Fatty Acid (FA) Composition and Contents of *trans* Unsaturated FA in Hydrogenated Vegetable Oils and Blended Fats from Pakistan

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ABSTRACT: This study presents the FA composition and *trans* FA (TFA) contents of different hydrogenated vegetable oils and blended fats marketed in Pakistan. Thirty-four vanaspati (vegetable ghee), 11 shortenings, and 11 margarines were analyzed. The contents of saturated FA, *cis* monounsaturated FA, and *cis* PUFA were in the following ranges: vanaspati 27.8–49.5, 22.2–27.5, 9.3–13.1%; vegetable shortenings 37.1–55.5, 15.8–36.0, 2.7–7.0%; and margarines 44.2–55.8, 21.7–39.9, 2.9–20.5%, respectively. Results showed significantly higher amounts of TFA in vanaspati samples, from 14.2 to 34.3%. Shortenings contained TFA proportions of 7.3–31.7%. The contents of TFA in hard-type margarines were in the range of 1.6–23.1%, whereas soft margarines contained less than 4.1% TFA.

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Because of the structurally relaxed position of *trans* isomers of FA, rapid *trans* formation occurs during industrial hydrogenation of *cis* unsaturated FA of liquid vegetable oils. This allows the FA to pack together more closely than their corresponding *cis* isomers, resulting in harder fats with more desirable physical properties, texture, and durability (1,2). Common *trans* isomers of C18:1 (octadecenoic acid) are those with unsaturation at the 9-, 10-, and 11-positions (3).

However, *trans* FA (TFA) have been reported to cause several health problems (4–7). Ongoing research and some epidemiological studies suggest a relationship between TFA and the risk of coronary heart disease (8–10). Consequently, recommendations to reduce the content of TFA in human dietary fats to less than 4% of the total FA have been put forth by The World Health Organization and Food and Agriculture Organization (11). Such recommendations also have been given by the Danish Nutrition Council (12), and on the basis of follow-up data, it has been urged that the margarine industry should comply with these recommendations (13).

Owing to the growing nutritional concerns regarding FA, TFA, and n-3 and n-6 PUFA, research on the FA composition of dietary fats has gained wide momentum worldwide. Arici *et al.* (14) reported the FA content and total TFA of Turkish margarines. Alonso *et al.* (15) described the FA content of Spanish margarines with special emphasis on *trans* unsaturated FA content, as determined by FTIR spectroscopy and GC. Bayard and Wolff (16) published a report of the *trans* C18:1 content of French tub margarines and shortenings. A TRANSFAIR study included the TFA content in dairy and meat products from 14 European countries (17). Alonso *et al.* (18) reported the FA and TFA content of margarines marketed in Spain.

Despite the awareness of the health impacts of dietary FA, a large proportion of the Pakistani population still uses hydrogenated vegetable oils and fats in their domestic cooking and frying. Vegetable oil production in Pakistan between the years 2000 and 2002 was around 620,000 tons annually, against the total requirement of edible oils, which is estimated at 1.55 million tons (Pakistan Vanaspati Manufacturers Association, unpublished data). The remaining 930,000 tons was met through imports of palm oil and soybean oil. These data clearly revealed a high consumption of oils and fats in Pakistan.

In Pakistan, no study has been reported on the FA and TFA contents of partially hydrogenated vegetable oils and blended fats. Since hydrogenated fats constitute a major portion of dietary fats of the local population, a current knowledge of the FA composition of these products is necessary to provide reliable and comparable data for the manufacturers, policy makers, and consumers.

The recent technological advances in measurements of positional and geometrical *trans* isomers by capillary GC have made it possible to conduct an in-depth survey of various oils and fats products marketed throughout Pakistan. The aim of the present comprehensive study was to investigate a series of locally marketed hydrogenated vegetable oils, shortenings, and margarines for their FA contents, with special emphasis on TFA.

