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ORIGINAL PAPER

Fatty Acid Profile Including *Trans* Fatty Acid Content of Margarines Marketed in Mexico

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Abstract In this study, the fatty acid profile of 42 margarines marketed in Mexico was identified and quantified including the total *trans* fatty acids (TFA). The ratio of the sum of cholesterol-lowering fatty acids CLFA (*cis*-oleic, linoleic and α-linolenic fatty acids) to the sum of cholesterol-raising fatty acids CRFA (C12:0, C14:0, C16:0, TFA) and the $\omega 6/\omega 3$ ratio were calculated to evaluate the nutritional quality of the margarine samples. The results showed that the high content of C12:0, C14:0 and C16:0 fatty acids in some samples indicated the use of coconut and palm oils instead of partially hydrogenated fatty acids in order to decreased TFA content. Of the samples, 33% had less than 1 g/100 g of fat which could be considered as "free from TFA" according to the Danish Legislation. The $\omega 6/\omega 3$ ratio ranged between 5.85:1 and 25.85:1, the ideal relation being 5–10:1. The CLFA/CRFA ranged from 0.46 to 3.10, being the recommended ratio as high as possible. Of the 42 margarines, only five samples had an acceptable fatty acid profile, that is, low TFA and saturated fatty acids, high monounsaturated fatty acids content and adequate $\omega 6/\omega 3$ and CLFA/CRFA ratios.

Keywords Margarine · Fatty acid profile · *Trans* fatty acids · Omega fatty acids · Nutritional quality

Introduction

The identification and quantification of fatty acids in food products are of paramount importance, since each type of fatty acid is associated with different health effects. Saturated fatty acids (SFA) and *trans* fatty acids (TFA) consumption is associated with an increased risk of cardiovascular diseases by raising the total-cholesterol to HDL-cholesterol ratio [1]. TFA alone increased this ratio nearly twofold compared with SFA [2]. On the other hand, it has been reported that monounsaturated (MUFA) and polyunsaturated fatty acid (PUFA), as well as omega-6 and omega-3 fatty acids consumption (in the 5–10:1 ratio) are beneficial to health [3].

Margarine is a butter-like product obtained from mixtures of various edible fats and oils. Usually, margarine contains appropriate ratios of hard vegetable fats from coconut, palm kernel, interesterified vegetable oils and/or hydrogenated vegetable oils [4]. Now a days, health specialists and consumers are evaluating products such as margarines because they are among the main sources of TFA due to the partially hydrogenated oils involved in their processing. Prompted by the growing evidence that consumption of TFA is detrimental to health, several countries, including the USA and Canada, have introduced legislation to reduce the TFA content in processed foods [5]. Denmark has one of the most rigorous set of standards [6] that limits

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TFA in foods to 2.0 g TFA/100 g of fat or oil, and the samples containing less than 1.0 g TFA/100 g of fat or oil are considered as free from TFA.

Information about *trans* fatty acids is generally lacking from food composition databases in most countries [7]. The amounts of TFA in margarines can vary considerably among similar items, reflecting the differences in the fat type used in the manufacturing process. This large variability of TFA content can limit the accuracy of estimates of dietary TFA intakes when analysis of diet information is made using an average value from nutrient databases [8]. Moreover, there is scarce information about individual fatty acids with relative low abundance such as alpha and gamma linolenic acid [7, 9].

The objective of this work was to identify and quantify the fatty acid profile of margarines marketed in Mexico, including TFA content, and to calculate two nutritional relationships between fatty acids ((CLFA/CRFA) and $\omega 6/\omega 3$ ratios) and discuss about nutritional quality of margarine samples.

Materials and Methods

Samples

Forty-two top-selling margarines, commercially available in Mexico City were analyzed. Twenty-two samples were stick margarines and twenty were spreadable (tub-type) margarines.

Preparation of Fatty Acid Methyl Esters (FAME)

All samples were melted at 60 °C to obtain the oily phase; this phase was removed by centrifugation and dried with anhydrous Na_2SO_4. The preparation of FAME was based on the standard IUPAC method 2.301 [10], except that the FAME were reconstituted in dichloromethane instead of hexane as stated in the IUPAC method. Dichloromethane was used in order to have the same solvent in the FAME samples as the one present in the standard mixture used for quantification (Restek 35077).

Determination of Fatty Acid Contents

Fatty acid contents were evaluated by gas chromatography. FAME were analyzed on a Clarus 500 gas chromatograph (Perkin Elmer, Shelton, CT, USA) with a flame ionization detector (FID). Analyses were performed with an Rtx®-2330 column (105 m × 0.25 mm i.d. × 0.20 mm film thickness; Restek, Bellefonte, USA). FID and the injector temperatures was set to 250 °C. Nitrogen was used as the carrier gas with a pressure of 40 psi, the split ratio was 100 mL/min. The FAME (1 μL) were injected at an initial temperature of 100 °C, which was increased after 10 min to 205 °C at a rate of 15 °C/min, then increased from 205 to 230 °C at 3 °C/min, and then to 245 °C at 1.3 °C/min, with a final isothermal period of 30 min. Peak retention times and area percentages of total fatty acids were identified by injecting a standard mixture of 37 known FAME (Restek 35077). The fatty acid composition data shown in "Results and Discussion" section are the averages for the analysis of two replicates, and the standard deviation is also included.

Statistical Analysis

In order to find significant differences between mean values of each fatty acid analyzed in the samples, a Fisher's Least Significant Difference (LSD) test was applied at the 95% confidence level ($P < 0.05$), using the Statistical Analysis System package (SAS v.8.1) (SAS Institute Inc., Cary, NC).

Results and Discussion

The results of the minimum and maximum amounts of each fatty acid (as % of total fatty acids) of the 42 margarines marketed in Mexico City are presented for saturated fatty acids in Fig. 1 for spreadable and Fig. 2 for stick margarines, and for unsaturated fatty acids in Fig. 3 for spreadable and Fig. 4 for stick margarines. The total fatty acid composition (as % of total fatty acids) of each margarine sample is presented for saturated fatty acids in Table 1 for spreadable and Table 2 for stick margarines, and for unsaturated fatty acids in Table 3 for spreadable and Table 4 for stick margarines. The margarine brands were coded with S for spreadable margarine and with P for stick margarine. Tables 3 and 4 include the TFA content per

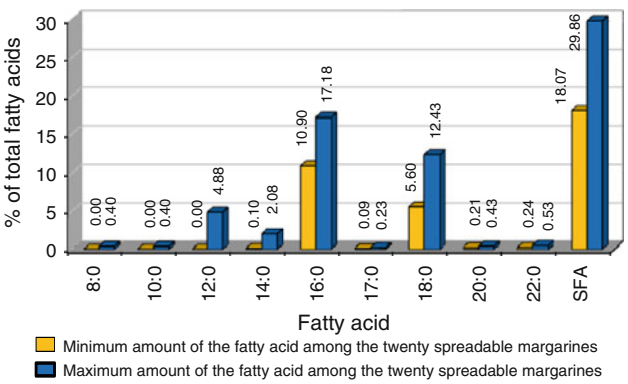

Fig. 1 Minimum and maximum amount of saturated fatty acid of spreadable margarines (% of total fatty acids)

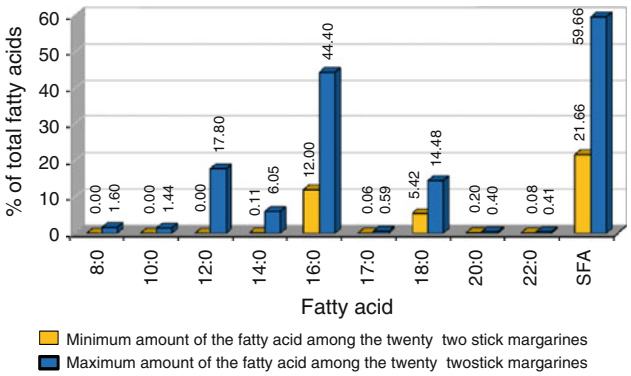

Fig. 2 Minimum and maximum amount of saturated fatty acid of stick margarines (% of total fatty acids)

