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Comparison of Physicochemical Characteristics of Some Margarines and Butters in Iranian Market during Storage

Narges Esmaeilifard[1], Manochehr Bahmaei[2*], Parvin Eshratabadi[3]

[1] *Department of Food Science & Technology, Pharmaceutical Science Branch, Islamic Azad University, Tehran, Iran.*

[2] *Islamic Azad University, North Tehran Branch, Tehran, Iran.*

[3] *Institute of Standard and Industrial Research, Karaj, Iran.*

Abstract

Margarine contains a higher level of unsaturated and trans-fatty acids (TFA) than butter. The aim of this study was to investigate the physicochemical properties of these products in Iranian market during storage. Physicochemical analyses included fatty acid composition, peroxide and Anisidine values, slip melting point (SMP), color, chlorophyll content, solid fat content (SFC) and texture analysis. Margarine, compared to the butter, contained a higher degree of unsaturation, TFA, SMP, peroxide and Anisidine than butter. Predominant TFA in butter and margarine were vaccenic (about 2.83-3.41%) and elaidic acids (about 7.55-9.26%), respectively. Peroxide and Anisidine values of margarine increased significantly during storage. a* value and SMP of all samples increased significantly during storage. The SMP of margarine-2 was more than that of other samples. Chlorophyll content of butter was significantly more than margarine. Also, the content of chlorophyll of all samples was constant during storage. L* and b* values of all samples decreased significantly during storage. SFC of butter was significantly ($p<0.05$) more than margarine at 5 to 10°C, but at temperatures ranging 20 to 35.5°C, SFC of margarine-2 was more than butter and margarine-1. At 5°C, a yield value of butter was significantly more than margarine-2, but at 20 and 30°C, a yield value of margarine-2 was more than butter and margarine-1. As a result, the comparison between butter and margarine showed that butter is superior in terms of qualitative factors. However, if the hydrogenation process in the manufacturing of margarine is removed and replaced by other safe methods it can lead to products with high nutritional value.

Keywords: Butter, Margarine, Physicochemical characteristics, Solid fat content, Trans-fatty acid.

***Corresponding author**: Manochehr Bahmaei, Islamic Azad University, North Tehran Branch, Tehran, Iran.
Tel: +98 912 148 8481
Fax: +98 212 224 8284
Email address: Mbahmaie@gmail.com

Abbreviations

AV: Anisidine value; CIE: Chemical Interesterification; CLA: Conjugated linoleic acid; CP: Cone penetrometer; CRP: C- reactive protein; EIE: Enzymatic Interesterification; GC: gas chromatography; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; PUFA: Polyunsaturated fatty acid; PV: Peroxide value; SFC: Solid fat content; SMP: Slip melting point; SPSS: Statistical Package for Social Sciences; TFA: Trans-fatty acid; WHO: World Health Organization.

Introduction

Margarine and butter are a water-in-oil emulsion containing at least 80% fat and 16% water in maximum. They are known as spreadable products. Butter contains about 70-75% of saturated fatty acids. Therefore it can increase cardiovascular disease. The dominant saturated fatty acid is palmitic, stearic and meristic acids and the dominant unsaturated fatty acids are oleic and palmitoleic acids (Samet-Bali et al. 2009). Trans fatty acid of butter produced by the microflora of cow rumen is called vacsenic acid. Fatty acid composition of butter depends on the type of animal breed, diet, season, genetic differences and lactation period. The dominant polymorphic in butter is beta´, because of its different type of fatty acids (the presence of about 400 types of fatty acids) (Dhibi et al 2013; Zock and Ktan 1996).

Margarine was invented in 1869 by French Morris. Generally, margarine can be produced by processes of hydrogenation, interesterification (enzymatic and chemical), fractionation and blending. In past, margarine was produced by the non-selective hydrogenation, resulting in products with high levels of saturated fatty acids and undesirable rheological properties. The dominant fatty acid in this product was stearic acid. The existence of this substance in products increases the firm texture of those products. The high level of the saturation of these products leads to cardiovascular disease. To improve rheological properties and to reduce the saturation product, the selective hydrogenation process was used. In this process, oleic acid is the prominent fatty acid that contributes to the softness and spreadability of the product. Interestingly, these characteristics are closely related to flow properties of products. However, during selected hydrogenation, the trans-fatty acid of elaidic acid is produced which increases the risk of cardiovascular disease, cancer, low-density lipoprotein (LDL) and diabetes and decreases high-density lipoprotein (HDL) (Gebauer et al. 2011).

