMES were determined using gas chromatography (Hewlett-Packard 6890 series- Agilent Technologies Inc., Santa Clara, CA, USA) fitted with flame ionization detector using the column BPX-70 (120 m×0.25 mm, internal diameter: 0.2 µm) from SGE Ltd. Nitrogen was used as the carrier gas with the flow rate of 0.6 mL min⁻¹. The oven temperature was maintained at 198 °C and that of the injector and detector was at 250 °C.

Iodine value

The AOAC Official Method 920.158 (Hanus method) was used to determine iodine values (IV)(AOAC 1995).

Acid value

Acid value (AV) was determined according to the AOCS Official Method Cd 3d-63 (AOCS 1996).

Peroxide value

Spectrophotometric method of International Dairy Federation as described by Shantha and Decker (1994) was used to determine the peroxide value (PV).

Oxidative stability by rancimat

Induction periods (IP) for the oxidation of formulations were measured according to the AOCS method Cd 12b-92 (AOCS 1996) using a Metrohm Rancimat instrument, model 743 (Herisau, Switzerland). The tests were done with 3g oil samples at 120 °C at the airflow rate of 15 L h⁻¹.

Solid fat content (SFC)

SFC of the vanaspati samples was determined by a minispec mq 20 pulsed nuclear magnetic resonance spectroscope (Bruker Corporation, Hamburg, Germany). The measurements were done at 10, 20, 30, and 40 °C according to AOCS Cd 16b-93 direct serial measurement method (AOCS 1996).

Slip melting point (SMP)

The SMP of each vanaspati sample was analyzed using AOCS Cc 3–25 open tube melting point standard method (AOCS 1996). Capillary tubes filled with the samples were stored in a refrigerator (6 °C) overnight before the measurements.

Statistical analyses

All the samples and subsequent analyses were measured in triplicate. Analysis of Variance (ANOVA) was used for data analyses (SPSS, 16). When F-values were significant ($P < 0.05$) in ANOVA, Duncan's multiple range test was used to compare the treatment means.

Results and discussion

Fatty acid composition

Fatty acid compositions of the POO, CAO, SBO and SFO and also those of the vanaspati formulations (A-F) are shown in Table 2.

“Approximate position of Table 2”

It can be observed that the formulations are distinguished from each other mainly due to the significant differences in the percentages of palmitic (C16:0), oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) acids. The total saturated fatty acids (SFA) in the vanaspati formulations ranged from 22.96 to 30.11 %. According to the ISIRI, standard number 144 (ISIRI 1997), SFA value of vanaspati should be ≤30 %. Consequently, the prepared formulations had the SFA values of nearly the same as or even better than the recommended value. A formulation showed the best significant percentage of SFA. In the previous studies, the SFA value in the vanaspati prepared by enzymatic and chemical transesterification of triple blends of fully hydrogenated soybean, rapeseed and sunflower oils (Farmani et al. 2007), chemical transesterification and blending techniques from palm olein, rapeseed and sunflower oils (Farmani et al. 2008), and physical blending of Palm Oil–palmstearin–palmolein (Nor Aini et al. 1999) has ranged from 27.1 to 44.5 %, 24.7 to 39.5 % and 51.1 to 52.4 %, respectively.

Percentage of the monounsaturated fatty acids (MUFA) of the vanaspati formulations suggested an order from greatest to lowest as A > C > E > F > D > B formulations. CAO had more oleic acid than SBO and SFO. Therefore, vanaspati formulation containing more ratio of CAO had more MUFA than the one containing SBO and SFO. The MUFA values determined in the present work were in agreement with those reported in the studies by Ray and Bhattacharyya (1996) and Nor Aini et al. (1999); but, compared with the research by Farmani et al. (2006), most formulation studied in the present work had much more MUFA (24.40–52.70 % against 24.2–29.5 %).

B formulation had the highest significant percentage of PUFA, followed by D, E, F, C, and A formulations. Due to the high level of C18:1, SBO and SFO showed higher significant percentage of PUFA than COO. Therefore, the

Table 2 The fatty acid composition (%) and chemical characteristics of the hydrogenated palmolein, Palmolein (POO), canola (CAO), soybean (SBO) and sunflower oil (SFO), and the formulated vanaspati examined in this study and commercial low trans vanaspati (LTV)