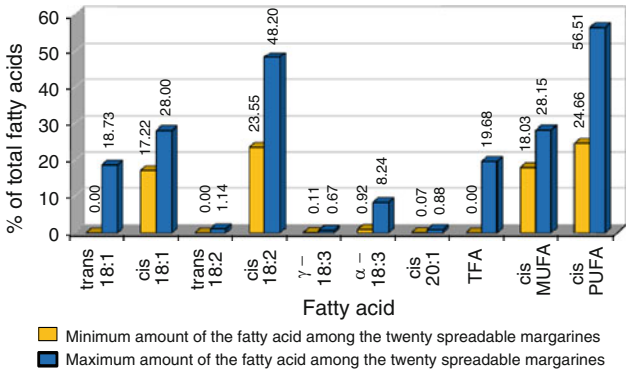

Fig. 3 Minimum and maximum amount of unsaturated fatty acid of spreadable margarines (% of total fatty acids)

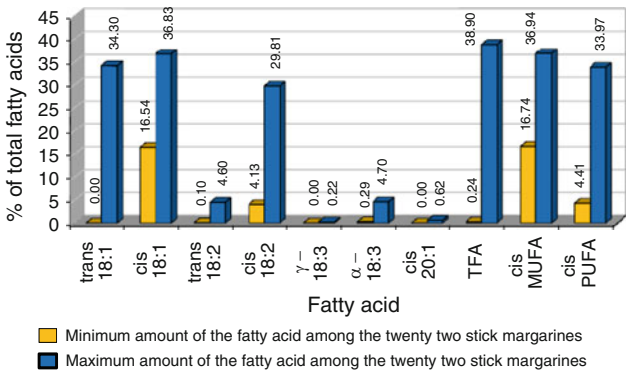

Fig. 4 Minimum and maximum amount of unsaturated fatty acid of stick margarines (% of total fatty acids)

100 g of fat in order to compare the results with the Danish Legislation, which as mentioned before is one of the most rigorous set of standards. Also the significant differences in fatty acids content of all samples according to the LSD test are presented in the above mention tables at the 95% confidence level.

Figures 1 and 2 show that in the 42 margarines samples the main saturated fatty acids (SFA) are palmitic acid (16:0), stearic acid (18:0), lauric acid (12:0), and myristic acid (14:0). Regarding spreadable margarines (Fig. 1), the content of 16:0, 18:0, 12:0, and 14:0 varied from 10.90 to 17.18, 5.60 to 12.43, 0.00 to 4.88, and 0.10 to 2.08%, respectively. For stick margarines (Fig. 2), the content of the same fatty acids ranged from 12.00 to 44.40, 5.42 to 14.48, 0.00 to 17.80, and 0.11 to 6.05%, respectively. Other SFA as 8:0, 10:0, 17:0, 20:0, and 22:0 are present but at concentrations lower than 1.60%. The predominant SFA in both types of margarine is 16:0, which indicates a greater contribution of tropical oils (coconut oil and palm oil) in the manufacture of margarine.

According to Tables 1 and 2, there were significant differences ($P < 0.05$) between total SFA of most of the samples, especially between the stick type. However, for some specific SFA there were more similarity in content at $P < 0.05$ in the different samples.

Figures 3 and 4 include the monounsaturated (*cis*-MUFA), polyunsaturated (*cis*-PUFA), and *trans* fatty acids (TFA) of spreadable (Fig. 3) and stick margarines (Fig. 4). Among the *cis*-MUFA, oleic acid (*cis*-18:1) was the major fatty acid present. Its content for spreadable and stick margarines varied between 17.18 and 28.00%, and for stick margarines from 16.54 to 36.83%. Another *cis*-MUFA, the *cis*-20:1 was also determined, but at concentrations lower than 0.88%.

Regarding polyunsaturated fatty acid (*cis*-PUFA), Figs. 3 and 4 show that linoleic acid (*cis*-18:2) was the major *cis*-PUFA for spreadable and stick margarines, ranging from 23.55 to 48.20% for the former and only from 4.13 to 29.81% for the latter. These results indicate, according to Table 4, that the low concentration of *cis*-18:2 fatty acid in some stick margarines (P1, P2, P13, P14, P15 and P19) could be due to the substitution of some polyunsaturated oils by tropical oils (palm or coconut oils) in the manufacture of margarines as indicated by the high content 16:0 fatty acid in these samples as shown in Table 2. Linolenic acid (*cis*-18:3) is present as γ and α isomers (ω-6 and ω-3, respectively). Spreadable margarines (Fig. 3) have a higher concentration of both *cis*-18:3 isomers than stick margarines (Fig. 4). The content of γ-18:3 and α-18:3 varied from 0.11 to 0.67% and from 0.92 to 8.24%, respectively for spreadable margarines, while for stick margarines, γ-18:3 and α-18:3 varied from 0.00 to 0.22% and from 0.29 to 4.70%, respectively. The large content of both *cis*-18:3 isomers in some margarine samples is probably due to the incorporation of soybean oil or canola oil in its manufacture, since it has been reported [11] that these oils have the highest content of linolenic acid (*cis*-18:3) ranging between 8 and 10% of total fatty acids.

As shown in Table 3, the total *cis*-MUFA and *cis*-PUFA contents show some similarity at $P < 0.05$ among

Table 1 Saturated fatty acid composition (% of total fatty acids) of spreadable margarines