MATERIALS AND METHODS

Samples and standards description. Four samples of each of 34 brands of hydrogenated vegetable oils/vegetable ghee (vanaspati), 11 shortenings, and 11 margarines (designated by

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sample codes) were obtained at local retail outlets. Samples of vanaspati and shortenings were warmed, homogenized, and used directly for the preparation of FAME. Margarine oils were recovered by melting samples in acid-washed beakers on a hot plate, allowing phase separation overnight at 95–100°C in an oven. The decanted oil was freed of moisture by drying on a rotary evaporator at 90°C for 1 h and stored frozen until analyzed. All reagents and solvents used were from E. Merck (Darmstadt, Germany). Pure FAME standards (purity >99%) were purchased from Sigma Chemical Co. (St. Louis, MO).

GC analysis of FAME. FAME were prepared by standard IUPAC method 2.301 (19) and analyzed on a PerkinElmer gas chromatograph, model 8700, fitted with a methyl lignocerate-coated, stationary-phase, polar capillary column SP-2340 (60 m × 0.25 mm) and an FID. Oxygen-free nitrogen was used as a carrier gas at a flow rate of 3.5 mL/min. Other conditions were as follows: initial oven temperature, 130°C; ramp rate, 5°C/min; final temperature, 220°C; injector temperature, 260°C; detector temperature, 270°C; temperature hold, 3 min before the run and 10 min after the run. A sample volume of 1.0 mL was injected. FAME were identified by comparing their relative and absolute retention times to those of authentic standards of FAME obtained from Sigma Chemical Co. All of the quantification was done by a built-in data-handling program provided by the manufacturer of the gas chromatograph (PerkinElmer). The data were transferred on an Epson LX-800 printer attached to the instrument through an RS-232-C port. The FA composition was reported as a relative percentage of the total peak area.

RESULTS AND DISCUSSION

Table 1 shows the FA composition of a collection of hydrogenated vegetable oils/vanaspati consumed in routine domestic cooking and frying. A larger variation in the content of component FA was observed within the different vanaspati samples, which may be attributed to differences in the source of vegetable oils and the extent of their hydrogenation. For practical reasons, the investigated ghee samples were divided into three categories based on their palmitic and stearic acid contents. Eight of them had greater than 40% of C16:0 and less than 8.5% C18:0, a homogenous composition, a relatively lower content of total *trans* isomers, and a higher content of saturated FA (SFA). This pattern of FA content suggests that these samples contained substantial but variable amounts of palm oil.

Another group of 22 hydrogenated vegetable oils contained <8.5% C18:0 and <40% C16:0 and showed a relatively lower content of SFA and a higher concentration of TFA. The third group, with <40% C16:0 and >8.5% C18:0, contained an even higher level of *trans* isomers and lower amounts of SFA. The content of *cis* C18 monunsaturated FA (MUFA), which has been shown to protect against age-related cognitive decline (20), was found to decrease across categories (a), (b), and (c) of vegetable ghee (Table 1). The results in this table indicate that two main types of hydrogenated vegetable oils are available in the local market: one containing palm oil as a major ingredient, and the other containing hydrogenated sunflower/soybean oil as their major ingredient. The *cis* PUFA fraction (mainly linoleic acid), which is the most valuable from a nutritional point of view, was somewhat variable, ranging from 13.14% in cate-

TABLE 1
FA Composition (wt% total FA, mean ± SD)[a] of Hydrogenated Vegetable Oils (vegetable ghee/vanaspati) Determined by GC