The consumption of 4- 5 g of trans-fatty acids in a day increases the possibility of getting heart disease by 25% and stimulates inflammatory mediators involved in heart disease. In addition, it increases C- reactive protein (CRP) and the risk of the rupture of atherosclerosis plaque, the resistance to insulin, type II diabetes, sudden death and allergic diseases (Mensink 2005). Trans-fatty acids increase heart disease, the ratio of total cholesterol to HDL, plasma triglyceride concentrations, the risk of colon and breast cancer, diabetes, obesity and the disorder in the metabolism of omega-3 and omega-6 fatty acids (Dhaka et al. 2011). Also, Lichtenstein et al. (2003) reported that the type of dietary fat (soybean oil, semiliquid margarine, soft margarine, shortening, traditional stick margarine or butter) did not have any significant effect on blood pressure and CRP. Therefore, their effect was low on the degree of insulin and glucose.

Many studies have been done on the basis of different methods for the production of trans-free margarine such as interesterification (Pande and Akoh 2013; Adhikari et al. 2010; Rodriguez et al. 2009), fractionation and blending. Both physical and chemical properties of the oil can be changed by Interesterification process. This process also changes the structure of triglyceride's intramolecular ester-ester. One of the benefits of Enzymatic Interesterification (EIE) method compared to

the Chemical Interesterification (CIE) is the absence of the use of toxic catalysts such as Sodium methoxide and Sodium ethoxide. Moreover, the enzyme is a protein that does not endanger the environment. However, because of the high cost of its procedure, it is less considered by producers. It has also been reported that although Interesterification decreases the amount of trans-fatty acids to zero, it cannot reduce the amount of the saturation (Saadi et al. 2012; Bruno et al. 2013).
In this study, butter and margarine were stored at 5°C for 42 days and evaluated at regular intervals. The aim of this paper was to evaluate physicochemical properties and oxidative stability of butter and margarine during storage.

Materials and methods

Materials

Two brands of butter and margarine were purchased from a supermarket in Tehran. All samples were kept at 5°C during 42 days. All the chemicals and solvents used were of analytical or gas chromatography (GC) grade.

Sample preparation

To prepare samples for the present research, for each experiment, the oil phase was separated from the aqueous phase. Then, it was evaluated in terms of the physicochemical properties of the oil phase.

Fatty acid composition by gas chromatography (GC)

The component fatty acids were determined using gas liquid chromatography (Agilant-technologies 6890 N, USA). Fatty acids were converted into methyl esters using transesterification methods of oils with sodium methoxide as a catalyst according to American Oil Chemists Society method (AOCS 1995a). The gas chromatograph was equipped with a flame ionization detector and a capillary column (120 m × 25 mm ID-BPX 700. 250) (USA). To determine the fatty acid composition, a capillary column with temperature programming was used according to AOCS method (AOCS 1995b). The injector, detector temperatures, and Split ratio were set at 220, 250 °C and 100:1, respectively. Helium was used as the carrier gas with a flow rate of 0.7ml/min. The oven was heated to 180˚C for 30 min, then increased to 200 ˚C with the rate of 1.5 ˚C/min and maintained at this temperature for 30 min.

Standard chemical analyses

Peroxide value (PV) and anisidine value (AV) of the samples were determined according to AOCS method (AOCS 1992).

Assessment of chlorophyll content

Evaluation of chlorophyll content was determined by PFX 995 Tintometer Lavibond (1977) in accordance with AOCS Cc 13d-55 (AOCS 1993).

Assessment of Color

The oil color "Lab" was measured by PFX 995 Tintometer Lovibond (made in Germany). L* (ranges from 0 to 100) is a value of the lightness. The positive or negative a* values are related to the redness and greenness, respectively. The positive and negative b* values refer to the yellowness and blueness, respectively.

Solid fat content (SFC)

SFC (%) was evaluated by a Bruker mini spec pulsed nuclear magnetic resonance (p-NMR) model of the 20i spectrometer (Karlsruhe, Germany) at 5, 10, 20, 30, 35.5°C according to the AOCS method (Cd 16b-93).

