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Original Article

Physicochemical Properties and Trans Fatty Acids Content of Commercial Shortenings Produced in Iran

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ABSTRACT

Background and Objectives: Shortenings are fats used mainly in the formulation of bakery, confectionery, dairy, and frying products. The aim of this study was to assess the physicochemical properties and trans fatty acid (TFA) content of shortenings produced in Iran.

Materials and Methods: Samples of 15 shortening brands produced in Iran (summer of 2016) were collected and characterized for their physicochemical properties.

Results: Iranian shortenings contained 0.21-15.54% TFA and 40.08-59.54% saturated fatty acids. The iodine value of Iranian shortenings was between 40.84 and 73.32. Lovibond yellow and red color indices of the samples were 2.1-13.6 and 28-70.4, respectively. The induction period of oxidation at 110°C (IP_{110}) of the samples was between 10.03 and 44.02 h. The slip melting point of the shortenings was between 42.5 and 49.3°C. Solid fat content of Iranian shortenings was 40.6-75.0% at 10°C, 24.2-59.5% at 20°C, 11.4-36.4% at 30°C, 7.8-27.3% at 35°C, and 3.1-17.4% at 40°C. Free fatty acid (FFA) content of shortenings ranged from 0.02 to 0.92%, and peroxide value was between 1.0 and 3.0 meq/kg.

Conclusions: Compared to the national standard for the specification of shortenings, 20.0% of samples had TFA content higher than the standard level (5%). Additionally, 13.3% of samples did not meet the standard limits of lauric acid content, 46.7% had FFA contents above and 53.3% showed IP_{110} below the standard level. Accordingly, efficient control protocols should be established by the authorities to assure the production of shortenings with the standard properties.

Keywords: Shortenings, Physicochemical properties, Trans fatty acids, Saturated fatty acids

Introduction

Shortenings are edible fats that are mainly used in the production of confectionery and bakery products. These fats are homogeneous blends of various oils and fats, that provide desirable physicochemical and textural properties to the final products (1). Physical and functional properties of shortenings can be controlled using several factors like the type and ratio of fat/oil base stocks, the production process and tempering conditions (including temperature and mechanical agitation rate), the use of additives like crystal modifiers, and the final solid fat content (SFC) profile and oxidative stability of the shortening (2). Accordingly, various types of shortenings, such as all-purpose, cake, icing, filler fat, bread, frying, pie crust, and pastry shortenings are available in the market (3). In the bakery food systems, shortenings prevent gluten and starch particles from adhering to each other and create the sensation of softness to the bakery products when chewed. Moreover, shortenings impart important functional

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properties such as tenderness and texture, aeration and stability, mouthfeel, and heat transfer to the products and contribute positively to the structure, geometry, and shelf-life of the products (1).

Traditionally, shortenings were made from partially hydrogenated fats. As a result, they were the major sources of saturated fatty acids (SFA) and trans fatty acids (TFA) and sometimes they contained 62.5% TFA and 85% TFA and SFA (4). With increasing evidence of harmful effects of TFAs on human health, such as increased risks of cardiovascular diseases (CVD) and various allergies and cancers, studies and regulatory authorities have focused on decreasing the intake of TFAs in diets (5). The Food and Drug Administration (FDA) of the USA asked producers to list the amount of TFAs on the nutrition facts labels of conventional foods and dietary supplements from January 2006 (6). In June 2018, partially hydrogenated vegetable oil (the major source of TFAs) was removed from the GRAS list (7). During the last two decades, several studies have focused on developing zero-trans shortenings and margarines (8–11). As TFAs play important roles in the physicochemical properties of fats, the elimination of TFAs greatly affects the functionality of the products (9). Mostly, TFAs have been replaced by the SFAs to achieve fats suitable for use as shortenings (12). Moreover, a growing trend has been reported in structuring liquid oils using oleogelation techniques in recent years (13). As shortenings are one of the main fat products used in the food industry, monitoring the physicochemical properties and health aspects of shortenings are greatly important. Standard no. 156 of the Iranian National Standards Organization (INSO) describes the specifications of the shortenings used in the food industry. Because of the changes in international policies on TFAs, the standard has been revised thrice since its first publication in 1977. The latest revision of the standard specifies the upper limits of TFAs and SFAs as 5 and 65%, respectively (14). Although several properties of shortenings are described in this standard, the melting characteristics of shortenings are not described.