	>40% Palmitic acid	<40% Palmitic acid	
FA	<8.5% Stearic acid (*n* = 8) (a)	<8.5% Stearic acid (*n* = 22) (b)	>8.5% Stearic acid (*n* = 4) (c)
C12:0	0.37 ± 0.75	0.44 ± 0.90	—[b]
C14:0	0.68 ± 0.51	0.60 ± 0.63	0.43 ± 0.51
C16:0	42.19 ± 1.08	34.40 ± 3.33	17.73 ± 10.74
C18:0	6.31 ± 0.57	6.51 ± 0.71	9.73 ± 1.64
C18:1*t*	13.73 ± 3.80	19.85 ± 5.05	31.92 ± 8.61
C18:1*c*	27.50 ± 5.20	24.32 ± 5.14	22.44 ± 5.45
C18:2*t*	0.51 ± 0.58	1.83 ± 1.03	2.44 ± 2.43
C18:2*c*	8.97 ± 3.08	10.12 ± 3.62	12.94 ± 6.58
C18:3	0.34 ± 0.47	0.30 ± 0.54	0.20 ± 0.38
Other[c]	0.12 ± 0.35	1.13 ± 1.05	2.24 ± 1.53
Total			
SFA	49.55	41.95	27.89
cis MUFA	27.50	24.42	22.24
cis PUFA	9.31	10.42	13.14
TFA	14.24	21.68	34.36
cis PUFA/(SFA + TFA)	0.14	0.16	0.21
(*cis* PUFA + *cis* MUFA)/(SFA + TFA)	0.57	0.54	0.57

[a]Values are average of four samples of each brand analyzed individually in triplicate.
[b]Not detected or below 0.10%.
[c]Geometrical and positional isomers that could not be identified. SFA, saturated FA; MUFA, monounsaturated FA; TFA, *trans* FA.

gory (c) to 9.31% in category (a). As shown in Table 1, the sums of the SFA—lauric, myristic, and palmitic acids—which are suspected to have more atherogenic potential than stearic acid (1,10), were 43.24% in (a), 35.44% in (b), and 18.16% in (c).

Within categories (Table 1), comparatively large variations in the contents of SFA and TFA were found. The contents of total *trans* (C18:1*t* + C18:2*t*) were much higher (34.36%) in the four samples of category (c). This may be due to inclusion of a high amount of heavily hydrogenated soybean or sunflower oil in these formulations. The eight samples in category (a), with palmitic acid >40%, were found to be significantly lower in their *trans* content (mean 14.24%). This shows these products contain palm oil in a relatively high proportion. One of the samples of vanaspati, marketed by a multinational company ["Dalda" (virtually *trans* fat free); Lever Brothers Pakistan Ltd., Karachi, Pakistan], was found to be virtually *trans* free (*trans* content <1%). This could be attributed to the interesterification of oils (21), which has recently gained momentum as an alternative to *trans*-encouraging hydrogenation of oils.

A significant correlation was found between the contents of total TFA and SFA. Generally, ghee samples low in SFA were high in TFA. However, within categories the mean values of the indexes most commonly used to express the nutritional value of edible fats (15)—[*cis* PUFA/(SFA + TFA)] and [(*cis* MUFA + *cis* PUFA)/(SFA + TFA)]—were quite low: 0.14, 0.16, 0.21, and 0.57, 0.54, 0.57 in categories (a), (b), and (c) of vanaspati samples, respectively. The values for these indexes of the vanaspati products could not be compared with the literature, as there are no previously published data with which to compare the results of our findings.

Table 2 shows the FA composition of 11 shortenings used for bakery and other food-manufacturing purposes. Within the 11 brands, a large variation in the contents of component FA was found. The proportion of total SFA ranged from 37.12 to 55.53%. The contents of palmitic, myristic, and lauric acids, which elevate blood cholesterol (10), were significantly ($P <$ 0.05) high and ranged from 27.92 to 52.17% (average 40.37%). This was much higher than the 28.70% reported by Ovesen *et al.* (1) in Danish shortenings, but slightly lower than the 45.5% reported by Alonso *et al.* (15) in the Spanish shortenings.