Texture analysis

The hardness of all samples was measured at 5 and 20°C by cone penetrometer using Stan Hope-seta according to the AOCS method (AOCS 1974 method Cc 16-60) cone penetrometer with an angle of 40° and the weight of the cone assembly of 79.03 g. In order to measure all samples and the cone penetrometer, they had to be stored at 5, 10, 20 and 30°C temperature for 24 h. The calculation is shown below:

$$C = (k \times W)/p_{1.6}$$

Where C = yield value (g/cm^2)
K = constant (5840 for 40° cone angle)
W = weight of cone (79.03)
P = penetration depth (in mm)

Statistical analysis

All examinations for each sample were performed for three times. Statistical Package for Social Sciences (SPSS) software, version 23 (IBM, New York, USA) was used for the statistical analysis. One-way analysis of variance (ANOVA) followed by Tukey's test ($p < 0.05$) was used to evaluate the differences between butter and margarine.

Results and discussion

Fatty acid composition

Fatty acid compositions for each sample are shown in Table 1. Predominant saturated fatty acids in butter were palmitic, stearic, myristic acids and these acids in margarine were palmitic and stearic acids. The predominant unsaturated fatty acid in butter was oleic acid and in margarine were oleic and linoleic acids. Predominant trans-fatty acid (TFA) in butter and margarine were vaccenic (trans18:1(n-11)) and elaidic acid (trans18:1(n-9)), respectively. TFA content in milk fat and butter is about 1.75- 8.60%. Butter contains the minimum amount of TFA in winter about 4.30- 4.90% and the highest amount in spring and summer about 6.50- 7.60%. Spring and summer forage consists of more polyunsaturated fatty acid (PUFA) in comparison to the winter fodder which leads to the differences in the TFA content in butter produced in summer and winter. However, the organizations such as the Heart Association of America, Institute of Medicine, console nutrition Denmark and the Association of Food and TFA acids of Agriculture of the United Nations have recommended reducing the amount of the saturated and trans-fatty acids in foods in order to reduce the risk of blockage of coronary heart disease. Therefore, many organizations have been permitted at most 1% TFA in food products. Also according to the World Health Organization (WHO), the total amount of trans-fat per day should be less than 1% of daily energy (Ratnayake et al. 1991). In the body, Vaccenic acid (11-trans octadenoic acid) is converted to Rumenic acid (9 –cis, 11 –trans octadecenoic acid) as an isomer of conjugated linoleic acid (CLA) by Δ9-desaturase. This conversion increases the amount of CLA available in the body (Mozaffarian et al. 2009). CLA is beneficial in the inhibition of tumor growth, a decrease in body fat, and the reduction of the risk of cancer and osteoporosis. Meijer et al. (2001) reported that the diet containing vaccenic acid rather than elaidic acid in male hamsters increased the ratio of LDL to HDL in plasma. Oomen et al. (2001) also claimed that elaidic acid increased cardiovascular risk while vaccenic acid has not had any negative effect on this disease. Elaidic acid of margarine in the markets of Turkey, Pakistan, Spain and Canada have been from 7.7 to 37.80%, from 2.45 to 21.1 %, from 0.15 to 20.21% and from 2 to 39.6%, respectively. (Alonso et al. 2000; Brat and Pokorny 2000; Schwalfenberg 2006; Tekin et al. 2002).

According to Table 1, a total of mono and polyunsaturated fatty acids of margarine was more than butter. Also, omega-6 to the omega-3 ratio of margarine was more than that of butter. Omega-6 to omega-3 ratio recommended by FAO/WHO is 5-10 to 1. However, clinical researche showed that the best omega-6 to omega-3 ratio is 2- 3 to 1 (Simopoulos 2002). So, manufacturers have to decrease this ratio in these products.

Table 1. Fatty acid composition of butter and margarine.