Several studies have been carried out to investigate the characteristics of oil and fat products worldwide. TFA content and/or physicochemical properties of shortenings and/or margarines marketed in Pakistan (15), Turkey (16), Slovenia (6), Portugal (17) and Estonia (18) have been reported in the last decade. Asgary et al (19), Abedi et al. (20), Saad Louy and Khandaghi (21) and Alipanah et al. (22) have investigated the fatty acid (FA) composition of commercially available edible oils and fats in Iran. Farmani and Gholitabar (23) assessed the physicochemical properties of vanaspati (mostly known as culinary hydrogenated oil) marketed in Iran. Recently, Esmaeili et al. (24) and Saghafi et al. (25) reported that there has been a decreasing trend in the TFA intake of Iranians as a result of effective governmental policy on the TFA content of oils and fats. However, physicochemical properties and TFA content of shortenings produced in Iran have not been well characterized. To achieve accurate information on the actual physicochemical properties and TFA content of shortenings as well as how legislations have affected these products, postmarketing analyses of the properties of these products seem necessary. This study has assessed the physicochemical properties and FA composition of commercial shortenings produced in Iran.

Materials and Methods

Materials

Fifteen shortening samples (5 kg) were purchased directly from various shortening production factories in Iran, in the summer of 2016. All samples were transferred to the laboratory, packaged and stored at 4 °C until analyses. Before the analyses, shortening samples were melted at 60 °C to achieve homogenous samples. Chemicals were of analytical grade and purchased from Merck, Germany.

Fatty Acid Composition

FA methyl esters were prepared according to the American Oil Chemists' Society (AOCS) method, Ce 2-66, and analyzed using an Agilent Acme 7890B Gas Chromatograph (Agilent, USA) equipped with a flame ionization detector and the capillary chromatographic column BPX70 (60 m, 0.25 mm id and 0.25 mm film thickness) according to AOCS method Ce 1-91 (26). Injection was carried out at a split ratio of 1:100 and the detector and injector temperatures were set at 270 and 250 °C, respectively. The column was run isothermally at 198 °C, the carrier gas was nitrogen and the column head pressure was 11.79 PSI.

Iodine Value

Iodine value (IV) was calculated from the FA composition using the following formula based on the AOCS method, Cd 1c-85 (26):

$$IV = (0.95 \times \%C16{:}1) + (0.86 \times \%C18{:}1) + (1.732 \times \%C18{:}2) + (2.616 \times \%C18{:}3) + (0.785 \times \%C20{:}1) + (0.723 \times \%C22{:}1)$$

Lovibond Color

Color of the samples was assessed using a Lovibond tintometer (Model E, Lovibond, UK) based on the AOCS method 13e-92 (26).

Free Fatty Acid Content

Free fatty acid (FFA) content was assessed based on the AOCS method Cd 8-53, using titration with sodium hydroxide (26).

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Peroxide Value

Peroxide value (PV) of the shortening samples was assessed using the acetic acid-chloroform method following the AOCS method Cd 8-53 (26).

Oxidative Stability

The induction period of oxidation at 110 °C (IP_{110}) of the samples was assessed based on the AOCS method Cd 12b-92, using Methrom Rancimat Instrument Model 743 (Herisau, Switzerland). The tests were carried out with 2.5 ± 0.2 g fat and an airflow rate of 2.5 ml/s (26).

Slip Melting Point

Slip melting point (SMP) of the shortenings was measured following the AOCS Cc 3-25 open tube melting point. Filled capillary tubes were stored at 6 ± 1 °C for 16 h before the measurements (26).

Solid Fat Content

A Minispec Mq 20 Pulsed Nuclear Magnetic Resonance (pNMR) Spectroscope (Bruker, Germany) was used to assess SFC in samples at 10, 20, 30, 35 and 40 °C according to the AOCS Cd 16b-93, direct serial measurement method (26). The shortening sample was melted at 100 °C and transferred into the pNMR tubes, then sample tubes were placed in an ice bath (0 °C) for 60 min before the first SFC measurement. Before the measurement, samples were conditioned for 35 min at the desired temperature.