The content of TFA was quite variable, from 7.34 to 31.70% (Table 2). TFA showed very high values; the average value for the six varieties having the highest TFA values was 27.61%, whereas the other five averaged 11.14%. This generally indicates the existence of two types of shortenings in the market: those obtained from heavily hydrogenated light vegetable oils and those made with a high proportion of palm oil in combination with slightly hydrogenated vegetable oils. The contents of *cis* MUFA and PUFA of these shortening products, which are more desirable for human health, ranged from 15.81 to 36 and 2.73 to 7.04%, respectively. This value of *cis* PUFA for shortenings from Pakistan was much lower than that reported by Alonso *et al.* (15) in the Spanish shortenings (7.39–16.76%).

The mean values of the indexes [*cis* PUFA/(SFA + TFA)] and [(*cis* MUFA + *cis* PUFA)/(SFA + TFA)] of the shortenings, which are most commonly used to express the nutritional value of edible fats, ranged between 0.04 and 0.10 (mean 0.06), and 0.25 and 0.73 (0.46), respectively. These values, although lower and higher than those reported by Alonso *et al.* (15) (mean 0.14, 0.35 in the Spanish shortenings), were in agreement with earlier reported values (15). This could be attributed to the heterogeneity of the shortening samples and to differences in the sources of fat, processing, and ultimate end uses.

Table 3 shows the FA composition of 11 margarine samples. These are classified into two categories based on their linoleic acid (LA) content: (i) hard margarines with less than 14% LA (6 brands), (ii) soft margarines (5 brands) with greater than 14% LA. The soft margarines, as generally expected, had a higher content of PUFA than the hard margarines. EFA are included in the PUFA group, which is of major importance for the biological and nutritional value of these products. The mean PUFA content (17.52%) for soft-type Pakistani margarines was much lower than those of recent results (14) reported from Bulgaria (36.30%), The Netherlands (42.50%), and Turkey (39.20%). However, the PUFA contents were comparable to those reported for margarines (18.30%) from Austria (14). The hard margarines had PUFA values between 2.96 and 9.0% (mean 6.23%), which were significantly ($P < 0.005$) lower than those reported for Turkish hard margarines (14). These values of PUFA show that margarines in Pakistan are mainly produced from palm oil and tropical and milk fats.

The proportion of total SFA of the margarines was high, between 44.20 and 55.86%. The contents of palmitic, myristic, and lauric acids, which have atherogenic potential (1,10), were 38.00 to 50.75% (average 42.18%), and much higher than Danish (1) and Spanish shortenings (15).

In the 6 hard margarines analyzed in the present study, the total TFA contents were higher (average 10.15%) than the 5 soft margarines (average 2.70%). The C18:1 *trans* acid was the major *trans* isomer that had a wide variation, from 1.45 to 21.05% for all 11 margarines. These values, ranging from 1.67 to 21.05% in hard margarines, were higher than those (1.45–4.08%) determined in soft margarine. Only two samples of hard margarines contained small amounts (1.55 to 2.04%) of C18:2 *trans* acids. The values of C18:1 *trans* and total TFA in Pakistani hard and soft margarines were significantly ($P < 0.005$) lower than those reported in Turkish margarines (14). However, none of the samples of margarines was found to be *trans* free. In Pakistan, margarines are usually prepared from partially hydrogenated vegetable oils; thus, variable amounts of *trans* isomers were present. However, some margarines are made from highly hydrogenated fats, which result in very high amounts of TFA. A comparison of the mean total TFA values for our hard margarines with those of recent data revealed that our values were higher than those from Denmark (3%) (13), France (3.8%) (16), and Greece (10%) (22). However, the total TFA contents of Pakistani margarines were quite low relative to recent margarine data for products for Canada (23.60%), Turkey (27.60%), the United States (22.60%), and Austria (21.30%) (14).