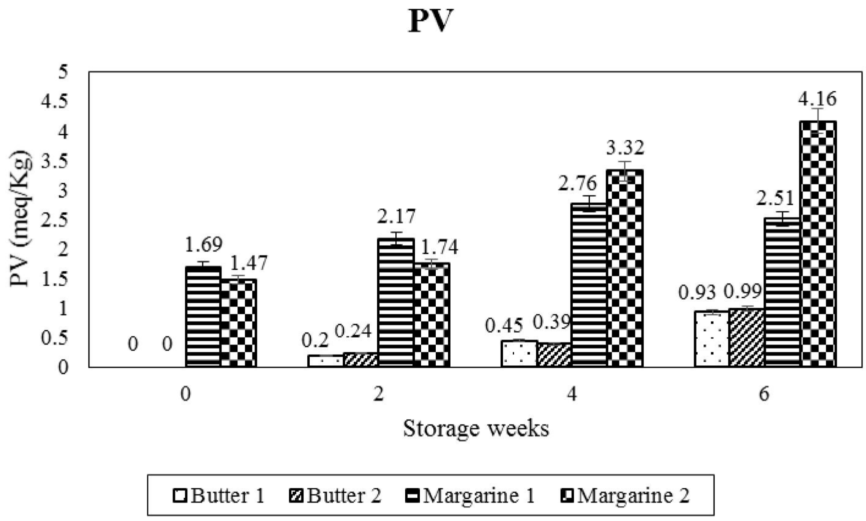
fatty acid	Samples			
	B-1	**B-2**	**M-1**	**M-2**
C4: 0	1.77 ± 0.01[b]	1.95 ± 0.01[c]	ND[a]	ND[a]
C6: 0	1.47 ± 0.03[b]	1.67 ± 0.01[c]	ND[a]	ND[a]
C8: 0	1.50 ± 0.01[c]	1.20 ± 0.01[b]	ND[a]	ND[a]
C10: 0	2.87 ± 0.02[b]	2.84 ± 0.03[b]	ND[a]	ND[a]
C12: 0	5.62 ± 0.01[d]	4.35 ± 0.00[c]	0.28 ± 0.01[b]	0.12 ± 0.01[a]
C14: 0	12.97 ± 0.05[c]	11.15 ± 0.01[b]	0.55 ± 0.05[a]	0.59 ± 0.02[a]
C14: 1	1.21 ± 0.03[c]	1.14 ± 0.01[b]	ND[a]	ND[a]
C16: 0	29.52 ± 0.05[c]	26.88 ± 0.01[b]	26.10 ± 0.03[a]	26.11 ± 0.02[a]
C16: 1	1.82 ± 0.01[c]	1.48 ± 0.01[b]	0.09 ± 0.00[a]	0.08 ± 0.02[a]
C17: 0	0.93 ± 0.03[c]	0.65 ± 0.00[b]	ND[a]	ND[a]
C17: 1	0.39 ± 0.01[c]	0.34 ± 0.01[b]	ND[a]	ND[a]
C18: 0	10.30 ± 0.01[c]	11.49 ± 0.01[d]	8.60 ± 0.02[a]	9.63 ± 0.01[b]
C18t: 1	2.83 ± 0.02[a]	3.41 ± 0.00[b]	9.26 ± 0.02[d]	7.55 ± 0.02[c]
C18c: 1	17.82 ± 0.04[a]	21.04 ± 0.05[b]	34.49 ± 0.01[d]	26.52 ± 0.04[c]
C18t:2	0.44 ± 0.03[a]	1.90 ± 0.02[c]	1.86 ± 0.01[c]	0.59 ± 0.03[b]
C18c: 2	1 ± 0.00[a]	1 ± 0.00[a]	15.20 ± 0.01[b]	25.56 ± 0.06[c]
C18t: 3	0.61 ± 0.02[c]	0.73 ± 0.01[d]	0.29 ± 0.01[b]	0.19 ± 0.02[a]
C18c: 3	0.94 ± 0.04[a]	1.01 ± 0.01[ab]	1.04 ± 0.01[b]	2.21 ± 0.00[c]
C20: 0	ND[a]	ND[a]	0.68 ± 0.03[b]	0.61 ± 0.02[b]
C20: 1	ND[a]	0.03 ± 0.01[b]	0.09 ± 0.00[c]	ND[a]
C22: 0	0.34 ± 0.03[c]	0.04 ± 0.00[a]	0.24 ± 0.02b[c]	0.22 ± 0.03[b]
TUFA	27.07 ± 0.09[a]	32.10 ± 0.03[b]	62.33 ± 0.01[c]	62.71 ± 0.15[d]
PUFA	2.99 ± 0.09[a]	4.65 ± 0.03[b]	18.39 ± 0.00[c]	28.55 ± 0.06[d]
MUFA	24.08 ± 0.00[a]	27.45 ± 0.06[b]	34.16 ± 0.08[c]	43.95 ± 0.01[d]
TSFA	67.31 ± 0.01[d]	62.23 ± 0.05[c]	36.47 ± 0.11[a]	37.29 ± 0.05[b]
TFA	3.89 ± 0.03[a]	6.05 ± 0.01[b]	11.41 ± 0.01[d]	8.34 ± 0.03[c]
SFA+TFA	71.20 ± 0.03[d]	68.28 ± 0.06[c]	47.88 ± 0.09[b]	45.88 ± 0.02[a]
Omega-3 content	1.55 ± 0.06[b]	1.74 ± 0.01[c]	1.33 ± 0.02[a]	2.40 ± 0.02[d]
Omega-6 content	1.44 ± 0.03[a]	2.90 ± 0.02[b]	17.05 ± 0.02[c]	26.15 ± 0.08[d]
n-6/*n*-3 ratio	0.92 ± 0.02[a]	1.66 ± 0.01[b]	12.79 ± 0.20[d]	10.87 ± 0.13[c]