Statistical Analysis

All the data are represented as the mean value ± SD (standard deviation) of triplicate measurements. The mean values, SD and ranges were calculated using SAS Software v.9 (SAS Institute, USA).

Results

Table 1 presents FA compositions of shortening samples. The TFA content of the shortenings varied from 0.21 to 15.54% (4.29% on average). Based on the definition, fat products with less than 5 or 2% TFA are referred to as low-*trans* or *trans*-free products, respectively (6). According to Table 1, 13.33% of the samples (Codes 5 and 11) were *trans*-free (containing less than 2% TFA) and 66.67% of the samples (Codes 1, 2, 3, 6, 8, 9, 10, 13, 14 and 15) were low-*trans* (containing 2–5% TFA). However, 20.00% of the samples (Codes 4, 7 and 12) contained 6.49–15.54% TFA, which was higher than the upper limit (5%) of TFA described in the standard no. 156-1 of the INSO for shortenings (14). The major *trans* isomer of the shortening samples was elaidic acid (*trans* 18:1) with a mean content of 3.52%. As can be seen in Table 1, the SFA content of the shortenings was between 40.08 and 59.54% (50.46% on average). These levels were similar to that of the INSO standard No. 156-1 (< 65%, 14). Palmitic acid was detected as the major SFA of the samples, indicating that palm oil and/or its derivatives (palm olein and stearin) were the major base stocks used in the formulation of the Iranian shortenings.

In the latest revision of the INSO shortening standard, an upper limit of 0.7% is set for lauric acid (14). This limits the application of lauric fats (e.g., palm kernel oil and coconut oil) in the formulation of shortenings. According to Table 1, the mean content of lauric acid in Iranian shortenings was 0.26%. However, 13.33% of the samples (Samples 1 and 2) contained lauric acid contents higher than the standard limits. Palmitic acid was the major SFA in the samples (25.48–48.90%, 35.46% on average). Oleic and linoleic acids were the dominant unsaturated fatty acids (UFA) (26.96–38.78 and 6.49–21.73%, respectively). There was also a small quantity of linolenic acid in Iranian shortenings (0.11–1.83%, 0.66% on average), which could be a source of essential omega-6 FAs for consumers. The INSO specifies no limits for the IV of shortenings (14). Based on Table 1, IV of the Iranian shortenings was between 40.84 and 73.32 (53.52 on average). IV is one of the important parameters of oils and fats, indicating their unsaturation levels. There is a direct relationship between the IV and the nutritional value of fat products (3).

The FFA content is one of the most important quality parameters of oils and fats at all processing and storage stages. This parameter is an indicator of hydrolytic rancidity. With the increase of the FFA content in fat products, the smoking point is reduced. Moreover, the rise of FFA during the storage of the product shows the progress of the hydrolytic rancidity (3). According to the INSO (14), the maximum FFA limit is 0.1%. As can be seen in Table 2, the FFA content of the shortenings was 0.02–0.92%. In fact, the FFA contents of 46.7% of the samples (5, 6, 7, 8, 9, 11 and 12) were above the standard limit. Technically, PV is an indicator of the initial oxidation products. Although peroxides are odorless, the secondary products of oxidation such as aldehydes and ketones produced from the breakdown of peroxides may cause off-flavor in the products. The PV measurement is the most common quality assay for oils and fats (3). The PV of the Iranian shortening samples was 1.0–3.0 meq/kg (table 2). According to the INSO standard, the maximum limit of the PV of shortenings is 1, 2 and 5 meq/kg at the times of production, import and consumption, respectively (14). As shown in Table 2, all the shortenings had PVs less than 5 meq/kg.