The mean values of the indexes [*cis* PUFA/(SFA + TFA)] and [(*cis* MUFA + *cis* PUFA)/(SFA +TFA)] of the investigated

TABLE 2
FA Composition (wt% total FA, mean ± SD)[a] of Shortenings Determined by GC

FA	Rbn.Sh	Rbl.Sh	Tul.Sh	Chi.Sh	Bmp.Sh	Bmc.Sh	Puf.Sh	Bmb.Sh	Ind.Sh-1	Ind.Sh-2	Ind.Sh-3
C12:0	—	—	—	—	—	—	—	—	1.12 ± 0.10	—	—
C14:0	0.56 ± 0.10	—	0.87 ± 0.25	0.97 ± 0.15	—	—	—	—	0.80 ± 0.11	—	—
C16:0	43.0 ± 0.32	45.90 ± 0.54	33.60 ± 0.63	37.0 ± 0.30	45.10 ± 0.60	50.00 ± 0.24	39.00 ± 0.20	52.17 ± 0.52	26.0 ± 0.30	30.00 ± 0.50	38.00 ± 0.50
C18:0	5.20 ± 0.32	3.52 ± 0.20	7.67 ± 0.40	12.20 ± 0.28	6.50 ± 0.30	4.00 ± 0.15	10.00 ± 0.38	3.36 ± 0.20	9.20 ± 0.25	8.70 ± 0.18	8.65 ± 0.30
C18:1*t*	11.0 ± 0.19	7.34 ± 0.25	22.40 ± 0.60	24.65 ± 0.39	22.14 ± 0.40	8.98 ± 0.40	24.59 ± 0.47	9.54 ± 0.29	25.60 ± 0.35	23.78 ± 0.38	16.40 ± 0.43
C18:1*c*	35.0 ± 0.46	36.00 ± 0.15	18.80 ± 0.40	16.35 ± 0.40	20.29 ± 0.32	33.02 ± 0.15	15.81 ± 0.40	31.46 ± 0.39	23.90 ± 0.40	26.72 ± 0.30	28.73 ± 0.39
C18:2*t*	—	—	5.00 ± 0.10	3.35 ± 0.13	1.23 ± 0.10	—	4.00 ± 0.20	0.54 ± 0.10	6.10 ± 0.25	2.87 ± 0.10	1.89 ± 0.13
C18:2*c*	4.00 ± 0.13	5.45 ± 0.20	7.04 ± 0.20	2.65 ± 0.18	2.77 ± 0.10	3.59 ± 0.20	3.00 ± 0.18	2.73 ± 0.10	2.90 ± 0.13	5.63 ± 0.20	5.11 ± 0.18
C18:3	—	—	—	0.70 ± 0.10	0.90 ± 0.10	—	0.70 ± 0.03	—	0.50 ± 0.15	—	—
Others[c]	1.0 ± 0.07	1.50 ± 0.20	4.00 ± 0.17	2.55 ± 0.10	2.00 ± 0.09	—	1.95 ± 0.20	—	3.00 ± 0.25	2.53 ± 0.15	1.0 ± 0.20
Total											
SFA	48.76	49.42	42.14	50.17	51.60	54.00	49.00	55.53	37.12	38.70	46.65
cis MUFA	35.00	36.00	18.80	16.35	20.29	33.02	15.81	31.46	23.90	26.72	28.73
cis PUFA	4.00	5.45	7.04	3.35	3.67	3.59	3.70	2.73	3.40	5.63	5.11
TFA	11	7.34	27.40	28.00	23.37	8.98	28.59	10.08	31.70	26.65	18.29
cis PUFA/(SFA + TFA)	0.06	0.09	0.10	0.04	0.05	0.06	0.04	0.04	0.05	0.08	0.08
(*cis* PUFA + *cis* MUFA)/(SFA + TFA)	0.65	0.73	0.37	0.25	0.32	0.58	0.25	0.52	0.40	0.50	0.52

[a]Values are average of four samples of each brand analyzed individually in triplicate. Identification of different brand-name abbreviations: Rbn.Sh, Royal Brown shortening; Rbl.Sh, Royal Blue shortening; Tul.Sh, Tullo shortening; Chi.Sh, Campion industrial shortening; Bmp.Sh, Backman puff shortening; Bmc.Sh, Backman Cremo shortening; Puf.Sh, puff shortening; Bmb.Sh, Backman Bisco shortening; In.Sh-1, industrial shortening-1; Ind.Sh-2, industrial shortening-2; Ind.Sh-3, industrial shortening-3.
[b]Not detected, or below 0.10%.
[c]Geometrical and positional isomers that could not be identified. For abbreviations, see Table 1.