All data are reported as mean ± SD. Means in the same row with different superscript small letters differ significantly ($p < 0.05$). TUFA: Total of unsaturated fatty acid, PUFA: Polyunsaturated fatty acid, MUFA: Monounsaturated fatty acid, TSFA: Total of saturated fatty acid. ND: Not detected.

Peroxide and Anisidine values

Peroxide and anisidine values for each sample are shown in Figure 1 (a and b). PV indicated the formation of hydroperoxides (primary oxidation products) in fat products. However, it is not a good indicator to evaluate oxidative stability of fat products. Therefore, in addition to PV, AV was used to evaluate oxidative stability during storage. AV indicates the amount of the formation of secondary oxidation products such as aldehydes and ketones (Guillen and Cabo 2002).

(a)



(b)

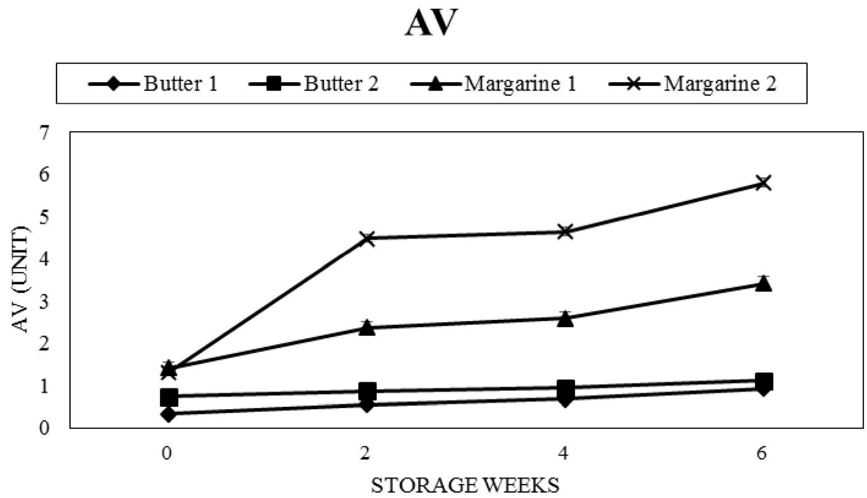


Figure 1: Peroxide (a) and anisidine (b) values of butter and margarine during storage.

PV of butter had not changed significantly ($p < 0.05$), but PV of margarine had changed significantly ($p < 0.05$) during storage. PV of margarine-1 (M-1) and margarine-2 (M-2) increased from first to the fifteenth day, but PV decreased on the thirtieth day. Meanwhile, AV of all samples increased during storage. The lowest and highest AV during storage belonged to butter and margarine, respectively. Because butter had high saturation level than margarine. So, margarine was more susceptible to oxidation. Orlien et al. (2006) reported that the storage of the oils at 5°C may increase the formation of products' secondary oxidation, and the decrease of temperature of oil's storage can reduce the formation of products' oxidation.

Slip melting point (SMP)

SMP has been influenced by the chain carbonic length (when the length of the carbonic chain of fatty acid increased, SMP increased), unsaturation level (by increasing the unsaturation level, the SMP is reduced) and trans-fatty acid content (trans-fatty acids have higher SMP than cis-fatty acids). Also, the SMP was related to hardness and solidification/melting behavior of fat products (Goh and Ker 1991). Table 2 shows the SMP of samples at different storage times. According to Table 2, SMP of M-2 was significantly ($p < 0.05$) higher than other products. The SMP of all samples has increased during storage. The SMP of all samples increased suddenly in the fourth week. The highest amount of SMP of butter-1 (B-1) was in the fourth week and this amount for the other samples happened in the sixth week.