Table 1. Fatty acid compositions and IVs of the Iranian shortenings

Fatty acids (%)	Shortening code															Mean±SD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
12:0	1.08±0.08	1.32±0.02	0.11±0.00	0.16±0.00	0.08±0.00	0.14±0.01	0.09±0.00	0.12±0.00	0.11±0.03	0.10±.0.00	0.11±.0.00	0.07±0.00	0.12±0.01	0.15±0.01	0.12±0.02	0.26±0.39
14:0	1.25±0.04	0.75±0.03	0.73±0.01	0.75±0.02	0.52±0.03	0.73±0.01	0.63±0.05	0.70±0.04	0.69±0.06	0.70±0.01	0.66±0.05	0.45±0.02	0.58±0.04	0.80±0.01	0.74±0.03	0.71±0.18
16:0	47.90±0.20	37.05±0.30	38.05±0.23	32.94±0.33	29.27±0.33	34.62±0.44	32.90±0.16	41.27±0.19	35.75±0.26	38.73±0.24	34.74±0.16	25.48±0.33	31.12±0.18	37.09±0.24	35.03±0.03	35.46±5.23
18:0	8.76±0.12	12.01±0.23	12.24±0.15	16.99±0.18	9.57±0.34	22.53±0.15	15.00±0.18	9.52±0.14	20.05±0.18	15.03±0.20	11.12±0.18	13.48±0.18	9.78±0.14	13.53±0.20	11.36±0.23	13.40±3.99
cis 18:1	29.25±0.21	32.13±0.32	33.45±0.30	26.96±0.22	35.57±0.32	30.96±0.41	29.80±0.26	27.97±0.14	29.97±0.17	34.11±0.26	31.65±0.23	36.68±0.20	38.78±0.15	37.52±0.25	37.90±0.32	32.85±3.79
cis 18:2	8.18±0.17	9.69±0.16	9.97±0.19	12.37±0.20	21.73±0.43	6.49±0.25	12.93±0.34	14.23±0.25	8.07±0.14	8.03±0.10	18.45±0.34	6.94±0.05	11.68±0.02	6.66±0.13	10.05±0.16	11.03±4.41
cis 18:3	0.11±0.02	0.58±0.00	0.62±0.05	1.08±0.02	1.83±0.03	0.18±0.00	1.08±0.02	1.30±0.03	0.37±0.02	0.13±0.02	1.43±0.02	0.35±0.02	0.65±0.03	0.13±0.02	0.66±0.00	0.70±0.53
20:0	0.41±0.05	0.42±0.03	0.43±0.08	0.41±0.6	0.41±0.05	0.45±0.01	0.43±0.00	0.39±0.00	0.47±0.08	0.45±0.03	0.37±0.00	0.38±0.02	0.43±0.00	0.43±0.03	0.42±0.05	0.43±0.03
20:1	0.15±0.03	0.12±0.03	0.00±0.00	0.10±0.00	0.15±0.01	0.10±0.01	0.11±00	0.11±0.07	0.10±0.08	0.12±0.00	0.12±0.00	0.10±0.01	0.16±0.07	0.13±0.00	0.13±0.02	0.11±0.04
22:0	0.07±0.01	0.18±0.00	0.19±0.03	0.15±0.02	0.17±0.02	0.11±0.00	0.15±0.01	0.11±0.02	0.00±0.00	0.11±0.00	0.13±0.01	0.25±0.02	0.18±0.01	0.08±0.00	0.12±0.00	0.13±0.06
24:0	0.07±0.02	0.08±0.00	0.08±0.00	0.08±0.01	0.06±0.01	0.07±0.00	0.08±0.01	0.07±0.00	0.14±0.00	0.06±0.00	0.06±0.00	0.07±0.02	0.10±0.00	0.08±0.00	0.08±0.00	0.08±0.02
trans 18:1	1.98±0.07	3.77±0.04	3.34±0.02	7.24±0.02	0.00±0.00	2.75±0.02	6.17±0.04	3.63±0.05	3.79±0.02	1.29±0.02	0.33±0.04	13.99±0.07	0.00±0.00	2.10±0.00	2.37±0.04	3.52±3.55
trans 18:2	0.09±0.00	0.77±0.00	0.51±0.07	0.19±0.07	0.21±0.00	0.09±0.00	0.32±0.05	0.43±0.02	0.42±0.02	0.79±0.05	0.50±0.00	1.55±0.11	4.05±0.02	0.95±0.00	0.69±0.00	0.77±0.98
TFA	2.07	4.54	3.85	7.43	0.21	2.84	6.49	4.06	4.21	2.08	0.83	15.54	4.05	3.05	3.06	4.29±3.49
SFA	59.54	51.81	51.83	51.48	40.08	58.65	49.28	52.18	57.19	55.18	47.19	40.18	42.31	52.16	47.89	50.46±6.13
USFA	37.69	42.52	44.04	40.51	59.28	37.73	43.92	43.61	38.51	42.39	51.65	44.07	51.27	44.44	48.74	44.69±5.90