Sample	8:0	10:0	12:0	14:0	16:0	17:0	18:0	20:0	22:0	SFA
S1	0.30 ± 0.01^{bc}	0.30 ± 0.03^{bc}	4.11 ± 0.14^{c}	1.52 ± 0.14^{c}	13.70 ± 0.28^{ef}	0.11 ± 0.02^{de}	7.20 ± 0.14^{de}	0.40 ± 0.03^{ab}	0.31 ± 0.03^{cde}	27.90 ± 0.54^{bcd}
S2	0.30 ± 0.03^{ab}	0.31 ± 0.01^{ab}	4.55 ± 0.14^{b}	1.80 ± 0.14^{b}	13.71 ± 0.01^{ef}	0.19 ± 0.01^{abc}	7.15 ± 0.07^{ed}	0.21 ± 0.01^{f}	0.29 ± 0.01^{cde}	28.50 ± 0.37^{cb}
S3	0.19 ± 0.01^{c}	0.21 ± 0.01^{c}	2.65 ± 0.21^{f}	1.15 ± 0.21^{ef}	12.49 ± 1.08^{ghi}	0.15 ± 0.07^{bcd}	6.40 ± 0.14^{fghi}	0.43 ± 0.11^{a}	0.32 ± 0.02^{bcd}	23.98 ± 1.01^{f}
S4	0.33 ± 0.08^{bc}	0.29 ± 0.01^{bc}	3.73 ± 0.25^{d}	1.43 ± 0.18^{cd}	12.75 ± 0.21^{gh}	0.09 ± 0.01^{e}	8.05 ± 0.21^{b}	0.38 ± 0.01^{abc}	0.33 ± 0.04^{bcd}	27.36 ± 0.25^{cd}
S5	0.34 ± 0.05^{bc}	0.30 ± 0.01^{bc}	4.23 ± 0.32^{c}	1.05 ± 0.07^{f}	12.60 ± 0.28^{gh}	0.13 ± 0.04^{de}	7.47 ± 0.18^{cd}	0.43 ± 0.04^{a}	0.24 ± 0.06^{e}	26.78 ± 0.05^{ed}
S6	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.10 ± 0.07^{h}	0.21 ± 0.01^{ghi}	12.18 ± 0.18^{hij}	0.19 ± 0.01^{abc}	6.01 ± 0.57^{ijkl}	0.29 ± 0.01^{cdef}	0.33 ± 0.04^{bcd}	19.29 ± 0.65^{h}
S7	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.20 ± 0.01^{ghi}	11.70 ± 0.14^{ijk}	0.22 ± 0.02^{a}	6.15 ± 0.21^{hijk}	0.25 ± 0.01^{ef}	0.27 ± 0.04^{cde}	18.78 ± 0.40^{h}
S8	0.40 ± 0.14^{a}	0.40 ± 0.07^{a}	4.88 ± 0.18^{a}	2.08 ± 0.11^{a}	14.02 ± 0.14^{de}	0.20 ± 0.01^{ab}	6.40 ± 0.28^{fghi}	0.29 ± 0.01^{cdef}	0.29 ± 0.01^{cde}	28.93 ± 0.46^{ab}
S9	0.33 ± 0.01^{bc}	0.30 ± 0.04^{bc}	3.40 ± 0.14^{e}	1.80 ± 0.14^{b}	12.18 ± 0.18^{hij}	0.11 ± 0.01^{ed}	7.23 ± 0.18^{de}	0.36 ± 0.03^{abcd}	0.31 ± 0.01^{bcd}	26.01 ± 0.49^{e}
S10	0.00 ± 0.0^{d}	0.00 ± 0.00^{d}	0.11 ± 0.01^{h}	0.31 ± 0.03^{g}	16.85 ± 0.49^{a}	0.12 ± 0.02^{ed}	5.78 ± 0.25^{jkl}	0.30 ± 0.02^{cdef}	0.29 ± 0.02^{cde}	23.74 ± 0.72^{f}
S11	0.31 ± 0.01^{ab}	0.33 ± 0.11^{ab}	3.60 ± 0.07^{de}	2.03 ± 0.14^{a}	12.85 ± 0.42^{fgh}	0.23 ± 0.04^{a}	7.80 ± 0.28^{bc}	0.31 ± 0.03^{bcde}	0.31 ± 0.01^{bcd}	27.72 ± 0.73^{bcd}
S12	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.28 ± 0.04^{ghi}	16.90 ± 0.28^{a}	0.12 ± 0.02^{ed}	5.65 ± 0.35^{kl}	0.27 ± 0.01^{def}	0.29 ± 0.01^{cde}	23.51 ± 0.12^{fg}
S13	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.09 ± 0.01^{h}	0.30 ± 0.01^{gh}	14.80 ± 0.14^{cd}	0.12 ± 0.02^{ed}	6.55 ± 0.14^{fgh}	0.32 ± 0.03^{bcde}	0.27 ± 0.05^{ed}	22.44 ± 0.50^{g}
S14	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.10 ± 0.01^{i}	10.90 ± 0.42^{k}	0.09 ± 0.01^{e}	6.73 ± 0.18^{efg}	0.30 ± 0.01^{cdef}	0.37 ± 0.05^{b}	18.48 ± 0.69^{h}
S15	0.21 ± 0.01^{d}	0.09 ± 0.01^{d}	1.58 ± 0.11^{g}	1.30 ± 0.03^{de}	13.30 ± 0.14^{efg}	0.11 ± 0.01^{ed}	12.43 ± 0.39^{a}	0.43 ± 0.04^{a}	0.53 ± 0.04^{a}	29.86 ± 0.59^{a}
S16	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.29 ± 0.03^{ghi}	15.83 ± 0.25^{b}	0.13 ± 0.04^{de}	6.05 ± 0.21^{hijkl}	0.29 ± 0.02^{def}	0.29 ± 0.02^{cde}	22.86 ± 0.49^{fg}
S17	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.28 ± 0.04^{ghi}	17.18 ± 0.18^{a}	0.23 ± 0.03^{a}	5.63 ± 0.32^{lk}	0.29 ± 0.02^{def}	0.31 ± 0.01^{bcd}	23.90 ± 0.57^{f}
S18	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.30 ± 0.03^{gh}	15.65 ± 0.92^{bc}	0.21 ± 0.01^{a}	6.28 ± 0.18^{ghij}	0.28 ± 0.05^{def}	0.29 ± 0.01^{cde}	23.02 ± 1.17^{fg}
S19	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.11 ± 0.01^{hi}	11.20 ± 0.28^{k}	0.09 ± 0.02^{e}	6.93 ± 0.25^{ef}	0.29 ± 0.13^{cdef}	0.32 ± 0.02^{bcd}	18.93 ± 0.39^{h}
S20	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.11 ± 0.01^{hi}	11.60 ± 0.28^{jk}	0.14 ± 0.05^{cde}	5.60 ± 0.14^{l}	0.30 ± 0.03^{cdef}	0.33 ± 0.04^{bc}	18.07 ± 0.35^{h}
Mean ±SD ($n = 20$)	0.13 ± 0.16	0.13 ± 0.15	1.65 ± 1.95	0.83 ± 0.72	13.62 ± 1.96	0.14 ± 0.05	6.87 ± 1.49	0.32 ± 0.07	0.31 ± 0.06	24.00 ± 3.80

Results are means ± standard deviation of two replicates

Values within columns followed by the same letter are not significantly different at the 95% confidence level according to the LSD test

Table 2 Saturated fatty acid composition (% of total fatty acids) of stick margarines