Although saturated fatty acid content in M-2 was less than that of butter, but it had higher SMP than other samples. This is because of the presence of short and medium-chain fatty acids in butter and existence of higher melting point triglycerides in M-2. Whereas the SMP of M-1 was less than M-2, the triglycerides content of M-1 must have had a lower melting point than the M-2.

Lai et al. (2000) stated that the amount of SMP of experimental table margarine increased during storage. Karabulut & Turan (2006) also believed that the amount of SMP of margarine in Turkey market was in the range of 31.20-34.90°C, while the amount of margarine SMP in Iranian market were 32 and 41.31°C.

Table 2. Slip melting point (SMP) of butter and margarine during storage.

Storage weeks	SMP (°C)			
	B-1	B-2	M-1	M-2
0	$32.10 \pm 0.00^{B\ a}$	$32 \pm 0.00^{A\ a}$	32 ± 0.00A a	$40.95 \pm 0.07^{C\ a}$
2	$32.15 \pm 0.05^{A\ ab}$	$32.14 \pm 0.03^{A\ b}$	$32.20 \pm 0.06^{B\ b}$	$41.08 \pm 0.02^{C\ b}$
4	$32.26 \pm 0.07^{A\ b}$	$32.29 \pm 0.02^{AB\ c}$	$32.37 \pm 0.08^{B\ c}$	$41.23 \pm 0.05^{C\ c}$
6	$32.13 \pm 0.04^{A\ a}$	$32.36 \pm 0.05^{B\ c}$	$32.45 \pm 0.03^{C\ c}$	$41.31 \pm 0.09^{D\ c}$

All data are reported as mean ± SD. Means in the same column with different superscript small letters differ significantly ($p < 0.05$). Also, Means in the same row with different superscript capital letters differ significantly ($p < 0.05$).

Chlorophyll content

Chlorophyll content for each sample is shown in Table 3. Chlorophyll is known as a sensitizing agent in photo-oxidation phenomenon and causes the formation of hydroperoxides.

According to Table 3, chlorophyll content of B-1 and butter-2 (B-2) were more than M-1 and M-2, because oils used in the formulation of studied margarine are refined. These compounds were removed from oil in bleaching stage. The presence of chlorophyll in butter was due to the vegetarian diet of cows. In addition, the content of chlorophyll of all samples was constant during storage.

Chlorophyll content is so effective on the quality of the final product (Mirzaee Ghazani et al., 2014) that Tautorus & Low (1994) claimed that chlorophyll and its derivatives (such as pheophytin and pheophorbide) contributed to the promotion of photooxidation as Pro-oxidants and therefore it causes instability of oils.

Color

The color for each sample is shown in Table 3 at different storage times. All of the samples had high lightness (L*), yellowness (b*) and redness (a*). L* and b* values of samples had decreased during storage, but a* value had increased significantly ($p < 0.05$) during storage. In fact, broken hydroperoxide caused the formation of aldehydes and ketones. Then, a Maillard reaction happened between aldehyde and amine of phospholipid. This reaction leads to the increased the redness of the products. Interestingly, the growth of this redness occurs more quickly in margarine than butter. In addition, unsaturation level is more effective in Maillard pigments formation (Hettiarachchy & Ziegler 1994). According to the reports by Rufian-Henares et al. (2004) and Augustin et al. (2006), Maillard browning reaction and formation of Maillard pigments decreased lightness (L* value) and increased redness and

Table 3. Color and chlorophyll content of butter and margarines during storage.