TFA, trans fatty acids; SFA, saturated fatty acids; USFA, unsaturated fatty aci

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Table 2. Free fatty acids, peroxide values, IP_{110} and Lovibond color indices of the Iranian commercial shortenings

Shortening code	FFA (%)	PV (meq/kg)	IP_{110} (h)	Lovibond color indices		
				Red	Yellow	Blue
1	0.06±0.01	1.20±0.02	20.10±0.30	3.80±0.40	50.00±0.10	0
2	0.05±0.02	1.50±0.01	21.67±0.62	5.20±0.20	70.20±0.20	0
3	0.02±0.01	1.20±0.32	18.34±0.20	13.60±0.10	70.40±0.10	0
4	0.09±0.03	1.80±0.13	36.22±0.53	11.20±0.40	70.00±0.20	0
5	0.92±0.02	2.00±0.11	11.68±0.41	7.60±0.50	70.10±0.10	0
6	0.59±0.01	1.20±0.04	38.42±0.45	8.70±0.60	70.40±0.30	0
7	0.11±0.04	1.40±0.05	10.46±0.80	6.80±0.40	70.20±0.20	0
8	0.25±0.02	1.40±0.10	18.54±0.22	11.50±0.80	70.10±0.00	0
9	0.39±0.04	1.00±0.00	38.02±0.25	10.80±0.40	70.20±0.30	0
10	0.05±0.02	2.50±0.20	39.51±0.21	8.40±0.20	70.00±0.10	0
11	0.16±0.05	1.80±0.32	10.30±0.57	6.30±0.50	70.20±0.00	0
12	0.12±0.02	3.00±0.14	34.46±0.90	3.10±0.20	34.30±0.50	0
13	0.04±0.00	2.00±0.13	21.44±0.81	2.10±0.20	28.00±0.30	0
14	0.08±0.01	1.40±0.06	40.72±0.74	4.50±0.60	50.60±0.70	0
15	0.08±0.01	1.60±0.12	44.02±0.89	5.90±0.70	70.30±0.40	0
Mean ±SD	0.20±0.25	1.67±0.54	26.89±0.26	7.30±3.39	63.33±14.48	0

FFA, free fatty acid; PV, peroxide value

Based on the INSO standard (14), IP_{110} of shortenings used in bakery and confectionery products must be at least 30 and 25 h, respectively. According to Table 2, IP_{110} of the shortenings in the Iranian market was 10.03–44.02 h. 53.3% of the shortenings (Samples 1, 2, 3, 5, 7, 8, 11 and 13) had an IP_{110} below 25 h and were not included in the standard range. Oxidative stability of the shortenings has not been reported in other studies. Oxidative stability of oils and fats is affected by UFAs, oxygen content and storage conditions. High contents of UFAs accelerate the oxidation process, thereby causing off-flavors, toxic compounds formation and loss of nutritional value. Nutritionally, toxic compounds resulting from rancidity can cause health problems such as tumors, heart failures, cataracts and brain dysfunctions. High oxidative stability is one of the most important characteristics of shortenings, which greatly affects the shelf-life of the final products (1).

Lovibond color determination is a common method to check the color of oils and fats (3). Lovibond color parameters of the shortenings are listed in Table 2. Lovibond red and yellow indices of the samples were 2.1–13.6 and 28–70.4, respectively, and no blue color was detected in the samples. In Table 3, the SMPs of the shortenings are shown. SMP of the Iranian shortening was in the range of 42.5–49.3 °C (45.53 °C on average). The INSO has not specified a certain limit for the SMP of shortenings (14). The SFC is not specified in the INSO standard, as well (14). The SFC of shortenings from the Iranian market at 10, 20, 30, 35 and 40 °C is shown in Table 3. The SFC of Iranian shortenings at 10, 20, 30, 35 and 40°C was 40.6–75, 24.2–59.5, 11.4–36.4, 7.8–27.3 and 3.1–17.4%, respectively. In general, samples with higher levels of saturation had higher levels of SFCs.