Sample	8:0	10:0	12:0	14:0	16:0	17:0	18:0	20:0	22:0	SFA
P1	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.21 ± 0.01^{fgh}	1.35 ± 0.21^{ef}	43.25 ± 0.64^{a}	0.19 ± 0.02^{c}	6.53 ± 0.18^{j}	0.40 ± 0.01^{a}	0.11 ± 0.01^{e}	52.05 ± 1.03^{c}
P2	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.22 ± 0.02^{fgh}	0.30 ± 0.01^{hi}	43.90 ± 1.27^{a}	0.13 ± 0.04^{d}	6.50 ± 0.21^{j}	0.39 ± 0.02^{a}	0.12 ± 0.02^{e}	51.55 ± 1.44^{c}
P3	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.43 ± 0.04^{f}	0.39 ± 0.01^{hi}	20.20 ± 0.29^{f}	0.19 ± 0.01^{c}	7.50 ± 0.28^{i}	0.21 ± 0.01^{c}	0.28 ± 0.01^{c}	29.19 ± 0.56^{kl}
P4	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.07 ± 0.03^{gh}	0.52 ± 0.04^{gh}	20.00 ± 0.71^{f}	0.20 ± 0.02^{c}	9.25 ± 0.35^{fg}	0.32 ± 0.02^{b}	0.28 ± 0.03^{c}	30.63 ± 1.08^{jk}
P5	0.83 ± 0.04^{c}	1.08 ± 0.03^{b}	13.53 ± 0.25^{c}	2.90 ± 0.14^{d}	19.35 ± 0.35^{fg}	0.18 ± 0.01^{c}	7.53 ± 0.25^{i}	0.29 ± 0.03^{b}	0.22 ± 0.02^{d}	45.90 ± 0.49^{de}
P6	1.60 ± 0.14^{a}	1.44 ± 0.06^{a}	17.80 ± 0.28^{a}	6.05 ± 0.07^{a}	22.0 ± 0.28^{e}	0.08 ± 0.02^{ef}	5.45 ± 0.21^{k}	0.20 ± 0.01^{c}	0.12 ± 0.02^{e}	54.75 ± 0.33^{b}
P7	0.47 ± 0.03^{e}	0.00 ± 0.00^{g}	0.00 ± 0.00^{h}	0.11 ± 0.01^{i}	12.00 ± 0.14^{l}	0.19 ± 0.02^{c}	8.43 ± 0.18^{h}	0.38 ± 0.01^{a}	0.29 ± 0.02^{bc}	21.66 ± 0.11^{m}
P8	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.07 ± 0.03^{gh}	0.53 ± 0.04^{gh}	25.51 ± 1.41^{d}	0.17 ± 0.03^{c}	9.63 ± 0.25^{f}	0.30 ± 0.01^{b}	0.27 ± 0.03^{c}	36.46 ± 1.12^{g}
P9	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.08 ± 0.03^{gh}	0.59 ± 0.01^{gh}	25.40 ± 0.57^{d}	0.19 ± 0.01^{c}	9.50 ± 0.14^{f}	0.32 ± 0.02^{b}	0.28 ± 0.03^{c}	36.36 ± 0.77^{g}
P10	1.08 ± 0.04^{b}	1.04 ± 0.05^{c}	15.11 ± 0.42^{b}	4.53 ± 0.39^{b}	22.80 ± 0.28^{e}	0.19 ± 0.02^{c}	10.22 ± 0.28^{e}	0.33 ± 0.04^{b}	0.08 ± 0.01^{e}	55.33 ± 0.26^{b}
P11	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.19 ± 0.01^{fgh}	0.79 ± 0.09^{g}	22.45 ± 1.06^{e}	0.18 ± 0.01^{c}	10.15 ± 0.21^{e}	0.38 ± 0.03^{a}	0.30 ± 0.01^{bc}	34.44 ± 1.44^{h}
P12	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.09 ± 0.02^{gh}	1.34 ± 0.06^{ef}	19.90 ± 0.14^{f}	0.59 ± 0.03^{a}	14.48 ± 0.33^{a}	0.20 ± 0.01^{c}	0.20 ± 0.02^{d}	36.78 ± 0.48^{g}
P13	0.83 ± 0.04^{c}	0.80 ± 0.01^{d}	11.62 ± 0.28^{d}	3.55 ± 0.25^{c}	31.93 ± 0.28^{b}	0.07 ± 0.03^{ef}	10.41 ± 0.14^{e}	0.32 ± 0.03^{b}	0.12 ± 0.02^{e}	59.66 ± 0.15^{a}
P14	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.34 ± 0.06^{fg}	1.43 ± 0.14^{e}	29.00 ± 0.42^{c}	0.48 ± 0.04^{b}	13.78 ± 0.11^{b}	0.31 ± 0.01^{b}	0.22 ± 0.02^{d}	45.52 ± 0.62^{e}
P15	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.19 ± 0.01^{fgh}	1.45 ± 0.11^{e}	29.45 ± 0.21^{c}	0.47 ± 0.03^{b}	13.33 ± 0.18^{c}	0.32 ± 0.02^{b}	0.20 ± 0.01^{d}	45.37 ± 0.52^{e}
P16	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.08 ± 0.04^{gh}	0.55 ± 0.07^{gh}	22.50 ± 0.28^{e}	0.21 ± 0.02^{c}	8.30 ± 0.14^{h}	0.23 ± 0.04^{c}	0.19 ± 0.01^{d}	32.05 ± 0.49^{ij}
P17	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.08 ± 0.03^{gh}	0.56 ± 0.06^{gh}	22.78 ± 0.32^{e}	0.08 ± 0.01^{ef}	8.39 ± 0.03^{h}	0.22 ± 0.03^{c}	0.21 ± 0.01^{d}	32.31 ± 0.35^{i}
P18	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.07 ± 0.03^{gh}	0.51 ± 0.01^{gh}	23.11 ± 0.29^{e}	0.21 ± 0.01^{c}	9.03 ± 0.18^{g}	0.33 ± 0.04^{b}	0.33 ± 0.04^{b}	33.57 ± 0.42^{hi}
P19	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.21 ± 0.02^{fgh}	1.09 ± 0.01^{f}	44.40 ± 0.75^{a}	0.06 ± 0.02^{f}	5.42 ± 0.19^{k}	0.39 ± 0.02^{a}	0.11 ± 0.01^{e}	51.65 ± 0.96^{c}
P20	0.73 ± 0.04^{d}	0.74 ± 0.04^{e}	11.35 ± 0.35^{d}	3.55 ± 0.21^{c}	22.23 ± 0.32^{e}	0.11 ± 0.01^{de}	8.02 ± 0.28^{h}	0.29 ± 0.02^{b}	0.22 ± 0.01^{d}	47.21 ± 0.25^{d}
P21	0.49 ± 0.01^{e}	0.52 ± 0.00^{f}	8.85 ± 0.07^{e}	3.48 ± 0.25^{c}	18.45 ± 0.21^{g}	0.10 ± 0.01^{def}	7.50 ± 0.21^{i}	0.30 ± 0.01^{b}	0.22 ± 0.02^{d}	39.89 ± 0.58^{f}
P22	0.00 ± 0.00^{f}	0.00 ± 0.03^{g}	0.00 ± 0.00^{h}	0.19 ± 0.01^{i}	14.55 ± 0.15^{h}	0.21 ± 0.01^{c}	12.43 ± 0.18^{d}	0.22 ± 0.02^{c}	0.41 ± 0.02^{a}	28.01 ± 0.28^{l}
Mean $\pm$ SD ($n = 22$)	0.27 ± 0.45	0.26 ± 0.45	3.66 ± 6.01	1.62 ± 1.62	25.23 ± 8.79	0.20 ± 0.14	9.17 ± 2.51	0.30 ± 0.07	0.21 ± 0.08	40.92 ± 10.32

Results are means $\pm$ standard deviation of two replicates

Values within columns followed by the same letter are not significantly different at the 95% confidence level according to the LSD test

Table 3 Unsaturated fatty acid composition (% of total fatty acids) of spreadable margarines

