Article

Margarines and fast-food French fries: low content of trans fatty acids

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Abbreviations: TFA: Trans fatty acids; SFA: Saturated fatty acids; PUFA: Polyunsaturated fatty acids; MUFA: Monounsaturated fatty acids

ABSTRACT: The lipid fraction of margarines and fast-food French-fries, two types of foods traditionally high in trans fatty acids (TFA), is assessed. TFA data reported worldwide during the last 20 years have been gathered, and show that some countries still report high TFA amounts in these products. The content of TFA was analysed in margarines (2 store and 4 premium brands) and French-fries from fast-food restaurants (5 chains). Margarines showed mean values of 0.68% and 0.43% (gTFA/100g fat) for store and premium brands, respectively. French-fries values ranged from 0.49% to 0.89%. All samples were lower than the 2% set by some European countries as the maximum legal content of TFA in fats, and contained less than 0.5g/serving, so they could also be considered "trans free products". This work confirmed that the presence of TFA is not significant in the two analysed products and contributes to update food composition tables, key tools for epidemiological and nutrition studies.

Keywords: food composition tables; lipid profile; trans fat; fast food; spreads

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1. INTRODUCTION

From 1990 to 2010 globally, the estimated proportional CHD (coronary heart disease) mortality increased by 4% for higher TFA (trans fatty acids) consumption, driven basically by increases in low and middle-income countries [1]. As a reaction to the evidences showing a detrimental effect on health caused by consumption of TFA [2], several countries and organizations established recommendations, limitations and bans in order to control TFA levels on food [3]. It has been stated that removing these fats from the food supply is considered an optimum public health intervention for reducing CVD risk and improving nutritional quality of diets [4]. Furthermore, these policies have resulted, for instance, in lower concentrations of trans fat in Canadian women's breast milk samples [5] and in lower plasma TFA concentrations in persons with type 2 diabetes [6].

The first organisation to suggest a guideline to regulate TFA content in food was the FDA in 1999. The proposal established the compulsory inclusion of the amount of TFA in the label of those products in which the content of TFA were higher than 0.5 or more grams (g) per serving. In 2003, Denmark was the first country that introduced a legislation regarding the use of TFA in industrial processed food, limiting the permitted level of TFA to 2g of TFA per 100g of fats or oil in the product as sold to the final consumer [7]. This initiative led to a decrease in their CVD mortality rates [8]. On the other hand, in 2009, WHO published a report in which the recommended intake for TFA was set at less than 1% of total energy intake (E) [9]. However, recently this value to 0.5% E has been decreased based on the impact of these FA on CHD mortality data [1].

The main reason for food industry to use TFA-containing fats is the interesting characteristics that these type of fatty acids present: solid edible fat at room temperature, enhanced stability, reduced oxidation susceptibility and improved organoleptic properties [10].

Since the above mentioned legislative measures were taken, different strategies to replace TFA have been studied: new processes, treatments and reformulations such as the modification of the hydrogenation process, interesterification, fractionation or combination of several technologies [11, 12].

In the past few years many efforts were made to reduce the presence and dietary intakes of TFA in foods traditionally rich in TFA such as bakery products, snacks, margarines, fats, fast foods with mixed success. This is the case of elegant works carried out in Portugal [13], Pakistan [14], Brazil [15], UK [16], Austria [17], Costa Rica [18], Estonia [19], New Zealand [20], Switzerland [21], Serbia [22] or Lebanon [23]. Our research group conducted a study in bakery products commercialized in Spain and also found very low TFA in these products [24]. Regarding fast food, some studies carried out a few years ago reported a high variability among products [25] and even between international fast food companies outlets located in different countries [26]. However, other studies carried out during the last years showed a significant reduction in the amounts of TFA. Thus, monitoring TFA in foods, and having updated databases, becomes crucial to verify that the progress in the reduction of their presence in the diet continues [3, 27, 28] and that this occurs across all food sectors and countries.

The objective of this work was to test the TFA amounts of different brands of margarines and French fries sold by different well known fast food chains. These two food items had traditionally high amounts of these fatty acids [29, 30]. A contribution to update food composition tables was also aimed in this paper. This second objective was in agreement with the proposal of the Spanish Federation of Scientific Societies of Food, Nutrition and Dietetics (FESNAD), who suggest including TFA content in food labels [29].

