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Solid fat contents and instrumental textural attributes of margarines sold in Turkish market

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Abstract

Trans fatty acids, solid fat content (SFC) and instrumental textural attributes of fourteen different table margarines sold in Turkey were examined in this study. According to the results, palmitic acid content was the highest in all samples. *Trans* fatty acid content of margarines was within the range of 1.1-2.2%. The SFC results obtained at different temperatures showed significant differences ($P<0.05$). Compared to margarines of other countries, Turkish table margarines had higher SFC values. Hardness, adhesiveness and cohesiveness values of samples did not differ significantly ($P>0.05$).

Keywords: hardness, solid fat content, table margarine, texture, *trans* fatty acid

1. Introduction

Margarine is a butter-like product obtained from mixtures of various edible fats and oils containing at least 70% of fat. Usually, margarine contains appropriate ratios of hard vegetable fats from coconut, palm kernel, interesterified vegetable oils and/or hydrogenated vegetable oils which improve the physical properties, the resistance to thermal and atmospheric oxidation and the plasticity of the products (Kandhro *et al.*, 2008; Tekin *et al.*, 2002).

During partial hydrogenation, some double bonds of fatty acids are saturated, but part of the *cis* double bonds are isomerized into their *trans* form (Karabulut and Turan, 2006). These isomers lack the essential metabolic activity of the corresponding compounds and inhibit the enzymatic desaturation of essential fatty acids (Kandhro *et al.*, 2008). *Trans* fatty acids (TFA) increase plasma concentrations of low-density lipoprotein cholesterol and reduces concentrations of high-density lipoprotein cholesterol relative to the corresponding natural fat (Matsuzaki *et al.*, 2002). This effect is more harmful compared to saturated fatty acids (Karabulut and Turan, 2006). In addition, TFA intake may be a risk factor for cardiovascular disease (Alonso *et al.*, 2000; Arici *et al.*, 2002; Kandhro *et al.*, 2008).

The quality of a margarine product is usually defined by its texture, consistency, hardness and plasticity. Hardness is the most significant attribute perceived by the consumers. The hardness of the butters, margarines and spreads are mainly influenced by their ingredients, especially solid fat content (SFC). Increasing SFC causes an increase in hardness (Glibowski *et al.*, 2008). In general, the SFC of the fat phase is responsible for several characteristics of the margarines, including general appearance, ease of packing, organoleptic properties (flavour release, coolness and thickness), ease of spreadability and oil exudation (Laia *et al.*, 2000).

For margarine, storage stability is very critical. During storage, the changes of the crystal size affect physical properties of margarine (Goli *et al.*, 2009). The crystal form in margarine greatly affects its texture. The ideal form is β' which promotes plasticity and immobilizes a large amount of the liquid oil which, if free, would make the product soggy. Palm oil and palm stearin impart a very

high stability to the β' crystal form as compared to the other common vegetable oil (Anonymous, 1996).

There are various types of margarine for specific applications of which the most popular are table (hard-type margarine), industrial and pastry margarine (Anonymous, 1996). In this study, the textural properties, solid fat content and TFA composition of table margarines marketed in Turkey were determined and evaluated.

2. Materials and methods

Samples and reagents

Fourteen different table margarines were purchased from local Turkish supermarkets and coded with a letter. Samples were kept in a refrigerator (4±1 °C) until being analysed. Fatty acid methyl ester (FAME) standards were provided from Supelco (Bellefonte, PA, USA). All chemicals and solvents used were from Merck Chemical Co. (Darmstadt, Germany).

Preparation of FAME

All samples were melted in an oven at 60 °C to obtain the fat phase and this phase was removed by centrifugation and dried with anhydrous sodium sulphate. They were frozen at -18 °C until analysis (Karabulut and Turan, 2006). Fatty acid methyl esters were prepared according to AOCS (1997). 100 mg of melted fat was placed into a centrifuge tube and 0.5 ml of 2 N methanolic potassium hydroxide and 2.5 ml of n-hexane (Merck, Darmstadt, Germany) were added. The mixture was then mixed vigorously and centrifuged at 6,000 rpm for 10 min (Hettich EBA 8S, Hettich, Tuttlingen, Germany). The upper clear supernatant, the FAME, was transferred to a screw-capped vial.

Analysis of FAME by gas chromatography

Fatty acid composition was investigated by using a Agilent 6890N gas chromatograph (GC) (Agilent Technologies, Amsterdam, the Netherlands). The fatty acid methyl esters were injected into a capillary DB-23 fused silica capillary column (60 m × 0.25 mm i.d., 0.25 μm film thickness, Supelco Inc., Bellefonte, PA, USA). The initial temperature of the GC oven was 175 °C for 28 min, raised to 210 °C at the rate of 1.30 °C/min and kept at 210 °C for 10 min. The injector and detector temperatures were 250 °C (Alonso *et al.*, 2000). Hydrogen was used as the carrier gas and its flow rate was 1 ml/min.