Table 3. Slip melting points and solid fat contents of the Iranian commercial shortenings

Shortening code	SFC (%)					SMP (°C)
	10 °C	20 °C	30 °C	35 °C	40 °C	
1	70.5±0.1	54.5±0.7	33.3±1.0	25.4±0.2	16.5±0.5	46.0±0.3
2	64.70±0.9	45.7±1.0	25.5±0.4	19.3±0.8	12.1±0.3	43.0±0.1
3	67.0±0.9	50.8±0.6	32.5±0.5	24.5±0.7	14.8±0.3	48.2±0.4
4	75.0±0.8	59.5±0.6	36.4±0.9	27.3±0.6	17.4±0.2	48.0±0.1
5	40.6±0.1	24.2±0.9	11.4±0.7	7.9±0.8	4.0±0.6	46.3±0.2
6	43.5±0.8	25.6±0.7	12.3±0.6	8.1±0.5	3.1±0.5	43.0±0.3
7	64.6±0.6	47.7±0.8	27.7±0.9	20.1±0.3	12.1±0.7	45.1±0.2
8	65.3±0.4	49.0±0.4	29.6±0.5	21.6±0.2	13.2±0.8	49.3±0.5
9	70.6±0.7	56.9±0.6	35.2±0.9	26.6±0.6	16.5±0.7	47.0±0.1
10	66.8±0.5	50.2±0.5	28.5±0.6	20.6±0.8	12.0±0.6	44.2±0.3
11	45.5±0.9	27.2±0.4	13.1±0.4	8.8±0.3	3.8±0.6	44.5±0.1
12	68.8±0.6	50.8±0.4	25.9±0.9	15.8±0.6	6.9±0.3	43.1±0.3
13	51.8±0.7	29.6±0.5	12.5±0.6	7.8±0.2	3.6±0.1	47.3±0.5
14	60.2±1.1	38.0±0.6	18.9±0.2	14.2±0.5	9.6±0.6	45.5±0.1
15	58.8±0.9	37.4±0.3	17.6±0.6	11.8±0.5	6.6±0.1	42.5±0.5
Mean ±SD	60.9±10.7	43.1±11.89	24.0±8.9	17.3±7.1	10.15±5.1	45.53±2.15