2. MATERIAL AND METHODS

2.1 Materials

Fatty acid methyl esters (individual standards and mixtures of isomers) were purchased from Sigma–Aldrich Chemical® (St. Louis, MO, USA), except for brassidic acid, from Nu-Check Prep. Inc. Boron trifluoride/methanol was obtained from Merck® (Whitehouse Station, NJ, USA). Methanol, chloroform, petroleum ether and potassium chloride were from Panreac® (Barcelona, Spain).

2.2 Sampling

Margarines: 18 samples from 6 different brands of well-known and widely distributed margarines were analysed (3 of them were three-quarter-fat margarine and 3 of them half-fat margarine, according to Council Regulation, EC, 1994) [31]. Among the ¾ Margarines, two of them were store brands (brand 1 and 2) and one of them premium brand (brand 3). All half-fat margarines were premium brands. All samples were purchased in regular supermarkets located in Pamplona (Navarra, Spain) and immediately transported to the laboratory, where they were kept in the fridge (4ºC) until analyses. For each brand, 3 samples (250g each) from different lots were collected in 3 different days (n=18).

The following fat sources were declared in the labels of margarines: Brand 1 (sunflower, rapeseed and palm oil), Brand 2 (palm and sunflower oil), Brand 3 (sunflower, palm and linseed oil), Brand 4 (sunflower, olive, palm and linseed oil), Brand 5 (sunflower, palm and linseed oil), Brand 6 (no ingredients reported). Energy value (Kcal /100g) declared for these products were: 544, 550, 540, 360, 320 and 316, respectively. Analyses in each batch were performed in triplicate.

French fries: 15 samples of French fries were purchased, in the same conditions as customers do, in fast food restaurants belonging to well-known international chains (these brands would cover approximately a 70% of the Spanish fast food market share). Restaurants were located in Pamplona (Navarra, Spain). After purchase they were immediately transported to the laboratory, homogenised and frozen (-20ºC) until further analyses. For each of the different 5 brands studied (food outlets), 3 batches (1 kg each) were collected in 3 different days (n=15). Serving sizes (small portions) reported by the companies for these products were: 100g, 90g, 103g, 80g and 215g for brand 1, 2, 3, 4 and 5, respectively. Energy value (Kcal /100g) declared for these products were: 323, 258, 223, 290 and 258, respectively. Analyses in each batch were performed in triplicate.

2.3 Analysis of samples

The official method 960.39 of the AOAC [32] was applied for quantitative fat extraction (Soxhlet with Petroleum ether as solvent) (Büchi model B-811 Extraction System). In order to carry out qualitative fat extraction for the further analysis of the lipid profile, the method described by Folch *et al*. [33] was followed.

Fatty acid profile was determined in the lipid extracts by gas chromatography [24]. Boron trifluoride/methanol was used for the preparation of fatty acid methyl esters (FAME) [34]. A Perkin-Elmer Autosystem XL gas chromatograph fitted with a capillary column SP™-2560 (100 m x 0.25 mm x 0.2 µm – Sigma Aldrich) and flame ionization detection was used. The temperature of the injection port was 250º C and of the detector was 260º C. The oven temperature was programmed at 175º C for 10 min and increased to 200º C at a rate of 10º C/min, then increased to 220º C at a rate of 4º C/min, which was kept for 15 min. The carrier gas was hydrogen, and the pressure was 20.5 psi. Split flow was 120 cm/s. The identification of the fatty acid methyl esters was done by comparison of the retention times of the peaks in the sample with those of standard pure compounds. Individual methylated standards were used for all fatty acids except for the following mixtures of isomers: linoleic acid isomers (mixture 47791), linolenic acid isomers (mixture 47792), mixture 20:1, 20:2, 20:4 and 20:5 (mixture 18912), all from Sigma-Aldrich (St. Louis, MO, USA). The order of elution in the case of mixtures of isomers (linoleic and linolenic acid cis/trans isomers) was also taken into account [Sigmaldrich.com – FAME Application guide, 35, 36]. Spiking the sample with each individual standard (or mixture of standards in the case of linoleic or linolenic acid isomers

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and the C20 mixture) was finally used for confirming the identification. The quantification of individual fatty acids was based on the internal standard method, using heptadecanoic acid methyl ester (Sigma-Aldrich, St. Louis, MO, USA). Elaidic acid (9t-18:1) eluted very closely to other 18:1 trans isomers (possibly t6 to t12), which were all located earlier than oleic acid (9c-18:1). Quantification for all these 18:1 trans isomers was done as the sum of all of them. Chromatograms obtained for margarine and French fries are shown as supplementary material (Figures S1 and S2, respectively).