Sample	*Trans* 18:1	*Cis* 18:1	*Trans* 18:2	*Cis* 18:2	γ-18:3	α-18:3	*Cis* 20:1	TFA	*Cis* MUFA	*Cis* PUFA	g TFA/100 g of fat
S1	0.13 ± 0.03^{hi}	17.90 ± 0.14^{hi}	0.24 ± 0.02^{hg}	44.75 ± 0.55^{b}	0.13 ± 0.03^{ghi}	6.24 ± 0.20^{b}	0.63 ± 0.03^{d}	0.37 ± 0.05^{h}	18.53 ± 0.17^{hi}	51.12 ± 0.58^{b}	0.39 ± 0.05^{h}
S2	0.00 ± 0.00^{i}	17.22 ± 0.16^{i}	0.48 ± 0.04^{cd}	44.66 ± 0.42^{b}	0.48 ± 0.03^{b}	5.50 ± 0.14^{c}	0.82 ± 0.02^{b}	0.48 ± 0.04^{h}	18.03 ± 0.18^{i}	50.58 ± 0.59^{bcd}	0.50 ± 0.04^{h}
S3	0.00 ± 0.00^{i}	17.65 ± 0.21^{i}	0.00 ± 0.00^{j}	48.20 ± 1.56^{a}	0.17 ± 0.04^{fg}	8.24 ± 0.19^{a}	0.80 ± 0.03^{b}	0.00 ± 0.00^{h}	18.45 ± 0.24^{hi}	56.51 ± 1.79^{a}	0.00 ± 0.00^{h}
S4	0.00 ± 0.00^{i}	19.93 ± 0.25^{fg}	0.09 ± 0.01^{ij}	43.65 ± 0.64^{bc}	0.47 ± 0.05^{b}	5.13 ± 0.35^{cde}	0.73 ± 0.01^{c}	0.09 ± 0.01^{h}	20.66 ± 0.26^{fg}	49.24 ± 1.03^{bcd}	0.09 ± 0.01^{h}
S5	0.47 ± 0.02^{h}	20.44 ± 0.30^{f}	0.83 ± 0.11^{a}	43.81 ± 0.69^{bc}	0.67 ± 0.05^{a}	4.30 ± 0.14^{h}	0.88 ± 0.04^{a}	1.29 ± 0.13^{g}	21.32 ± 0.34^{f}	48.78 ± 0.88^{d}	1.35 ± 0.13^{g}
S6	10.01 ± 0.28^{b}	23.90 ± 0.57^{de}	1.14 ± 0.14^{a}	38.85 ± 0.59^{ef}	0.31 ± 0.03^{c}	4.20 ± 0.28^{h}	0.79 ± 0.02^{bc}	11.14 ± 0.42^{b}	24.69 ± 0.59^{de}	43.26 ± 0.81^{fgh}	11.64 ± 0.44^{b}
S7	10.05 ± 0.35^{b}	23.03 ± 1.45^{e}	0.34 ± 0.02^{efg}	39.53 ± 0.81^{de}	0.31 ± 0.02^{c}	4.85 ± 0.21^{defg}	0.44 ± 0.01^{e}	10.39 ± 0.37^{c}	23.47 ± 1.46^{e}	44.69 ± 1.03^{ef}	10.85 ± 0.39^{c}
S8	0.00 ± 0.00^{i}	19.33 ± 0.15^{fgh}	0.30 ± 0.01^{efg}	42.60 ± 1.98^{c}	0.16 ± 0.03^{fghi}	6.14 ± 0.37^{b}	0.11 ± 0.01^{jk}	0.30 ± 0.01^{h}	19.44 ± 0.16^{ghi}	48.93 ± 2.38^{cd}	0.31 ± 0.01^{h}
S9	0.00 ± 0.00^{i}	19.60 ± 0.28^{fg}	0.10 ± 0.02^{ij}	44.78 ± 0.93^{b}	0.15 ± 0.02^{fghi}	6.20 ± 0.46^{b}	0.37 ± 0.04^{f}	0.10 ± 0.02^{h}	19.97 ± 0.33^{fgh}	50.99 ± 0.70^{bc}	0.10 ± 0.02^{h}
S10	6.15 ± 0.21^{e}	25.43 ± 0.46^{bc}	0.39 ± 0.02^{de}	37.30 ± 0.42^{fg}	0.24 ± 0.01^{de}	4.83 ± 0.18^{defg}	0.17 ± 0.04^{ghi}	6.54 ± 0.23^{e}	25.60 ± 0.50^{cbd}	42.37 ± 0.61^{gh}	6.83 ± 0.24^{e}
S11	0.00 ± 0.00^{i}	18.46 ± 0.35^{ghi}	0.11 ± 0.01^{i}	44.33 ± 0.39^{b}	0.16 ± 0.03^{fgh}	6.40 ± 0.28^{b}	0.08 ± 0.01^{jk}	0.11 ± 0.01^{h}	18.54 ± 0.36^{hi}	50.89 ± 0.70^{bc}	0.11 ± 0.01^{h}
S12	5.43 ± 0.18^{fg}	25.25 ± 0.49^{bcd}	0.50 ± 0.04^{c}	38.24 ± 0.34^{efg}	0.28 ± 0.03^{cd}	4.42 ± 0.16^{gh}	0.18 ± 0.03^{gh}	5.93 ± 0.22^{f}	25.45 ± 0.52^{bcd}	42.94 ± 0.53^{fgh}	6.19 ± 0.23^{f}
S13	6.23 ± 0.25^{de}	25.53 ± 0.32^{bc}	0.28 ± 0.02^{fg}	37.23 ± 0.33^{fg}	0.15 ± 0.03^{ghi}	5.05 ± 0.21^{cdef}	0.14 ± 0.02^{hij}	6.50 ± 0.27^{e}	25.66 ± 0.34^{cbd}	42.43 ± 0.57^{gh}	6.79 ± 0.28^{e}
S14	5.00 ± 0.28^{g}	24.95 ± 1.34^{cd}	0.53 ± 0.03^{c}	43.35 ± 0.49^{bc}	0.20 ± 0.01^{ef}	6.03 ± 0.25^{b}	0.12 ± 0.03^{jik}	5.53 ± 0.31^{f}	25.07 ± 1.37^{cd}	49.59 ± 0.73^{bcd}	5.78 ± 0.33^{f}
S15	18.73 ± 0.46^{a}	22.73 ± 0.39^{e}	1.05 ± 0.07^{a}	23.55 ± 0.35^{h}	0.15 ± 0.04^{ghi}	0.92 ± 0.03^{i}	0.77 ± 0.04^{bc}	19.68 ± 0.58^{a}	23.50 ± 0.43^{e}	24.66 ± 0.42^{i}	20.66 ± 0.55^{a}
S16	6.63 ± 0.25^{d}	25.85 ± 0.64^{bc}	0.12 ± 0.03^{i}	36.98 ± 0.38^{g}	0.12 ± 0.02^{hi}	5.26 ± 0.08^{cd}	0.11 ± 0.01^{jk}	6.75 ± 0.28^{e}	25.96 ± 0.62^{cbd}	42.17 ± 0.34^{gh}	7.05 ± 0.29^{e}
S17	6.42 ± 0.30^{de}	25.30 ± 0.57^{bcd}	0.17 ± 0.01^{hi}	38.49 ± 0.30^{ef}	0.15 ± 0.01^{ghi}	5.16 ± 0.22^{cde}	0.13 ± 0.02^{hijk}	6.58 ± 0.31^{e}	25.43 ± 0.59^{bcd}	43.79 ± 0.53^{efgh}	6.88 ± 0.33^{e}
S18	6.48 ± 0.11^{de}	26.40 ± 0.85^{bc}	0.30 ± 0.02^{efg}	37.19 ± 0.26^{fg}	0.29 ± 0.02^{cd}	4.55 ± 0.35^{fgh}	0.22 ± 0.04^{g}	6.77 ± 0.11^{e}	26.65 ± 0.88^{ab}	42.03 ± 0.63^{h}	7.07 ± 0.12^{e}
S19	7.44 ± 0.16^{c}	26.45 ± 1.20^{b}	0.50 ± 0.02^{c}	38.95 ± 0.64^{de}	0.11 ± 0.01^{i}	5.14 ± 0.02^{cde}	0.07 ± 0.03^{k}	7.93 ± 0.18^{d}	26.52 ± 1.23^{cb}	44.20 ± 0.83^{efg}	8.29 ± 0.19^{d}
S20	5.53 ± 0.18^{f}	28.00 ± 1.41^{a}	0.35 ± 0.01^{ef}	40.56 ± 0.77^{d}	0.21 ± 0.03^{ef}	4.70 ± 0.28^{efgh}	0.11 ± 0.01^{jk}	5.88 ± 0.19^{f}	28.15 ± 1.41^{a}	45.37 ± 1.04^{e}	6.14 ± 0.20^{f}
Mean ± SD ($n = 20$)	4.73 ± 4.79	22.67 ± 3.48	0.39 ± 0.31	40.36 ± 5.15	0.25 ± 0.14	5.16 ± 1.37	0.37 ± 0.31	5.12 ± 4.98	23.05 ± 3.32	45.73 ± 6.40	5.35 ± 5.21

Results are means ± standard deviation of two replicates

Values within columns followed by the same letter are not significantly different at the 95% confidence level according to the LSD test

Table 4 Unsaturated fatty acid composition (% of total fatty acids) of stick margarines