Solid fat content

SFC of the samples was measured by using a Bruker SFC Analyzer Minispec Plus (Karlsruhe, Germany) according to the AOCS official method Cd 16b-93 (1989). The fat was firstly melted at 80 °C and placed in test tubes, then placed in an ice-bath (0 °C) for 60 min before SFC measurement. Before measuring, the samples were conditioned for 30 min at the desired temperature. Measurements were carried out at 10, 20, 30, 35 and 40 °C.

Instrumental textural analysis

A TA.XT II Plus Texture Analyzer (Godalming, UK) was used for the determination of textural attributes of margarine samples. Probe of the texture analyser was a SMS P/2 (cylindrical probe having a diameter of 2 mm). Pre-test speed was 1 mm/s, whereas test speed and post-test speeds were 2 mm/s. Distance mode was used and set as 12 mm. Load of the texture analyser was 5 kg and data acquisition rate was set as 200 pixels per second. Six measurements were performed for each sample. According to the graphic obtained, instrumental textural profile attributes (hardness, cohesiveness and adhesiveness) of the samples were calculated as mentioned by Bourne (1978).

Hardness (N) is the maximum height of first peak on first compression, cohesiveness (A_2/A_1) is the ratio of second compression to first compression positive areas, whereas adhesiveness is the area under the x-axis (N.s). Adhesiveness describes the work for overcoming the force of attraction between the area of food and other solids coming into contact with each other (Domagala, 2012). Temperature of the samples was averagely determined as 7±1 °C (Testo mini thermometer, Lenzkirch, Germany).

Statistical analysis

Findings obtained from the analyses were evaluated by the PROC GLM procedure of the SAS statistical analyses programme according to the completely randomized design. Correlation coefficients among hardness, cohesiveness, adhesiveness and SFC values of samples were also calculated using the PROC-CORR procedure of SAS (version 8.2., 2001, SAS Institute, Cary, NC, USA). The number of replication was two.

3. Results and discussion

Table 1 shows the fatty acid and *trans* fatty acid compositions of fourteen margarines. Generally the margarines were rich in palmitic acid (16:0). On the other hand, the samples, except for B, D, G and N, had high amounts of lauric acid (12:0) and myristic acid (14:0). The amount of oleic acid (18:1 *cis*) was also higher and above 25% in the samples except for F, K and L, depending on the type of the vegetable oils used in the margarine. The amount of linoleic acid (18:2 *cis*) is not as high as that of 18:1 *cis*. The amount of caprylic acid (8:0), capric acid (10:0) and linolenic acid (18:3 *cis*) were detected averagely below 1.0% in all samples. Some fatty acids like palmitoleic acid (16:1), margaric acid (17:0),

Table 1. Fatty acid and *trans* fatty acid composition (%) of fourteen Turkish table margarines.