Sample Parameter	HPO	POO	CAO	SBO	SFO	Vanaspati formulations						
						A	B	C	D	E	F	LTV
Fatty acids	12:0	0.16±0.01	0.20±0.01	—	—	0.06±0.01 ^a	0.04±0.00 ^a	0.07±0.00 ^a	0.06±0.00 ^a	0.05±0.00 ^a	0.09±0.00 ^a	0.06±0.01 ^a
	14:0	0.76±0.01	0.87±0.01	0.05±0.01	0.10±0.01	0.07±0.01	0.25±0.00 ^a	0.35±0.00 ^a	0.34±0.00 ^a	0.27±0.00 ^a	0.43±0.00 ^a	0.26±0.01 ^a
	16:0	35.65±0.02	37.60±0.06	4.91±0.01	12.54±0.02	6.95±0.06	13.10±0.02 ^e	16.50±0.02 ^c	16.50±0.06 ^c	18.20±0.01 ^b	20.10±0.04 ^a	16.70±0.06 ^c
	16:1	—	0.15±0.01	0.13±0.01	0.07±0.01	0.08±0.01	0.14±0.01 ^a	0.10±0.00 ^a	0.13±0.00 ^a	0.10±0.00 ^a	0.12±0.00 ^a	0.08±0.00 ^a
	18:0	35.60±0.2	4.63±0.01	2.77±0.01	4.63±0.02	3.70±0.01	8.08±0.07 ^b	9.14±0.03 ^a	8.23±0.01 ^b	8.9±0.01 ^b	8.51±0.01 ^b	7.51±0.04 ^b
	18:1	1.77±0.02	43.21±0.05	64.47±0.04	27.57±0.03	28.42±0.03	52.70±0.02 ^a	24.40±0.01 ^g	44.40±0.03 ^b	30.30±0.01 ^f	38.70±0.03 ^c	36.02±0.04 ^d
	18:2	—	10.95±0.03	16.99±0.03	48.93±0.05	58.87±0.03	13.70±0.07 ^g	38.00±0.01 ^a	20.80±0.04 ^f	32.30±0.01 ^b	26.70±0.02 ^d	29.00±0.01 ^c
	18:3	—	0.37±0.01	6.02±0.02	4.79±0.02	0.20±0.02	4.25±0.02 ^a	3.38±0.01 ^b	2.89±0.01 ^c	2.25±0.00 ^e	4.36±0.02 ^a	0.28±0.02 ^f
	20:0	0.43±0.01	0.46±0.01	0.35±0.01	0.41±0.01	0.24±0.01	1.03±0.00 ^a	1.07±0.00 ^a	0.67±0.00 ^b	0.71±0.00 ^b	0.80±0.00 ^b	0.29±0.02 ^c
	TFA	25.53±0.03	—	—	—	—	3.64±0.05 ^e	5.81±0.02 ^b	3.75±0.01 ^d	5.28±0.01 ^c	3.58±0.01 ^e	3.77±0.04 ^d
MUFA	SFA	72.70±0.05	43.85±0.04	8.43±0.03	18.11±0.04	11.58±0.02	22.96±0.04 ^g	27.62±0.04 ^c	26.33±0.07 ^d	28.78±0.00 ^b	24.92±0.06 ^f	30.11±0.03 ^a
	MUFA	1.77±0.01	43.55±0.03	67.55±0.02	27.83±0.05	28.64±0.03	55.12±0.05 ^a	24.65±0.09 ^g	45.88±0.04 ^b	31.15±0.02 ^f	40.06±0.06 ^c	36.54±0.05 ^d
	PUFA	—	11.32±0.05	23.01±0.03	53.72±0.04	59.07±0.06	17.95±0.09 ^g	41.38±0.04 ^a	23.69±0.05 ^f	34.55±0.05 ^b	31.06±0.05 ^c	29.28±0.03 ^d
	PUFA/SFA	—	0.25±0.02	2.73±0.07	2.97±0.05	5.10±0.15	0.78±0.02 ^b	1.50±0.03 ^a	0.90±0.01 ^b	1.20±0.02 ^a	1.25±0.02 ^a	0.97±0.01 ^b
IV	PV	0.4±0.01	2.2±0.09	1.9±0.08	1.8±0.08	2.1±0.09	0.13±0.02 ^a	0.17±0.03 ^a	0.17±0.02 ^a	0.13±0.01 ^a	0.20±0.02 ^a	0.20±0.04 ^a
	AV	0.18±0.01	0.10±0.01	0.07±0.01	0.08±0.01	0.07±0.01	0.06±0.01 ^a	0.06±0.01 ^a	0.06±0.01 ^a	0.06±0.01 ^a	0.05±0.01 ^a	0.06±0.01 ^a
	TV	34±0.38	57±0.89	110±0.77	122±0.69	129±0.82	96.1±0.3 ^f	108±0.6 ^c	104±0.5 ^d	110.8±0.6 ^b	101.5±0.4 ^e	113.2±0.4 ^a
												91.9±0.5 ^g