3. STATISTICAL ANALYSIS

Statistical analyses were performed with software Stata IC 12 (Copyright 1985-2011 StataCorp LPm, Revision 2014). Mean and standard deviation of data are reported in the tables. Median, 25 and 75 percentiles are shown in the figures. One-way ANOVA test (Analysis of variance) followed by a post-estimation test (Bonferroni) were used to determine significant differences among the different brands. Significance level of $p \leq 0.05$ was used for all evaluations. Pearson correlation test was applied for the evaluation of the association between PUFA and TFA content in French fries.

4. RESULTS AND DISCUSSION

Information on trans-fat intake in several countries of the WHO European Region is still very limited, and still a large number of products containing high levels of trans fat are available on the market [4]. A display of the TFA content of foods in the Nutrition Facts table is not mandatory according to current legislation in Europe, and therefore consumers and health-related professionals are not provided with information on levels of TFA in products. Thus, this work reports updated lipid composition data of two products included within the list of foodstuffs susceptible to contain TFA [30].

Table 1 gathers lipid composition data of margarines and French fries reported by different research groups during the last decades. Regarding margarines, although a general trend towards an average reduction in the TFA content was observed, large differences among countries were noticed. Also Stender et al. [37] pointed out wide differences in the TFA content of several popular foods in Europe. These are probably linked to the different types of interventions to reduce intake of industrially produced TFA worldwide (legislative limits or voluntary policy programs), showing certain variability in their success [38]. In 2003 the first regulation on TFA content in foods came into force in Denmark. Since then, only 7 out of 37 types of margarines and spreads analysed all over the world and presented in Table 1, showed mean values lower than 2%TFA. Moreover, in the last 5 years values of up to 30% TFA of total fat were still observed in some European margarine samples [19, 22]. In Spain, last data published on these products showed an average TFA content of 2.8g/100g fat [39]. Since then, careful reformulation of products were undertaken by the Spanish industry, evident by the data provided in this study.

Much fewer studies reported the TFA content in French fries (Table 1). Although the results showed great diversity, there was a trend towards a lower TFA content is these products in the last few years.

4.1 Analysed Margarines

The detailed lipid profile (g/100g fatty acids) of the 6 types of margarines analysed in this study is shown in Table 2. TFA mean overall data was 0.51g/100g, with a minimum value of 0.29g/100g (mean for brand 4) and a maximum one of 0.72g/100g (mean for brand 2). A comparison of the ¾ to the ½ fat containing margarine showed in general that the former had a higher proportion of TFA. However, brand 3 (premium brand), showed similar TFA values as the ½ fat margarines. Based on these results it was concluded that there was on average a 5.5-fold reduction in TFA content compared to the data published in 2009 [39]. Remarkably, none of the samples reached the 2% value set by those European countries in which a trans-fat policy is currently in place by legislation (Denmark, Switzerland, Austria, Iceland, Hungary and Norway). None of the samples declared partially hydrogenated vegetable oils among their ingredients, which is in agreement with our results. The current results were consistent with those found for two margarines analysed by ATR-FTIR spectroscopy in Spain [40].

In all cases, the solution to reach a compromise between a healthier lipid profile and desired textural properties for these products was adequately addressed without the use of partially hydrogenated oils. A complete lipid analysis of the margarine showed that oleic acid was the most abundant fatty acid in 3 out of 6 brands, which suggested that olive oil or rapeseed oil was used in their formulations. In fact, brand 1 (store brand) showed the highest MUFA and lowest n-6/n-3 ratio among all tested margarines, which would suggest that rapeseed was included in this product. In brands 2, 3 and 5 it was linoleic acid the major fatty acid, consistent with the use of sunflower oil in their formulae. Relevant percentages of alpha-linolenic acid were also noticed (up to 8.68% in brand 5), as a consequence of the incorporation of linseed oil in the fat blends. When this oil was present in the blends (in brands 3, 4, 5), it significantly contributed to obtain the n-6/n-3 ratios of 4.7 to 5.9. However, it did not contribute with trans linolenic isomers.