Sample	*Trans* 18:1	*Cis* 18:1	*Trans* 18:2	*Cis* 18:2	γ-18:3	α-18:3	*Cis* 20:1	TFA	*Cis* MUFA	*Cis* PUFA	g TFA/100 g of fat
P1	1.45 ± 0.07^{i}	30.27 ± 0.19^{d}	0.32 ± 0.01^{hij}	13.58 ± 0.18^{l}	0.10 ± 0.01^{efg}	1.07 ± 0.11^{j}	0.60 ± 0.02^{a}	1.77 ± 0.08^{i}	30.94 ± 0.17^{cd}	14.74 ± 0.30^{l}	1.84 ± 0.08^{i}
P2	1.50 ± 0.14^{i}	30.23 ± 0.07^{de}	0.30 ± 0.01^{hijk}	14.15 ± 0.21^{k}	0.11 ± 0.01^{defg}	1.08 ± 0.11^{j}	0.62 ± 0.01^{a}	1.85 ± 0.15^{i}	30.64 ± 0.40^{cd}	15.44 ± 0.32^{l}	1.88 ± 0.16^{i}
P3	11.55 ± 0.42^{d}	23.14 ± 0.49^{j}	1.91 ± 0.02^{c}	29.81 ± 0.29^{a}	0.19 ± 0.02^{ab}	1.19 ± 0.05^{ij}	0.20 ± 0.01^{de}	13.46 ± 0.44^{c}	23.35 ± 0.49^{i}	31.24 ± 0.36^{c}	14.07 ± 0.46^{c}
P4	10.67 ± 0.47^{e}	30.54 ± 0.75^{cd}	1.75 ± 0.13^{d}	22.05 ± 0.35^{def}	0.21 ± 0.01^{a}	1.40 ± 0.01^{i}	0.19 ± 0.01^{de}	12.41 ± 0.61^{d}	30.74 ± 0.76^{d}	23.66 ± 0.38^{hi}	12.97 ± 0.64^{d}
P5	0.20 ± 0.14^{j}	17.57 ± 0.30^{jk}	0.21 ± 0.01^{ijklm}	29.78 ± 0.18^{a}	0.12 ± 0.01^{de}	4.08 ± 0.25^{b}	0.00 ± 0.00^{k}	0.41 ± 0.15^{j}	17.64 ± 0.30^{jk}	33.97 ± 0.44^{a}	0.43 ± 0.16^{j}
P6	0.14 ± 0.04^{j}	17.30 ± 0.26^{jk}	0.17 ± 0.03^{klm}	22.55 ± 0.35^{d}	0.07 ± 0.03^{g}	2.28 ± 0.11^{gh}	0.07 ± 0.02^{j}	0.32 ± 0.07^{j}	17.36 ± 0.28^{jk}	24.90 ± 0.49^{efg}	0.33 ± 0.08^{j}
P7	12.18 ± 0.33^{c}	36.83 ± 0.78^{a}	1.70 ± 0.07^{d}	22.54 ± 0.33^{d}	0.14 ± 0.01^{cd}	2.56 ± 0.20^{ef}	0.13 ± 0.02^{g}	13.88 ± 0.40^{c}	36.94 ± 0.79^{a}	25.25 ± 0.54^{e}	14.50 ± 0.41^{c}
P8	7.71 ± 0.33^{g}	29.07 ± 0.61^{ef}	0.90 ± 0.03^{f}	20.30 ± 0.14^{h}	0.19 ± 0.03^{ab}	2.33 ± 0.18^{fgh}	0.17 ± 0.03^{ef}	8.65 ± 0.36^{g}	29.25 ± 0.64^{ef}	22.82 ± 0.35^{i}	8.99 ± 0.38^{g}
P9	7.94 ± 0.20^{g}	28.51 ± 0.47^{f}	0.90 ± 0.01^{f}	21.53 ± 0.32^{efg}	0.20 ± 0.03^{ab}	2.50 ± 0.14^{fg}	0.19 ± 0.01^{de}	8.85 ± 0.21^{g}	28.70 ± 0.49^{f}	24.23 ± 0.49^{fgh}	9.24 ± 0.22^{g}
P10	0.12 ± 0.03^{j}	16.54 ± 0.53^{k}	0.12 ± 0.01^{lm}	23.33 ± 0.33^{c}	0.07 ± 0.02^{fg}	2.92 ± 0.16^{d}	0.17 ± 0.01^{ef}	0.24 ± 0.04^{j}	16.74 ± 0.54^{k}	26.34 ± 0.50^{d}	0.25 ± 0.04^{j}
P11	9.63 ± 0.28^{f}	28.00 ± 0.85^{fg}	0.42 ± 0.05^{h}	22.13 ± 0.07^{de}	0.11 ± 0.01^{def}	2.89 ± 0.17^{d}	0.11 ± 0.0^{ghi}	10.04 ± 0.33^{f}	28.11 ± 0.83^{fg}	25.09 ± 0.86^{ef}	10.49 ± 0.34^{f}
P12	20.61 ± 0.42^{b}	26.22 ± 0.69^{h}	2.24 ± 0.16^{b}	11.05 ± 0.21^{n}	0.11 ± 0.01^{def}	0.59 ± 0.03^{k}	0.21 ± 0.01^{d}	22.84 ± 0.58^{b}	26.43 ± 0.70^{h}	11.64 ± 0.30^{n}	23.87 ± 0.61^{b}
P13	0.12 ± 0.01^{j}	18.07 ± 0.36^{j}	0.19 ± 0.01^{jklm}	17.37 ± 0.23^{i}	0.00 ± 0.00^{h}	2.21 ± 0.07^{h}	0.00 ± 0.00^{k}	0.31 ± 0.02^{j}	18.07 ± 0.36^{j}	19.58 ± 0.30^{j}	0.32 ± 0.02^{j}
P14	5.71 ± 0.31^{h}	32.13 ± 1.26^{b}	1.15 ± 0.05^{e}	12.10 ± 0.29^{m}	0.20 ± 0.01^{ab}	0.54 ± 0.02^{kl}	0.39 ± 0.02^{b}	6.79 ± 0.36^{h}	32.52 ± 1.27^{b}	12.84 ± 0.32^{m}	7.16 ± 0.38^{h}
P15	5.61 ± 0.17^{h}	31.70 ± 1.00^{bc}	1.17 ± 0.10^{e}	12.11 ± 0.14^{m}	0.13 ± 0.01^{de}	0.58 ± 0.03^{k}	0.36 ± 0.01^{b}	6.78 ± 0.27^{h}	32.06 ± 1.01^{bc}	12.74 ± 0.18^{m}	7.08 ± 0.28^{h}
P16	10.15 ± 0.26^{ef}	31.42 ± 0.30^{bcd}	0.69 ± 0.01^{g}	21.14 ± 0.37^{g}	0.10 ± 0.01^{efg}	2.79 ± 0.03^{de}	0.12 ± 0.01^{gh}	10.85 ± 0.28^{e}	31.54 ± 0.32^{bcd}	24.02 ± 0.41^{hg}	11.32 ± 0.29^{e}
P17	10.07 ± 0.23^{ef}	30.63 ± 0.35^{cd}	0.62 ± 0.03^{g}	21.44 ± 0.20^{fg}	0.13 ± 0.02^{de}	2.84 ± 0.07^{d}	0.10 ± 0.01^{hij}	10.75 ± 0.25^{ef}	30.72 ± 0.35^{d}	24.41 ± 0.29^{efgh}	11.17 ± 0.27^{ef}
P18	12.78 ± 0.46^{c}	26.85 ± 0.64^{gh}	0.62 ± 0.03^{g}	21.20 ± 0.22^{g}	0.22 ± 0.01^{a}	2.47 ± 0.09^{fgh}	0.14 ± 0.02^{fg}	13.40 ± 0.49^{c}	26.99 ± 0.66^{gh}	23.88 ± 0.33^{h}	14.00 ± 0.51^{c}
P19	0.11 ± 0.02^{j}	30.31 ± 0.28^{d}	0.34 ± 0.01^{hi}	15.50 ± 0.28^{j}	0.13 ± 0.02^{de}	1.30 ± 0.01^{ij}	0.08 ± 0.01^{ij}	0.45 ± 0.03^{j}	30.39 ± 0.29^{de}	16.93 ± 0.32^{k}	0.47 ± 0.03^{j}
P20	0.23 ± 0.02^{j}	16.77 ± 0.31^{k}	0.10 ± 0.07^{m}	29.08 ± 0.47^{b}	0.17 ± 0.02^{bc}	3.60 ± 0.28^{c}	0.12 ± 0.03^{gh}	0.33 ± 0.09^{j}	16.89 ± 0.34^{jk}	32.84 ± 0.77^{b}	0.34 ± 0.09^{j}
P21	0.00 ± 0.00^{j}	23.75 ± 0.35^{i}	0.24 ± 0.01^{ijkl}	28.73 ± 0.33^{b}	0.11 ± 0.02^{defg}	4.70 ± 0.14^{a}	0.29 ± 0.02^{c}	0.25 ± 0.00^{j}	24.05 ± 0.37^{i}	33.54 ± 0.49^{ab}	0.25 ± 0.00^{j}
P22	34.30 ± 0.71^{a}	26.50 ± 0.14^{h}	4.60 ± 0.17^{a}	4.13 ± 0.11^{o}	0.00 ± 0.00^{h}	0.29 ± 0.02^{l}	0.00 ± 0.00^{k}	38.90 ± 0.88^{a}	26.50 ± 0.14^{h}	4.41 ± 0.13^{o}	40.65 ± 0.92^{a}
Mean ± SD ($n = 22$)	7.40 ± 8.20	26.48 ± 5.82	0.94 ± 1.03	19.81 ± 6.65	0.13 ± 0.06	2.10 ± 1.19	0.19 ± 0.17	8.34 ± 9.25	26.64 ± 5.89	22.04 ± 7.66	8.71 ± 9.56

Results are means ± standard deviation of two replicates

Values within columns followed by the same letter are not significantly different at the 95% confidence level according to the LSD test

spreadable margarine samples, but there is a more notable difference in total *cis*-MUFA and *cis*-PUFA among stick margarines as indicated by the LSD test ($P < 0.05$).