SMP, slip melting point; SFC, solid fat content

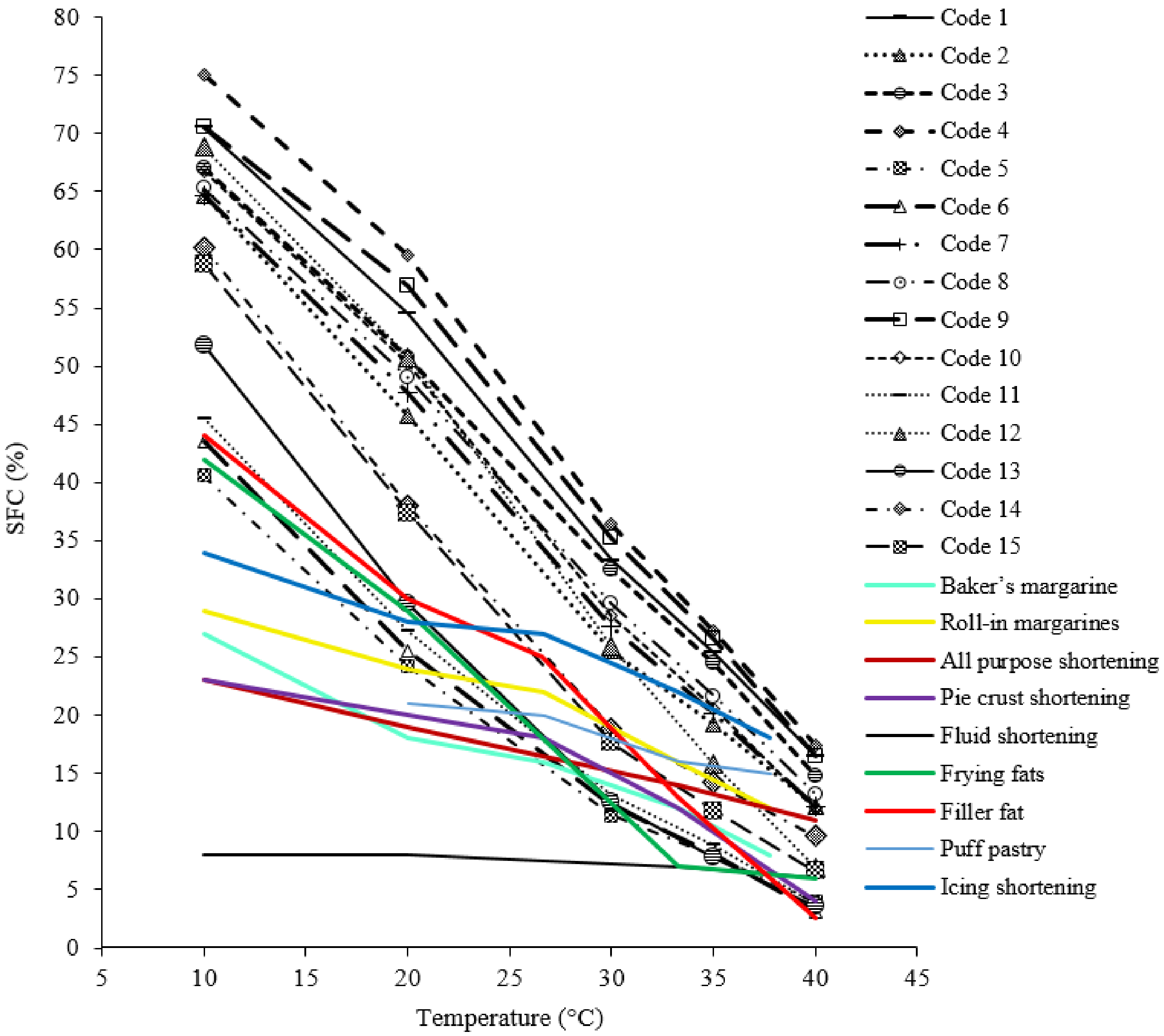

Figure 1. Comparison of solid fat content curves of the Iranian commercial shortenings with typical solid fat content curves of shortenings and margarines

Discussion

Based on the results of this study, the SFA content and PV of the samples met the standard levels described in the INSO standard. Nazari et al. (27) reported the level of SFAs in commercial cake samples as 27.60 ±11.55% on the fat basis, which was much lower than the SFA level found in this study. In fact, by setting the maximum limit of TFAs in fat products to 5% in 2015 (14), producers have to replace the TFAs with SFAs because both SFAs and TFAs play significant roles in oxidative stability, consistency, plasticity and melting characteristics. As shown in this study, samples with higher TFA and/or SFA contents had lower PVs. This is because the increase in the content of TFAs and SFAs increases the oxidative stability of the fat products (3). As shown in this study, 20% of the shortening samples did not meet the INSO standard and could not be regarded as low- or zero-trans fats. Moreover, lauric acid contents of 13.33% of samples were higher than the standard limit and nearly half of the samples did not meet the standard levels of FFAs or IP_{110}. This means that further efficient controls are needed to assure production of shortenings with the standard qualitiy.

Little data were available on the TFA content of shortenings produced in Iran. Nazari et al. (27) studied the FA composition of junk foods and dairy and bakery products marketed in Iran. Based on their results, cake samples contained 36.10 ± 8.01% TFAs (on the fat basis). According to Ghazavi et al. (28), the TFA level of the traditional Iranian pastries marketed in Isfahan city, Iran, was in the range of 0.04–7.9% (on the fat basis). This shows that TFA levels of shortenings have decreased significantly in recent years, which is due to the setting of an upper limit of 5% for TFAs by the INSO in 2015. The TFA content of Iranian shortenings was much lower than those reported for the shortenings marketed in Pakistan (7.34–31.70%, 15) but higher than those reported for the margarines and shortenings in Portugal (0.26–2.16%, 17) and the shortenings in Slovenia (0.1–11.2%, 6).