The use of palm oil is one of the technological strategies currently applied to reduce the TFA content in margarines without drastic modification of their textural properties. Its content of SFA and high melting point make this oil a good alternative for that purpose. Palm oil was present in all analysed products, which resulted in increased levels of palmitic acid from 13% (brand 3) to 19% (brand 1). The incorporation of palm oil into the final blends was well balanced from the nutritional perspective. The total SFA content of the new margarines is lower (Table 2) than in the high TFA margarines of the past where the mean value of SFA plus TFA was generally 25g/100g fat (Table 1), a value that even exceeded the content of MUFA or PUFA in the earlier products. Furthermore, according to current European nutrition claims regulation (Regulation 1924/2006) [41], brands 3 and 5 could claim "high in polyunsaturated fat" (>45% PUFA content, and PUFA providing >20% total energy of the product).

Table 3 shows the lipid profile data expressed over g/100g product. Brands 1 to 3 contained approximately 60g fat/100g, and led to higher TFA values (up to 0.44g/100g product) than brands 4 to 6, which contained only 40% fat, and lower TFA values (up to 0.22g/100g).

When comparing these data to the limit set by the USA regulation to consider a "trans free product" (0.5g TFA/serving), all of them complied with this condition, including the store brands, with values from 0.02 to 0.07g/serving (serving size=15g). Regarding SFA content, that should be declared in the nutrition facts table, it ranged from 9.66 g/100g product (brand 5), to 16.72 g/100g (brand 2). Thus, one serving of the analysed products would supply approximately 1% of total energy value, which can be considered low, taking into account the suggestion to limit the intake of SFA to less that 10% of total energy [1].

4.2. Analysed French fries

Frying process implies degradation of oils and fats, leading to numerous fatty acid alteration products that are absorbed by the fried foods. Among the degradation products are trans fatty acids formed as a consequence of geometrical isomerization of double bonds [42]. In this sense, it has been described that repeated use of the frying oil for two weeks resulted in a significant increase in TFA content in the extracted oils from French fries purchased in fast food restaurants [43]. It was for this reason that partially hydrogenated oils were generally used for deep fat frying because to the stability of these lipids against oxidative deterioration during frying.

For some time now, frying methods and oils used had been progressively altered to minimize TFA presence in French fries. As evident in Table 1, better frying practices led to decrease TFA content from values around 30% in 1998 [44], and even up to 42% in 2006 [45], to values lower than 2% in more recent studies [14, 16, 43].

Our data confirmed the reduction of TFA in French fries available from 5 Spanish fast food chains (Table 4). While most contained about 0.5 g/100g fatty acids, brand 4 contained much more (0.89 g/100g) fatty acid. All these values were significantly lower than those detected in the last study conducted in Spain on these products (20.9g/100g fatty acids) [39], which indicated, on

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average, a 33 fold reduction. Brand 4, the highest in TFA, was characterized by a higher linoleic and lower oleic content as compared to the rest of brands. Oleic was by far the most abundant fatty acid in brands 1, 2, 3 and 5 (mean value 64.13%), while linoleic acid was the most abundant acid in brand 4 (51.03%). These data were related to another remarkable difference of brand 4, which was the the relative abundance of the trans 18:2 to the trans 18:1 FA isomers: only a 30% of total TFA derived from C18:1 isomers, being C18:2 isomers the major contributors to this type of lipids (64%). The high oleic acid content in 4 of the 5 brands analysed could be explained by the use of high oleic sunflower oil (probably in brands 1 and 5, where very low values of palmitic acid were noticed), or by the use of olive oil or blends of high oleic sunflower with palm oil (brands 2 and 3, with palmitic around 14%).

Also a noticeable reduction in the total fat content of the French fries was observed in this study (Table 5) compared to previous reports. Fernández-San Juan [39] reported an average fat content of 20.4 g/100g, whereas in our study the percentage of fat for different brands ranged from 8.32% (Brand 3) to 14.58% (Brand 1). This decrease in the fat content led to a significantly lower energy value of these products, which was a positive consequence, as high energy content has been one of the drawbacks that has traditionally been pointed out for fast food French fries [46].

Expressing TFA content on g/100g (Table 5) product led to very low values, ranging from 0.04 to 0.11 g TFA/100g product. It has to be mentioned that a significant correlation was found between the PUFA content and the TFA content (Pearson R=0.6; $p<0.001$), whereas no association was found for TFA and MUFA, pointing to a higher susceptibility of trans fat formation from PUFA than from MUFA. Using the serving size criteria, very low values were also found (lower than 0.11g TFA/serving), which allowed all these products to claim "trans free product". On the other hand, the energy supply from the high MUFA content in brands 1, 2, 3 and 4 (>20% of total energy) allowed these products to claim "high monounsaturated fat" according to the current European Regulation 1924/2006.