Means ± SD (standard deviation) within a row with the same lowercase letters are not significantly different at $P<0.05$. SFA saturated fatty acids, MUFA

Fig. 1 The Induction period at 120 °C (IP) of the the vanaspati formulations (A- E) and commercial low-trans vanaspati (LTV). Bars with different superscripts have significant difference at $P < 0.05$

formulations consisting of more contributions of SBO and SFO demonstrated more levels of PUFA. Compared with the research by Nor Aini et al. (1999), formulations studied in the present work had much more PUFA (20.37–41.63 % against 6.6–10.5 %). The PUFA percentages determined in the present work were in agreement with those reported by Ray and Bhattacharyya (1996) and Farmani et al. (2006 and 2007). According to the above-stated information, the PUFA/SFA ratio (known as an important nutritional index) was the greatest and the lowest for B and A formulations, respectively. WHO/FAO experts have reported guidelines for a "balanced diet" in which the suggested ratio of PUFA/SFA is above 0.4 (Health Department Organisation 1994; Wood et al. 2004). From this aspect, all the examined samples have favorable (from 0.78 to 1.50) PUFA/SFA ratio (Table 2).

Compared with the commercial low-trans Iranian vanaspati (LTV), the formulations studied in the present work had much lower trans-fatty acids (3.58–5.81 % against 9.81 %); but, more PUFA + MUFA (65.70–73.07 % against 62.44 %). Food and Agriculture Organization (FAO) and World Health Organization (WHO) recommended in 1994 (WHO 1993) that fats for human consumption contain less than 4 % of the total fat as trans and urged the food industry to reduce the presence of trans fats in their product to these levels (WHO 1993). Therefore, the percentage of trans-fatty acids obtained

for vanaspati formulations is within the recommended value, except for B and D formulations (5.81 and 5.28, respectively). As mentioned before, vanaspati is traditionally produced by partial hydrogenation of vegetable oils. However, concentration of PUFA is reduced, content of SFA is increased and trans-fatty acids are formed during this process, all of which are indicators of increased risk for cardiovascular diseases. lack of reduction in the amount of PUFA with no increase in trans-fatty acids content of vanaspati to a level similar to that obtained by partial hydrogenation was the important achievement of this study.

Chemical characteristics

PV and AV of the vegetable oils and vanaspati formulations were all less than $0.20 \text{ mequiv kg}^{-1}$ and 0.10 mg g^{-1} , respectively, indicating that they were unoxidized and had high initial quality (Table 2). According to the ISIRI, standard number 144 (ISIRI 1997), IV of vanaspati should be < 75 . As shown in Table 2, CAO, SBO and SFO had IV higher, while POO and hydrogenated POO had IV of less than 75. Therefore, the limiting fractions in the formulation were POO and hydrogenated POO and their portion in the formulation should be carefully controlled and calculated (total portion of POO and hydrogenated POO in formulations was less than 25 %). IV of vanaspati formulations ranged from 96.1 to 113.2 and all the formulations had higher IV than the commercial low-trans vanaspati. These values were in accordance with those reported in the studies by Farmani et al. (2006 and 2008); but, compared with the research by Ray and Bhattacharyya (1996) and Nor Aini et al. (1999 and 2005), the formulation studied in the present work had much more IV (96.1–113.2 % against 36.6–50.0 %).

Oxidative stability

Induction period at 120 °C (IP) of vanaspati formulations is given in Fig. 1.

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

Formulations	Solid fat content (%)				SMP (°C)
	10 °C	20 °C	30 °C	40 °C	
A	20.64±0.04 ^d	13.55±0.09 ^c	7.93±0.02 ^b	2.66±0.10 ^a	39.0±0.1 ^b
B	19.27±0.03 ^e	12.79±0.09 ^d	7.82±0.11 ^c	2.38±0.05 ^a	38.9±0.2 ^b
C	23.92±0.02 ^c	14.78±0.15 ^b	8.38±0.14 ^b	2.57±0.16 ^a	39.2±0.2 ^b
D	23.93±0.10 ^c	14.41±0.10 ^b	8.26±0.09 ^b	2.59±0.06 ^a	39.3±0.1 ^b
E	20.03±0.08 ^d	13.41±0.14 ^c	8.05±0.08 ^b	2.83±0.08 ^a	38.9±0.1 ^b
F	27.19±0.05 ^a	16.43±0.06 ^a	9.02±0.17 ^a	2.88±0.11 ^a	39.8±0.1 ^a
LTV	26.35±0.18 ^b	12.19±0.09 ^c	4.55±0.02 ^d	0.00±0.00 ^b	36.2±0.1 ^c