TABLE 3
FA Composition (wt% total FA, mean ± SD)[a] of Margarines Determined by GC

FA	Blb.Ma	Pkb.Ma	Bak-1.Ma	Bak-2.Ma	Bak-3.Ma	Sof.Ma	Pas.Ma	Tab.Ma	Cre.Ma	Bak-4.Mar	Sof-1.Ma
C12:0	10.02 ± 0.30	13.00 ± 0.40	—[b]	—	—	10.00 ± 0.21	3.00 ± 0.16	12.02 ± 0.30	1.00 ± 0.12	7.73 ± 0.30	15.02 ± 0.50
C14:0	4.21 ± 0.22	3.98 ± 0.12	1.00 ± 0.10	—	—	4.20 ± 0.22	1.21 ± 0.29	5.00 ± 0.35	—	2.66 ± 0.30	3.21 ± 0.12
C16:0	29.00 ± 0.20	26.00 ± 0.30	36.00 ± 0.50	50.75 ± 0.70	38.00 ± 0.40	27.00 ± 0.19	36.00 ± 0.19	25.00 ± 0.13	44.00 ± 0.40	30.00 ± 0.50	25.00 ± 0.60
C18:0	12.63 ± 0.25	10.60 ± 0.13	7.20 ± 0.18	4.20 ± 0.30	9.00 ± 0.28	13.03 ± 0.26	8.13 ± 0.25	11.73 ± 0.24	5.00 ± 0.25	6.31 ± 0.30	10.63 ± 0.25
C18:1*t*	1.45 ± 0.10	2.09 ± 0.15	14.55 ± 0.32	9.75 ± 0.40	21.05 ± 0.60	3.00 ± 0.15	7.20 ± 0.30	4.08 ± 0.20	3.10 ± 0.25	1.67 ± 0.20	2.90 ± 0.16
C18:1*c*	24.55 ± 0.50	21.71 ± 0.30	32.95 ± 0.40	29.25 ± 0.35	24.45 ± 0.30	24.30 ± 0.50	34.80 ± 0.30	23.92 ± 0.19	39.91 ± 0.20	38.33 ± 0.30	27.10 ± 0.28
C18:2*t*	—	—	1.55 ± 2.0	—	2.04 ± 0.15	—	—	—	—	—	—
C18:2*c*	17.00 ± 0.20	20.00 ± 0.20	5.45 ± 0.18	4.00 ± 0.15	2.96 ± 0.18	19.00 ± 0.18	8.00 ± 0.20	14.90 ± 0.50	8.00 ± 0.32	9.00 ± 0.30	15.00 ± 0.40
C18:3	—	0.56 ± 0.10	—	—	—	—	—	—	—	—	1.05 ± 0.01
Others[c]	01.67 ± 0.10	1.00 ± 0.20	0.85 ± 0.10	1.40 ± 0.25	1.95 ± 0.20	2.00 ± 0.10	1.17 ± 0.15	2.03 ± 0.20	1.65 ± 0.30	2.66 ± 0.25	—
Total											
SFA	55.86	53.58	44.20	54.95	47.00	54.23	48.34	53.75	50.00	46.70	53.86
cis MUFA	26.00	21.71	32.95	29.25	24.45	24.30	34.80	23.92	39.91	38.33	27.10
cis PUFA	17.00	20.56	5.45	4.00	2.96	19.00	8.00	14.90	8.00	9.00	16.05
TFA	1.45	2.09	16.1	9.75	23.09	3.00	7.20	4.08	3.10	1.67	2.90
cis PUFA/(SFA + TFA)	0.29	0.37	0.09	0.06	0.04	0.33	0.14	0.26	0.15	0.18	0.28
(*cis* PUFA + *cis* MUFA)/(SFA + TFA)	0.72	0.76	0.63	0.51	0.40	0.75	0.77	0.67	0.90	0.97	0.76