Storage weeks	sampl	Chlorophyll a (mg/Kg)	Lab		
			L*	a*	b*
0	B-1	0.17 ± 0.003d	76.36 ± 0.04j	26.85 ± 0.05g	124.88 ± 0.09g
	B-2	0.12 ± 0.002c	87.09 ± 0.05l	6.40 ± 0.12a	136.96 ± 0.05j
	M-1	0.05 ± 0.00b	86.92 ± 0.09k	11.27 ± 0.06c	137.33 ± 0.03k
	M-2	0.04 ± 0.00a	74.30 ± 0.03i	20.24 ± 0.04e	131.88 ± 0.06i
3	B-1	0.17 ± 0.004d	70.02 ± 0.07f	29.48 ± 0.15h	108.29 ± 0.05c
	B-2	0.13 ± 0.005c	73.82 ± 0.08h	8.50 ± 0.02b	113.59 ± 0.08e
	M-1	0.05 ± 0.00b	71.48 ± 0.04g	23.06 ± 0.09f	126.15 ± 0.11h
	M-2	0.04 ± 0.002a	69.51 ± 0.06e	31.17 ± 0.06i	118.63 ± 0.08f
6	B-1	0.17 ± 0.001d	63.75 ± 0.10b	32.24 ± 0.05j	98.16 ± 0.14a
	B-2	0.13 ± 0.008c	66.94 ± 0.12d	17.33 ± 0.08d	103.58 ± 0.07b
	M-1	0.05 ± 0.00b	65.30 ± 0.15c	26.79 ± 0.09g	108.55 ± 0.04c
	M-2	0.04 ± 0.00a	63.00 ± 0.11a	35.20 ± 0.07k	110.51 ± 0.09d

All data are reported as mean ± SD. Means in the same column with different superscript small letters differ significantly (p < 0.05).

yellowness (a* and b* values). Also, Bicanic et al. (2010) reported that high concentration of beta-carotene in mango led to an increase and a decrease in a* and L* values, respectively.

Solid fat content (SFC)

Solid fat content (SFC) for each sample are shown in Figure 2. Solid fat content is known as an important quality factor in fat products such as margarine and butter. It is responsible for many characteristics of margarine and butter (such as their appearance, organoleptic, spreadability and oil exudation properties). SFC is solid to the liquid fat ratio at different temperature (Rebeiro et al. 2009). Solid fat forms a network and traps liquid oil into its structure. It also maintains plasticity of the product. In addition, the hardness of margarine can be determined at any temperature by its SFC. The SFC of a fat product at 5 °C indicated its ease of spreading at refrigeration temperatures; at 25 °C, it was due to the resistance to oil exudation at room temperature; at 35°C, the SFC depended on the texture and properties of liberation of flavor and aroma in the mouth (Dian et al. 2007). Lida and Ali (1998) claimed that the SFC of margarine should not have been more than 32% at 10°C. Therefore, its spreadability at refrigeration temperature should be considered.

Rao et al. (2001) reported that SFC has to be over 10% at 20°C to create desirable texture and spreadability. At 20°C, SFC of B-1, B-2, M-1 and M-2 were 17.81, 17.80, 19.17 and 26.72%, respectively. The slope of the curves of B-1, B-2 and M-1 was faster than M-2. The lowest and highest SFC at 5, 10 and 20°C belonged to M-2 and B-2 and at 30, 35.5°C belong to B-1 and M-2. The SFC at 35°C is ascribed to the melting and mouth feel product (Osorio et al. 2006). However, a waxy sensation in the mouth could be avoided if margarine had SFCs below 3.5% at 33.30°C and melt completely at body temperature (Karabulut et al. 2004). The SFC in all samples does not change significantly during storage ($p < 0.05$).

Penetration test

The yield value (g/cm^2) for each sample is shown in Figure 3. Consistency in margarine and butter is dependent on softness, smoothness and plasticity state of the product. Also, spreadability can be defined as being easily and simply rubbed a thin layer of margarine

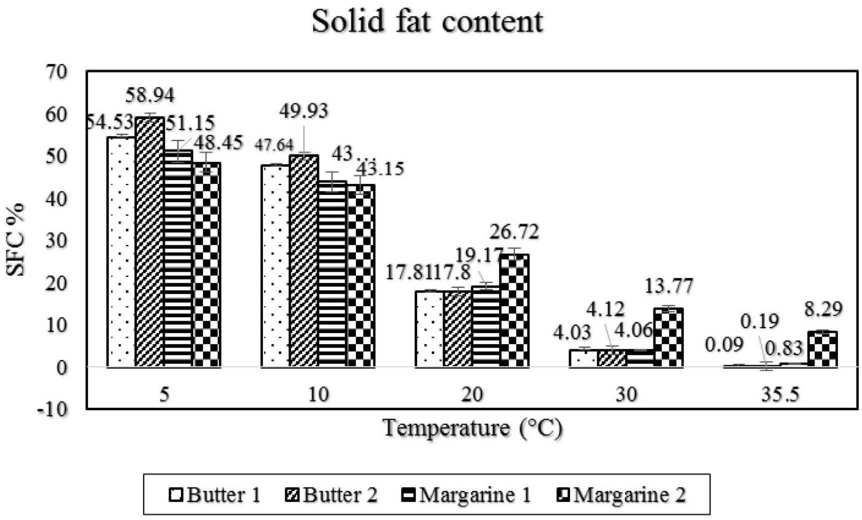


Figure 2: Solid fat content (SFC) of butter and margarine at 5- 35.5°C.