The major *trans* fatty acid observed in most of the margarines is elaidic acid (*trans*-18:1) (Figs. 3, 4). Its content varied for spreadable margarines from 0.00 to 18.73% and for stick margarines from 0.00 to 34.30%. *Trans* linoleic fatty acid (*trans*-18:2) was also detected in all samples, except in sample S3 (Table 3), but in general at lower concentration. The content of *trans*-18:2 ranged for spreadable margarines from 0.00 to 1.14% and for stick margarines from 0.10 to 4.60%, as shown in Figs. 3 and 4, respectively.

The results from Figs. 3 and 4 reveal a wide range in *trans* fatty acid content (TFA) in the different samples. It is worth mentioning that in the present work, the total TFA content only considered *trans*-18:1 and *trans*-18:2.

From the data shown in Tables 3 and 4, significant differences ($P < 0.05$) were observed for total TFA of most of samples. The 79% of total margarine samples had a TFA content ranging from 0.30 to 13.88% (as % of total fatty acids). This tables show a considerable high TFA content in some samples (S15, P12, P22) which indicates the use of large amounts of partially hydrogenated fats as raw materials in the production of margarines as reported by Basol and Tasan [8]. It is also shown in these tables that fourteen margarines (33% of samples) have less than 0.48% of TFA content with no significant differences ($P < 0.05$) among these samples. Also, 25 margarines (60% of samples) have a TFA content between 1.3 and 13.9% (Tables 3, 4). Margarines with less than 1 g/100 g of fat can be considered as "free from *trans* fatty acids" [6]. According to the last column of Tables 3 and 4, 33% of margarines samples can be considered as free from TFA, and only the 40% of the samples comply with the Danish Legislation relating to the level of industrially produced *trans* fatty acids in food.

Comparing data of Table 4 with those of Table 2, it can be seen that in some samples of stick margarines as for instance P13 and P19, the low TFA content is associated with an increased of SFA mainly 12:0 and 16:0. This indicates that oils of coconut, palm or palm kernel were probably used in margarine production in substitution of partially hydrogenated oils; coconut oil and palm kernel oil are the major sources of lauric acid and palm oil is the major source of palmitic acid [11]. Practices like that are common because this strategy leads to decreased TFA content and maintain the hardness in margarines.

Palm oil is a suitable alternative for partially hydrogenated vegetable oils used in the food industry. Replacement of TFA with SFA decreased the total-cholesterol to HDL-cholesterol ratio, which is a more specific marker of coronary artery disease (CAD) than is LDL-cholesterol [1]. However, unsaturated vegetable oils produce a higher decreased in total-cholesterol to HDL-cholesterol ratio than do either palm oil or hydrogenated oils. For this reason unsaturated vegetable oils should be preferred and have to be consumed in large proportion in order to keep SFA + TFA in one-third of total dietary fatty acid intake [12].

Table 5 shows the sum of cholesterol-lowering fatty acids (CLFA) to the sum of cholesterol-raising fatty acids (CRFA), and omega-6 to omega-3 ratios as indicators of the nutritional quality of both spreadable and stick margarine samples [13]. As can be seen in this table, although there are significant differences ($P < 0.05$) among the samples of spreadable margarine, the nutritional ratios of fatty acids are very similar among them, with the exception of sample S15. This situation is different for stick margarines, where a more notorious difference of the nutritional ratios among samples was obtained.

CLFA represents all cholesterol-lowering *cis*-unsaturated fatty acids: *cis*-oleic acid isomers, linoleic and α-linolenic acid. CRFA represents all the cholesterol-raising fatty acids: 12:0, 14:0, 16:0 and TFA. Its ratio CLFA/CRFA is a useful index for comparing the nutritional quality of different dietary fats. It is recommended that this ratio should be as high as possible [14]. As can be seen in Table 5, for spreadable margarines, this ratio ranged from 2.20 to 3.10, except for sample S15 (whose value is 0.95); while for stick margarines the ratio ranged from 0.46 to 1.73. These results indicate that spreadable margarines have a more favorable fatty acid profile than stick margarines and therefore could minimize cardiovascular disease risk.

On the other hand, the ratio between omega-6 to omega-3 is represented by linoleic acid (*cis*-18:2, ω-6) and α-linolenic acid (*cis*-18:3, ω-3). These fatty acids are important components of a more healthyl diet, because it has been demonstrated that they are cholesterol-lowering fatty acids, but their benefits depend to some degree on the consumption of an appropriate balance of these two fatty acids [14]. The recommended relationship should be 5–10 to 1 between ω-6 and ω-3 fatty acids, respectively [3]; but a value close to 1:1 would be more desirable for protection against degenerative pathologies [15]. For this reason, it is important to know this ratio, which is presented in Table 5. For spreadable margarines the proportion of ω-6 to ω-3 varied between 5.85 and 10.14, except for sample S15 (whose value is 25.58); while for stick margarines it ranged between 6.11 and 23.95. As can be observed from Table 5, 18 out of 20 samples of spreadable margarines which correspond to 90% of all samples have a good balance in the dietary levels of ω-6 to ω-3 fatty acids (5–10:1), while for stick margarines only 13 out of 22 samples, which

Table 5 Indicators of nutritional quality of spreadable and stick margarines as sum of cholesterol-lowering to the sum of cholesterol-raising fatty acids and omega-6 to omega-3 ratios

Spreadable margarines			Stick margarines		
Sample	CLFA/CRFA Ratio	$\omega 6/\omega 3$ Ratio	Sample	CLFA/CRFA Ratio	$\omega 6/\omega 3$ Ratio
S1	2.44 ± 0.07^{cd}	7.17 ± 0.17^{ghi}	P1	0.83 ± 0.02^{k}	12.75 ± 1.18^{gh}
S2	2.32 ± 0.05^{ed}	8.11 ± 0.13^{def}	P2	0.85 ± 0.01^{k}	13.26 ± 1.19^{g}
S3	3.09 ± 0.21^{a}	5.85 ± 0.05^{j}	P3	1.27 ± 0.01^{cd}	23.95 ± 0.72^{a}
S4	2.50 ± 0.02^{c}	8.55 ± 0.45^{d}	P4	1.26 ± 0.02^{d}	15.75 ± 0.09^{e}
S5	2.44 ± 0.03^{cd}	10.14 ± 0.17^{b}	P5	1.11 ± 0.02^{g}	7.32 ± 0.40^{m}
S6	2.20 ± 0.03^{f}	9.24 ± 0.50^{c}	P6	0.77 ± 0.01^{l}	9.92 ± 0.31^{i}
S7	2.31 ± 0.02^{ef}	8.15 ± 0.19^{def}	P7	1.73 ± 0.01^{a}	8.82 ± 0.55^{ij}
S8	2.33 ± 0.05^{ed}	6.91 ± 0.10^{i}	P8	1.15 ± 0.04^{f}	8.75 ± 0.60^{jk}
S9	2.70 ± 0.01^{b}	7.25 ± 0.39^{ghi}	P9	1.16 ± 0.00^{ef}	8.62 ± 0.36^{jkl}
S10	2.23 ± 0.04^{ef}	7.73 ± 0.20^{efg}	P10	0.78 ± 0.02^{l}	8.08 ± 0.34^{jklm}
S11	2.49 ± 0.03^{c}	6.93 ± 0.25^{i}	P11	1.19 ± 0.01^{e}	7.66 ± 0.22^{klm}
S12	2.31 ± 0.01^{ef}	8.67 ± 0.24^{cd}	P12	0.63 ± 0.00^{m}	18.74 ± 0.54^{d}
S13	2.34 ± 0.03^{ed}	7.38 ± 0.25^{ghi}	P13	0.62 ± 0.01^{m}	7.86 ± 0.15^{jklm}
S14	3.10 ± 0.04^{a}	7.20 ± 0.21^{ghi}	P14	0.85 ± 0.01^{k}	22.30 ± 0.19^{b}
S15	0.95 ± 0.01^{g}	25.58 ± 0.41^{a}	P15	0.84 ± 0.01^{k}	20.88 ± 0.77^{c}
S16	2.29 ± 0.03^{ef}	7.00 ± 0.05^{hi}	P16	1.29 ± 0.01^{c}	7.57 ± 0.06^{m}
S17	2.26 ± 0.03^{ef}	7.47 ± 0.26^{ghi}	P17	1.28 ± 0.00^{cd}	7.55 ± 0.12^{m}
S18	2.29 ± 0.05^{ef}	8.20 ± 0.58^{de}	P18	1.08 ± 0.00^{h}	8.60 ± 0.23^{jkl}
S19	2.63 ± 0.02^{b}	7.58 ± 0.17^{fgh}	P19	0.90 ± 0.01^{j}	11.92 ± 0.09^{h}
S20	3.05 ± 0.03^{a}	8.62 ± 0.35^{d}	P20	1.04 ± 0.03^{i}	8.1 ± 0.51^{jklm}
			P21	1.42 ± 0.00^{b}	6.11 ± 0.11^{n}
			P22	0.46 ± 0.00^{n}	14.50 ± 0.71^{f}
Mean $\pm$ SD ($n = 20$)	2.41 ± 0.44	8.69 ± 4.09	Mean $\pm$ SD ($n = 22$)	1.02 ± 0.30	11.77 ± 5.37
Range	0.95–3.10	5.85–25.58	Range	0.46–1.73	6.11–23.95