[a]Values are average of four samples of each brand analyzed individually in triplicate. Identification of different brand-name abbreviations: Blb.Ma, Blue Band margarine; Pkb.Ma, Pak Band margarine; Bak-1.Ma, bakery-1 margarine; Bak-2.Ma, bakery-2 margarine; Bak-3.Ma, bakery-3 margarine; Sof.Ma, Sofy margarine; Sof-1.Ma, Sofy-1 margarine, Pas.Ma, pastry margarine; Tab.Ma, table margarine; Cre.Ma, creamy margarine; Bak-4.Ma, bakery-4 margarine.
[b]Not detected or below 0.10%.
[c]Geometrical and positional isomers that could not be identified. For abbreviations, see Table 1. Soft and hard margarine: soft = with linoleic acid (LA) >14%; hard <14% LA.

TABLE 4
FA Composition (g/100 g FA)[a] of Unused and Used Frying Fat from a Local Food Shop

FA	Unused vegetable fat	Used vegetable fat
C16:0	12.7	14.2
C18:0	12.5	13.0
C18:1*c*	29.4	28.8
C18:1*t*	21.9	24.8
C18:2*c*	14.6	10.6
C18:2*t*	1.2	0.7
C18:3	0.7	0.3

[a]Values are the mean of three separate determinations.

margarines that are most commonly used to express nutritional value of edible fats were 0.29 and 0.71, respectively. These values are much lower than those obtained by Alonso *et al.* (18) for Spanish vegetable margarines (1.25 and 1.92, respectively) but very similar to those reported for Spanish shortenings (0.22 and 0.66, respectively) (15).

Frying practices in Pakistan commonly include repeated uses of cooking oil. The *trans* contents are already high in partially hydrogenated vegetable oils, and these increase somewhat after being used at least four times, indicating that TFA are also formed during frying (Table 4). Ovesen *et al.* (1) also had reported a slight increase in the content of *trans* C18:1 during repeated frying of fats.

The results of the present study indicate that, despite a certain resemblance in the FA composition of Pakistani fat products to those of some similar products from other countries, there were considerable differences in the amounts of TFA, *cis* PUFA, and *trans* FA in the investigated margarines and shortenings. The data presented here will therefore be used to estimate the total intake of various FA groups in different products from Pakistan, and thus contribute to the establishment of a database. Modern technologies such as industrial and enzymatic interesterification may eventually allow for the cost-effective development of products with a nutritionally balanced and improved FA pattern and reduced *trans* contents.