Fatty acid	Sample													
	A	B	C	D	E	F	G	H	J	K	L	M	N	O
C8:0	0.9	0.3	1.2	0.2	1.0	1.3	0.5	0.5	0.7	1.1	1.2	0.9	0.3	1.2
C10:0	0.7	0.2	1.0	0.1	0.9	1.1	0.4	0.5	0.6	1.0	1.0	0.7	0.3	1.0
C12:0	8.5	2.4	11.5	1.4	9.4	12.2	4.2	7.0	8.5	11.5	11.6	8.3	2.4	8.9
C14:0	3.8	1.7	4.2	1.3	4.0	4.4	2.2	3.2	3.7	4.2	4.2	3.2	1.6	4.1
C16:0	34.0	41.5	29.5	38.5	34.7	31.2	39.2	39.0	38.0	30.9	28.9	30.8	36.4	36.1
C16:1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.1
C17:0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
C18:0	8.0	6.4	11.7	5.7	7.9	11.2	7.2	4.6	4.7	11.5	13.1	10.8	5.4	7.3
C18:1 *trans*	1.1	0.9	0.9	1.2	0.9	0.9	1.1	0.7	0.8	0.8	0.8	1.1	1.5	0.9
C18:1 *cis*	29.8	32.3	25.3	36.5	29.4	20.1	31.3	32.0	31.0	21.7	22.4	25.2	37.3	28.8
C18:2 *trans*	0.4	0.2	0.8	0.3	0.4	1.2	0.3	0.2	0.3	0.3	1.1	0.6	0.3	0.2
C18:2 *cis*	10.8	13.0	12.2	12.6	10.3	15.3	12.1	11.2	10.9	15.8	14.4	17.3	11.7	9.9
C18:3 *trans*	0.1	nd	0.1	0.1	0.1	0.1	0.1	nd	nd	0.1	nd	nd	0.1	nd
C18:3 *cis*	0.9	0.2	0.8	1.2	0.8	0.2	0.7	0.2	0.1	0.3	0.3	0.3	1.6	0.6
C20:0	0.3	0.4	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.3
C20:1	0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.2
C20:2	0.1	nd	0.1	0.2	0.1	0.2	nd	0.1	0.1	0.1	0.2	0.1	0.1	0.1
C22:0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Total SFA	56.5 ^{bcde}	53.1 ^{e}	59.7 ^{abc}	47.7 ^{f}	58.4 ^{abcd}	61.8 ^{a}	54.1 ^{de}	55.4 ^{cde}	56.6 ^{bcde}	60.7 ^{ab}	60.6 ^{ab}	55.2 ^{cde}	47.1 ^{f}	59.2 ^{abc}
Total MUFA	31.2 ^{cd}	33.5 ^{bc}	26.6 ^{de}	38.1 ^{ab}	30.7 ^{cd}	21.3 ^{e}	32.8 ^{bc}	32.9 ^{bc}	32.0 ^{cd}	22.8 ^{e}	23.5 ^{e}	26.6 ^{de}	39.3 ^{a}	30.0 ^{cd}
Total PUFA	12.3 ^{d}	13.3 ^{cd}	14.0 ^{bcd}	14.3 ^{bcd}	11.6 ^{d}	16.9 ^{ab}	13.2 ^{cd}	11.6 ^{d}	11.4 ^{d}	16.5 ^{abc}	16.0 ^{abc}	18.4 ^{a}	13.9 ^{bcd}	10.8 ^{d}
Total *trans*	1.6 ^{abc}	1.1 ^{bc}	1.8 ^{abc}	1.6 ^{abc}	1.4 ^{abc}	2.2 ^{a}	1.4 ^{abc}	1.0 ^{c}	1.1 ^{bc}	1.2 ^{bc}	2.0 ^{ab}	1.7 ^{abc}	1.8 ^{abc}	1.2 ^{bc}

nd = not detected; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SFA = saturated fatty acids.
Values with different superscripts in a column are significantly different from each other (P<0.05).

arachidic acid (20:0), eicosenoic acid (20:1), eicosadienoic acid (20:2) and behenic acid (22:0) were also detected in margarine samples. As a consequence, table margarines produced in Turkey had a higher content of total saturated fatty acids (SFA) and total monounsaturated fatty acids (MUFA) and had a lower content in total polyunsaturated fatty acids (PUFA) which is the most valuable from a nutritional point of view. The mean PUFA values for Turkish table margarines (13.9%) are comparable to PUFA results (18.3%) for Austrian margarine (Arici *et al.*, 2002).

The TFA content of table margarine samples was found within the range of 1.0-2.2% (Table 1). Whereas the amounts of *trans*-18:1 isomers in the samples ranged from 0.7% to 1.5%, *trans* 18:2 isomers ranged from 0.2% to 1.2%. The *trans*-18:3 isomer contents were detected only in eight different trademarks of margarines in amounts of 0.1%. The occurrence of these isomers is mainly associated with the presence of physically refined or deodorized oils in mixture (Alonso *et al.*, 2000). Turkish margarines contain vegetable oils that have been partially hydrogenated, resulting in the formation of variable amounts of *trans* isomers (Arici *et al.*, 2002). The occurrence of these isomers is also associated with the presence of physically refined or deodorized oils in mixture (Alonso *et al.*, 2000). All of the margarines samples had lower TFA than those reported for margarines of other countries (Arici *et al.*, 2002; Matsuzaki *et al.*, 2002; Ratnayake *et al.*, 1998). Average SFA, MUFA and PUFA contents of margarines sold under different trademarks were different from each other (P<0.0001), whereas the TFA content were not (P>0.05). Improvements in conditions of the hydrogenation process have reduced the amount of *trans* fatty acids in margarines, often to values close to zero (Alonso *et al.*, 2000).

The SFC values of table margarines ranged from 44.6 to 56.1% at 10 °C, 25 to 36.3% at 20 °C, 9.3 to 18.3 at 30 °C, 5.1 to 11.7% at 35 °C and 0.1 to 6.1 at 40 °C (Table 2). Average SFC values of different margarines were different from each other (P<0.01) at all applied temperatures. The SFC values at 20 °C were higher than 20% in all of our samples. The SFC values which are not less than 10% at 20 °C are essential to prevent oiling off (Laia *et al.*, 2000). The highest SFC values were obtained for sample G. Solid fat content

Table 2. Solid fat content (SFC) values of fourteen Turkish table margarines at different temperatures.