Results are means $\pm$ standard deviation of two replicates

Values within columns followed by the same letter are not significantly different at the 95% confidence level according to the LSD test

correspond to 59% of all samples have a good ω-6 to ω-3 balance.

In this context, oils with a high content of *cis*-MUFA rather than oils with a high *cis*-PUFA or SFA should be considered as alternatives to partially hydrogenated oils in margarine manufacture [16], because the former oils are a healthier alternative to the latter and do not modify the ω-6/ω-3 ratio.

Thus, samples with the fatty acid profile most desirable are those with low TFA content (less than 1 g/100 g of fat), high content of *cis*-MUFA (primarily as oleic acid), low SFA content, an appropriate proportion of ω-6 to ω-3 and CLFA to CRFA. From the analyzed margarines, only five samples (S3, S4, S9, S11, P21) are close to all these requirements.

For comparison reasons, Table 6 shows the fatty acid profile of margarines that has been reported in some countries compared with the ones obtain in the present work. These data shows that margarines from different countries have different fatty acid profiles. In countries like New Zealand [17], Costa Rica [7] and Pakistan [4] some unusual fatty acids in vegetable oils as 15:0 and 17:0 were found in margarines [4]. This last fatty acid (17:0) was also found in some margarines marketed in Mexico (present work), it could be due to the incorporation of animal fats in margarine production since almost all animal fats contain 17:0 fatty acid [18]. Table 6 also shows that in Mexico as well as in Turkey [19, 20], Pakistan [4, 21], Costa Rica [7] and New Zealand [17] is common to use palm or coconut oil in margarines indicated by the high content of 16:0 found, with values as high as 44% of total fatty acids. Only in countries like Spain [22] and Canada [14] the content of 16:0 is less than 18.5%. In regard to the *trans* fatty acids represented mainly by *trans*-18:1, margarines from the different countries can have either a very low (0%) or a very high (34.3%) content of this fatty acid. Margarines marketed in Mexico have a maximum *trans*-18:1 content comparable with the margarines from Pakistan [4], Canada

Table 6 Fatty acid composition of margarines in different countries (% of total fatty acids)

Fatty acid	Spain 2000 [22]	Turkey 2002 [19]	Pakistan 2006 [21]	Turkey 2006 [20]	Canada 2007 [14]	Costa Rica 2007 [7]	New Zealand 2008 [17]	Pakistan 2008 [4]	Mexico 2011 Present work
6:0	–	–	–	–	–	–	ND-0.7	–	–
8:0	0.13–1.04	tr–1.1	–	–	–	0.00	ND-0.7	0.2–0.7	0.00–1.60
10:0	0.15–0.86	tr–1.3	–	–	–	0.00	ND-1.8	0.1–0.9	0.00–1.40
12:0	0.10–7.84	0.2–16.9	ND-14.0	0.1–12.7	0.0–4.5	0.02–0.48	ND-2.3	0.1–11.2	0.00–17.80
14:0	0.16–2.99	0.5–5.8	ND-3.3	0.1–4.8	0.1–1.7	0.11–0.78	0.3–7.3	0.2–8.7	0.10–6.05
c-14:1	–	–	–	–	–	0.00	ND-0.4	–	–
15:0	–	–	–	–	–	0.01-0.03	ND-0.8	0.1–1.7	–
16:0	7.87–18.45	11.8–31.3	24.4–40.02	7.3–34.3	5.1–15.3	11.7–27.17	11.3–25.3	16.9–33.8	10.90–44.40
c-16:1	0.07–0.10	–	–	–	–	0.09–0.11	ND-1.4	0.1–2.3	–
17:0	–	–	–	–	–	0.09–0.10	ND-0.2	0.1–2.7	0.06–0.59
c-17:1	–	–	–	–	–	0.00	–	–	–
18:0	4.76–9.32	5.6–9.4	6.2–12.83	3.7–7.6	2.3–9.4	5.04–8.06	5.0–10.7	6.1–19.0	5.42–14.48
19:0	–	–	–	–	–	0.13–0.18	–	–	–
t-18:1	0.15–20.21	7.7–31.9	2.45–19.10	0.4–8.5	0.1–38.4	6.37–12.75	1.6–6.9	2.2–34.7	0.00–34.30
c-18:1	17.46–29.05	17.1–41.2	21.9–35.8	21.0–49.5	19.7–59.2	22.12–28.87	31.3–50.1	4.2–34.8	16.54–36.83
t-18:2	0.24–0.99	0.8–5.5	ND-2.0	–	0.0–1.4	1.15–4.5	ND-0.5	0.1–1.5	0.00–4.60
c-18:2	25.24–49.15	9.2–37.5	7.0–21.0	1.2–38.8	5.3–46.6	16.33–41.96	6.3–37.6	0.1–19.1	4.13–48.20
c-18:3γ	–	–	–	–	–	0.00	–	–	0.00-0.67
c-18:3α	0.24–4.19	0.3–4.3	0.5–1.45	0.4-4.0	0.3–8.8	1.13–4.57	1.9–7.4	0.2–2.0	0.29–8.24
t-18:3	0.06–0.47	–	–	–	0.0–0.5	–	ND-0.9	–	–
20:0	0.26–0.42	–	–	–	–	0.26–0.29	0.3–0.5	0.1–0.3	0.20–0.43
21:0	–	–	–	–	–	0.00–0.04	–	–	–
c-20:1	0.09–0.16	–	–	–	–	0.10–0.16	ND-0.8	0.1–0.7	0.00–0.88
c-20:2	–	–	–	–	–	0.00–0.02	–	–	–
c-20:5	–	–	–	–	–	0.05–0.07	–	–	–
22:0	0.12–0.62	–	–	–	–	0.12–0.24	ND-0.4	0.1–0.8	0.08–0.53
c-22:1	–	–	–	–	–	–	–	0.1–1.5	–
c-22:2	–	–	–	–	–	0.00	–	–	–
23:0	–	–	–	–	–	0.00–0.02	–	0.1	–
24:0	–	–	–	–	–	–	–	–	–
Others	–	0.1–1.1	1.0–2.66	0.2–1.7	–	–	–	–	0.41–3.02

ND not detected (detection limit 0.1%); *tr* trace; "–", not reported; *others* fatty acids that could not be identified

[14], and Turkey [19]. In contrast, margarines from New Zealand [17] show the lowest *trans*-18:1 fatty acid content with a maximum of 6.9%.

Conclusions

The fatty acid profiles presented in this work show that among the currently top-selling margarines available in Mexico City, only 5 samples out of 42 (12% of total samples) have desirable fatty acid profiles, that is, low TFA content, high content of *cis*-MUFA, low SFA content, and appropriate proportions of ω-6 to ω-3 and CLFA to CRFA. Although 33% of the total margarine samples have a low TFA content (less than 1 g/100 g of fat), they have low nutritional quality because of their high content of SFA and a high ratio of ω-6 to ω-3. This information should alert consumers to select margarines with better nutritional quality.

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