To the best of the authors' knowledge, physicochemical characteristics (except the FA composition) of shortenings produced in Iran have not been assessed. Additionally, IV, color indices, melting point and SFC of shortenings are not described in the INSO standard no. 156-1 (14). The IV of Iranian shortenings was much lower than that of Iranian vanaspati (91.9–106.4%; 23). It can be concluded that Iranian shortenings currently contain lower quantities of UFAs and relatively lower IVs. As shown in Table 2, the Lovibond color range of the shortenings was rather wide; some samples were more colored, while others were less colored, which was due to the wide range of uses for shortenings in various food products. In fact, the final use of the shortening (products receiving the shortenings) and the buyers' demands determine the Lovibond color. Yellow/red colors of the fats originate from the natural or added carotenoids. Processes such as bleaching and deodorizing lead to the thermal removal of carotenoids. Therefore, beta-carotene is usually added to the deodorized fats to compensate for the yellow/red color decrease and production of products with appropriate standard color characteristics (29).

Melting point is one of the most important physical properties of fat products. Factors such as unsaturation, carbon-chain length, isomeric form (*cis* and *trans*), FAs and their position in the glycerol backbone and tempering time and conditions affect the melting point of fats. The SMP, which determines the beginning of the melting range, is the most common factor (30). In general, shortenings should be solid at room temperature. Also, to prevent waxy mouthfeel, the melting point should be as close as possible to the body temperature (37 °C). Karabulut and Turan (31) studied physicochemical characteristics of ten shortening and 15 margarine samples in the Turkish market. The SMP of Turkish shortenings and margarines were in the ranges of 33–43 and 31.2–34.9 °C, respectively, which were lower than that of shortenings marketed in Iran. They also reported that the SMP of all the shortenings was higher than that of margarines.

SFC is one of the most important physical properties of fats, which directly affects their characteristics such as general appearance, ease of packaging, spreadability and consistency as well as textural, rheological and sensory characteristics (11, 32, 33). Karabulut and Turan (31) reported that SFCs of shortenings in the Turkish market at 10, 20, 25, 30, 35 and 40 °C were 37.9–55.6, 22.4–43.5, 14.9–38.4, 8.3–29.4, 3.3–18.3 and 0.0–8.0%, respectively. It can be concluded that the SFCs of most Iranian shortenings were higher than those of Turkish samples (particularly at 10 and 20 °C), which might be due to the lower IV and higher saturation of Iranian shortenings (Tables 1 and 3). The SFC curve is an indicator of rigidity and plasticity of fats at various temperatures from the refrigerator to body temperature. The SFC curve can be used to determine the specific uses of fats. For example, frying shortenings should have a steep SFC curve, while shortenings used in the production of layered pastries should have a flat SFC curve (1, 3). The SFC curves of Iranian shortenings are compared with the typical SFC curves of various types of shortenings (Fig. 1). The SFC of most Iranian shortenings was higher than the SFC of common margarines and shortenings. Another important point is the sharper slope of SFC curves of Iranian shortenings, compared to the common SFC curves of various margarines and shortenings (Fig. 1).

Conclusion

In summary, the TFA and SFA contents of the Iranian shortenings were 0.21–15.54 and 40.08–59.54%, respectively. Nearly 13.33% of the shortening samples were *trans*-free (TFA > 2%) and 66.67% of the samples were low-*trans* (TFA > 5%). The mean FFA content, PV and IP_{110} of the shortenings samples were 0.20%, 1.67 meq/kg and 26.89 h, respectively. Shortenings produced in Iran showed SMPs of 42.5–49.3 °C. The SFC curves of shortenings were rather steep. All samples met the INSO standard for SFA content and PV. However, TFAs, lauric acid, FFA, PV and IP_{110} of some samples did not meet the INSO standard specifications of shortenings. This creates concerns as violating the standard levels may threaten the general health of the consumers. Accordingly, organizations should establish further powerful protocols to keep the health-linked properties of the shortenings within safe limits.

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