on bread. The yield value in butter at 5 and 10 °C was significantly more than margarine. However, butter had higher saturation degree than margarine, but at 20 and 30°C, the consistency value in M-2 was significantly over butter and M-1. The present of short and medium-chain fatty acids in butter and the presence of the high amount of triglycerides of a low melting point in M-1 may have played a role in their lower consistencies than M-2 at 20°C. According to Figure 3, the SFC of butter and margarine at temperatures between 10 and 20°C reduced significantly and this reduction correlated with the consistency values of products. The higher stability of M-2 was attributed to triglycerides with high melting point and the formation of a strong crystal network that prevented the separation of the (oil or water) phase.
Haighton et al. (1959) stated that there is such a direct relationship between consistency and yield value that the yield value for margarine and shortening, which are stored at refrigerator temperature, is in the range of <50 g/cm^2 leading to the soft texture and >1500 g/cm^2 to hard one. Therefore, based on this report, butter had very hard texture while margarine had a hard texture with satisfactory spreadability. Moreover, Deman et al. (1989) claimed that desirable spreadability of margarine is placed within the range of yield value between 125 and 800 g/cm^2. Also, Garcia et al. (2013) showed that the yield value of trans-free margarine is in the range of 0-5000 g/cm^2 at different temperatures.

Conclusion

Butter and margarine are fat products mostly used by societies. However, nowadays, the market share of margarine is more than butter. Margarine contains more trans-fatty acids and the level of unsaturation in comparison to those of butter because margarine is more prone to oxidation than butter. All products are in the range of yellow-red colors. The amount of the redness, PV, and AV during storage significantly increased, while the yellowness, lightness decreased significantly. The content of chlorophyll was constant during storage. The slope of the curves of SFC of butter is more than that of margarine. Also, the yield value of butter at 5 and 10°C was significantly more than that of margarine. However,

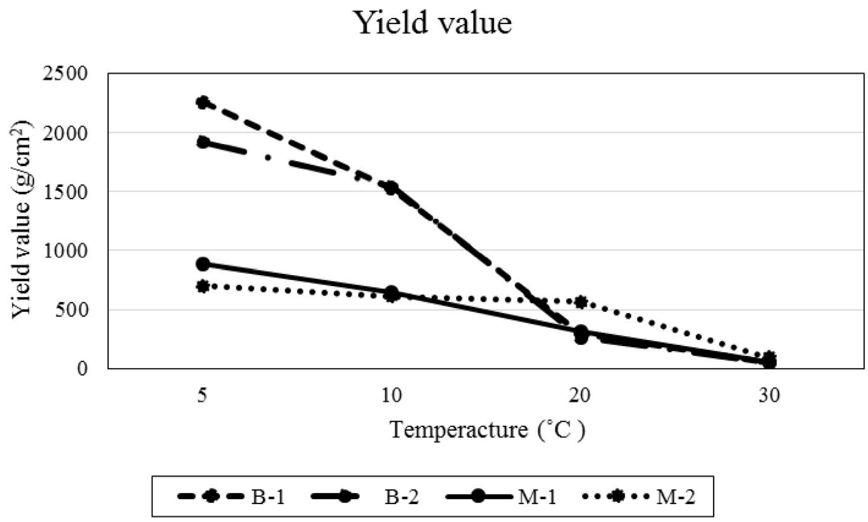


Figure 3. Yield value (g/cm2) of butter and margarine at 5- 30°C.

this index at 20°C was more in M-2 rather than in butter and M-1. The result of this research revealed that trans-free products can be produced if the selective hydrogenation process in the manufacturing margarine is eliminated and replaced by interesterification, fractionation, and blending methods. Thus, margarine can be a good alternative to butter (because of high saturation of butter). In addition, both the production of products consisting of CLA and adjustment of the ratio of omega-6 to omega-3 can compensate the lack of these compounds in the diet.

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Conflicts of Interest

None of the authors have any conflict of interest associated with this study.

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