REFERENCES

1. Ovesen, L. T. Leth, and K. Hansen, Fatty Acid Composition and Contents of *trans*-Monounsaturated Fatty Acids in Frying Fats, and in Margarines and Shortenings Marketed in Denmark, *J. Am. Oil Chem. Soc. 75*:1079–1083 (1998).
2. Gurr, M.I., Dietary Fatty Acids with *trans* Unsaturation, *Nutr. Res. Rev. 9*:259–279 (1996).
3. Sampugna J., L.A. Pallansch, M.G. Enig, and M. Keeney, Rapid Analysis of *trans* Fatty Acids on SP-2340 Glass Capillary Column, *J. Chromatogr. 249*:245–255 (1982).
4. Klaus, W., W.J. Peacock, and I.L. Lesley, Effect of *trans* Fatty Acids on Platelet Aggregation, *World Rev. Nutr. Diet. 75*:183–186 (1994).
5. Houwelingen, V., C. Adrian, and H. Gerard, *Trans* Fatty Acids in Early Human Development, *Ibid. 75*:175–178 (1994).
6. King, J.M., and P.J. White, Impact of Processing on Formation of *trans*-Fatty Acids, *Adv. Exp. Med. Biol. 459*:51–65 (1999).
7. Kummerow, F.A., Q. Zhou, and M.M. Mahfouz, Effect of *trans* Fatty Acids on Calcium Influx into Human Arterial Endothelial Cells, *Am. J. Clin. Nutr. 70*:832–838 (1999).
8. Martjin, K.B., and Z.L. Peter, *Trans* Fatty Acids: The Current Position, *Lipid Nutr. Curr. Hot Top., Proc. Conf.*:71–79 (1996).
9. Kritchevsky, D., *Trans* Fatty Acids and Cardiovascular Risk, *Prostaglandins Leukotrienes Essent. Fatty Acids 57*:399–402 (1997).
10. Mensink, R.P., and M.B. Katan, Effect of Dietary Fatty Acids on Serum Lipids and Lipoprotein. A Meta-analysis of 27 Trials, *Arterioscler. Thromb. 21*: 911–919 (1992).
11. Food and Agriculture Organization of the United Nations, Fat and Oils in Human Nutrition, Report of a Joint Expert Consultation, Food and Agriculture Organization of the United Nations and the World Health Organization, Rome, October 19–26, 1993, Food and Nutrition Paper No. 57 (1994).
12. Stender, S., J. Dyerberg, G. Holmer, L. Ovesen, and B. Sandstrom, The Influence of *trans* Fatty Acids on Health: A Report from the Danish Nutrition Council, *Clin. Sci. (London) 88*:375– 392 (1995).
13. Ovesen, L., T. Leth, and K. Hanson, Fatty Acid Composition of Danish Margarines and Shortenings, with Special Emphasis on *trans* Fatty Acids, *Lipids 31*:971–976 (1996).
14. Arici, M., T. Tasan, U. Gecgel, and S. Ozsoy, Determination of Fatty Acid Composition and Total *trans* Fatty Acid of Turkish Margarines by Capillary GLC, *J. Am. Oil. Chem. Soc. 79*:439–441 (2002).
15. Alonso, L., M.J. Fraga, M. Juarez, and P. Carmona, Fatty Acid Composition of Spanish Shortenings with Special Emphasis on *trans* Unsaturation Content as Determined by Fourier Transform Infrared Spectroscopy and Gas Chromatography, *Ibid. 79*:1–6 (2002).
16. Bayard, C.C., and R.L. Wolff, *Trans*-18:1 Acids in French Tub Margarine and Shortenings: Recent Trends, *Ibid. 72*:1485–1489 (1995).
17. Aro, A., J.M. Antoine, L. Pizzoferrato, O. Reykdal, and G. van Poppel, *Trans* Fatty Acids in Dairy and Meat Products from 14 European Countries: The TRANSFAIR Study, *J. Food Compos. Anal. 11*:130–160 (1998).
18. Alonso, L., M.J. Fraga, and M. Juarez, Determination of *trans* Fatty Acids and Fatty Acid Profile in Margarines Marketed in Spain, *J. Am. Oil Chem. Soc. 77*:31–136 (2000).
19. *IUPAC Standard Methods for the Analysis of Oils, Fats and Derivatives*, 6th edn., edited by C. Paquot, Pergamon Press, Oxford, United Kingdom, 1979, pp. 96–98.
20. Solfrizzi, V., F. Panza, F. Torres, F. Mastroianni, A. Delprigi, A. Venezia, and A. Capurso, High Monounsaturated Fatty Acids Intake Protects Against Age-Related Cognitive Decline, *Neurology 52*:1563–1569 (1999).
21. Wataru, M., Interesterification of Fats and Oils, *Nihon Yukagakkishi 48*:1151–1159 (1999).
22. Kafatos, A., D. Chrysafidis, and E. Peraki, Fatty Acid Composition of Greek Margarines, Consumption by the Population of Crete and Its Relationship to the Adipose Tissue Analysis, *Int. J. Food Sci. Nutr. 45*:107–114 (1994).

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