Sample	SFC (%)				
	10 °C	20 °C	30 °C	35 °C	40 °C
A	50.4^{ab}	29.2^{def}	12.9^{cd}	7.4^{cde}	2.0^{cd}
B	50.7^{ab}	28.3^{efg}	12.7^{cd}	8.0^{cd}	4.4^{b}
C	52.7^{a}	31.7^{bc}	13.6^{bc}	6.9^{def}	1.2^{cde}
D	45.1^{bc}	26.3^{gh}	12.5^{cd}	8.4^{bc}	5.2^{ab}
E	53.1^{a}	30.1^{cde}	13.0^{bcd}	7.3^{cde}	2.0^{c}
F	54.6^{a}	32.5^{b}	13.2^{bcd}	6.4^{efg}	1.1^{cde}
G	56.1^{a}	36.3^{a}	18.3^{a}	11.7^{a}	5.7^{ab}
H	50.4^{ab}	26.4^{gh}	10.0^{e}	5.1^{gh}	0.8^{cde}
J	51.3^{a}	27.7^{fg}	10.2^{e}	5.2^{gh}	1.3^{cde}
K	53.5^{a}	31.1^{bcd}	12.4^{d}	6.1^{efg}	0.5^{de}
L	54.2^{a}	32.0^{bc}	12.1^{d}	5.6^{fgh}	0.1^{e}
M	45.2^{bc}	25.0^{h}	9.3^{e}	4.4^{h}	0.2^{e}
N	44.6^{c}	27.7^{fg}	14.0^{b}	9.5^{b}	6.1^{a}
O	53.6^{a}	31.4^{bc}	13.5^{bc}	7.4^{cde}	2.1^{c}

Values with different superscripts in a column are significantly different from each other (P<0.05).

Table 3. Hardness, adhesiveness and cohesiveness values of fourteen Turkish table margarines.

Sample	Hardness (N)	Adhesiveness (N.s)	Cohesiveness
A	20.01	2.19	0.59
B	45.63	2.71	0.57
C	40.76	3.16	0.59
D	26.20	2.12	0.63
E	40.59	3.15	0.60
F	34.97	3.08	0.60
G	20.86	2.54	0.63
H	34.04	2.44	0.53
J	29.50	2.55	0.62
K	25.57	2.23	0.63
L	12.08	2.01	0.6
M	15.77	2.11	0.65
N	30.33	3.13	0.69
O	31.91	2.61	0.54

is an important property of the oil or fat. The ratio of the solid fats composing of fat crystals which incorporate liquid oil in a crystal network, to the total phase at a particular temperature is one of the determining factors in the texture of plastic fats (Goli *et al.*, 2009; Laia *et al.*, 2000). In our study, the SFC values of samples were higher than those reported by Tekin *et al.* (2002) and Karabulut and Turan (2006).

Textural attributes of the samples are given in Table 3. As can be seen from the table, average hardness values of the samples ranged from 12.08 N to 45.63 N. Glibowski *et al.* (2008) reported hardness values ranging from 4 N to 65 N in their study.

On the other hand, adhesiveness scores of the samples changed between 2.01 N.s and 3.16 N.s. It was observed that there was a significant and high positive correlation between the hardness and adhesiveness scores of the samples (P<0.05, r=0.75). Cohesiveness scores of the samples are given in Table 3. Cohesiveness scores of the samples were between 0.53 N and 0.69 N. Sample E was found to be the most adhesive, whereas sample N was the most cohesive. It was observed that there was a negative correlation between the cohesiveness and hardness values of the samples (r=-0.49). Glibowski *et al.* (2008) reported cohesiveness values between 0.10 and 0.71, and adhesiveness values between -2.62 N.s. and -42.49 N.s. in table fats (margarine, butter and mixed fat product). They observed high correlation between hardness and cohesiveness. It is thought that this difference may be originated from the amounts and types of vegetable fats used in the production of margarines.

According to the statistical analysis results of the samples, the hardness, adhesiveness and cohesiveness values of margarines were not different from each other (P>0.05). Also positive and high correlations were determined between hardness and SFC at 20 °C (r=0.94) and SFC at 30 °C (r=0.93), respectively.

4. Conclusion

In conclusion, the SFA, MUFA and PUFA contents of samples were different from each other, except for *trans* fatty acids. Low TFA contents were detected in all samples. From these data, an increase in demand for Turkish table margarines is well justified due to their greatly reduced *trans* isomer content. The SFC values of Turkish table margarines sold under different trade marks were higher compared with margarines of other countries depending on their composition. The hardness values of samples were found to be higher. Also, a negative correlation was observed between the hardness and cohesiveness values of the samples, whereas a high and positive correlation was present among hardness and adhesiveness.

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