Means ± SD (standard deviation) within a row with the same lowercase letters are not significantly different at $P < 0.05$

“Approximate position of Fig. 1”

The term oxidative stability refers to the susceptibility of edible oils to lipid oxidation, which causes rancid odors and flavors. Thus, IP is a criterion for predicting the length of time before a sample will go rancid. In this work, there were no significant IP differences between C and F vanaspati and between E and D vanaspati, whereas these amounts were significantly lower than that of A vanaspati and higher than that of B vanaspati, respectively. These results indicated that, by increasing CAO and decreasing SBO in the formulation, IP of the blends increased. Among the initial vegetable oil, POO as a result of its high IP oxidation (data not shown) was a good choice for formulating blends with improved oxidative stability. However, because of high content of SFA and low IV (Table 2) of POO, its application in the vanaspati formulation was limited. Only A vanaspati had the IP of higher than the commercial low-trans vanaspati ($P < 0.5$), which was probably due to the presence of less unsaturated fatty acids in A vanaspati formulation. Comparatively, the vanaspati formulated in the present work had the IP of nearly the same as or better than the vanaspati prepared by enzymatic and chemical transesterification methods (Farmani et al. 2006, 2008). According to the literature, less oxidative stability of transesterified fats may be due to the formation of free fatty acids and partial acylglycerols and removal of natural antioxidants present in fat (Kowalski et al. 2004; Ledóchowska and Wilczyńska 1998) along with the alteration of fatty acid position in triacylglycerol (Hoshina et al. 2004).

SMP and SFC

The examined initial vegetable oils had very slight SMP (data not shown), except for the hydrogenated POO, which had very high SMP (55 °C). This issue can be attributed to the presence of high amounts of palmitic, especially stearic acid, in hydrogenated POO. Generally, melting point of vanaspati must not exceed 40 °C (Nor Aini et al. 1999 and Farmani et al. 2007); on the other hand, if melting point of vanaspati is very low, its structure will become fluent and two-phase, which is not favorable for consumers. Therefore, neither hydrogenated POO nor initial vegetable oils were suitable individually for use as vanaspati. However, blending hydrogenated POO with other four oils resulted in a favorable change in the resulted vanaspati SMP. SMP of all vanaspati formulations was higher than the commercial low-trans vanaspati ($P < 0.05$), but lower than 40 °C (Table 3).

“Approximate position of Table 3”

SFC is one of the physical parameters associated with the quality of vanaspati including general appearance and organoleptic properties (Chu et al. 2002). SFC of a fat at a certain temperature indicates the portion of its solid phase in mixing with liquid phase. It is clear that, in the comparison between two fats at a certain temperature, the one with higher

consistency has higher SFC. SFC of common vanaspati with desirable characteristics is about 6–22 at 30 °C and 0–5 at 40 °C (Nor Aini and Noor Lida 2005). SFC at 10–40 °C of the vanaspati formulations is shown in Table 3. All the formulations had a narrow plastic range and low SFC at 40 °C (higher than body temperature), which caused no greasiness in the mouth. SFC at all four temperatures was the greatest and the lowest for F and B formulations, respectively. As can be seen in Table 2, B vanaspati formulation had PUFA content which was considerably higher; but, SFA content slightly lower than that of the F vanaspati formulation. Therefore, the quite obvious superiority of F to B vanaspati can be attributed to the greater effect of PUFA than SFA on SFC. Generally, the SFC at 20–30 °C of a fat can reflect its physical state at ambient temperature. All the formulated vanaspati had higher (better) SFC at 20–30 °C than the commercial low-trans vanaspati. SFC of vanaspati determined in the present work was in agreement with those reported in the study by Farmani et al. (2007).

Conclusions

This study showed that a combination of techniques including non-selective hydrogenation and physical blending of vegetable oils could be used to prepare fat products similar to hydrogenated vanaspati, but with low-trans fatty acid and substantial PUFA content. The formulated vanaspati was nutritionally and physically (SMP and SCF) equivalent to or, somehow, better than, the trans-fatty acid rich and essential fatty acid-deficient vanaspati products (made by partial and selective hydrogenation of liquid oils) and even compared with the vanaspati prepared by transesterification. In addition, compared with transesterification, the method applied in the present work decreased the processing cost.

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