Considering the well-known implications of SFA and TFA on coronary heart disease, optimal dietary intake of SFA is set on <10% total energy value (E), whereas for TFA is set on <0.5% E [1]. The sum of both types of fatty acids (g/100g product) is presented in figure 1. In the case of margarines, premium brands showed lower total values as compared to store brands. In these samples, the sum SFA+TFA (9.8 - 17.2 g/100g product) supplied between 22-29.5% of the total energy of the food. However, in the case of French fries, the contribution of SFA+TFA (1.1 - 2.1 g/100g product) to total energy value was very low (4-7%). Daily average intakes of these two products should be taken into account to determine their contribution of these amounts in the total diet.

4.3 Conclusion

Food frequency questionnaires and food composition tables are two remarkable and useful tools in many epidemiological and interventional studies, whose role is to provide accurate information and detect appropriate targets for public health nutrition campaigns. According to Brownell and Pomeranz [47], the government has the authority and responsibility to regulate the unhealthful aspects of the food supply, and this should be done relying on accurate data. This paper reported data of Spanish margarines (premium and store brands) and fast-food French fries from 5 well-known international chains, showing the very low TFA contents of both types of products. In the case of margarines, the low TFA content was achieved using appropriate oils blends, and in the case of French fries, the reduction was due to the combined effect of using better quality oils and applying frying methods that result in lower total fat content in the product. Interestingly, the decrease in TFA was not linked to increments in the SFA content.

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6. AUTHOR CONTRIBUTIONS

G. Gatta and E. Abella performed the analysis in the laboratory and D. Ansorena and I. Astiasarán designed the study and wrote the manuscript.

7. CONFLICT OF INTEREST

No conflict of interest are declared.

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Table 1. Evolution of trans fat content in margarines and French fries worldwide (references in chronological order).

	Ref	Notes	%fat	g TFA/100g fat	g TFA/100g product	g TFA+SFA/100g fat
Margarines						
Lake et al. (1996) – New Zealand	[48]	Margarines	68.9	**16.4 (12.6-19.7)**	11.3 (8.7-13.6)	
		Table spreads	37.38	**15.7 (14.3-16.9)**	5.9 (5.3-6.3)	
		Butter/margarine blends	64.42	9.6 (6.1-**13.1**)	6.2 (3.9-8.4)	
Ratnayake et al. (1998) - Canada	[49]	Tub margarines from non hydrogenated VO	-	2.2 (0.9-5.0)	-	-
		Tub margarines from partially hydrogenated VO	-	**21.4 (10.5-44.8)**	-	-
		Print margarines from partially hydrogenated VO	-	**34.3 (16.3-47.7)**	-	-
Wagner et al. (2000)- Austria	[50]	Margarines	-	1.6 (0.3-3.73)	-	-
Alonso et al. (2000) - Spain	[51]	Margarines	63.5	8.87 (0.40-**21.28**)	5.63	35.03 (27.4-45.27)
Tavella et al. (2000)- Argentina	[52]	Margarines	82	**25.38**	20.81	-
		Margarines	50	**31.84**	15.92	-
Tekin et al. (2002) - Turkey	[53]	Margarines - Stick	-	**19** (0-**37.8**)	-	56.3
Marekov et al. (2002) - Bulgaria	[54]	Margarines	80	1.6	1.28	28.5
Karabulut & Turan (2006) – Turkey	[55]	Shortenings	-	8.95 (2-**16.5**)		50.8
Baylin et al. (2007) – Costa Rica	[18]	Stick regular	-	**13.25**	-	50.47
Ratnayake et al. (2007) - Canada	[56]	Tub margarines from non hydrogenated VO	-	0.8 (0.5-1.7)	-	-
		Tub margarines from partially hydrogenated VO	-	**20 (17.0-32.6)**	-	-
		Print margarines from partially hydrogenated VO	-	**39.3 (39.2-42.9)**	-	-
McCarthy et al. (2008) - Australia	[57]	Hard margarines	90.4 (80.5-100)	3.2 (1.7-4.5)	3.0 (1.7-4.5)	-
		Soft margarines	64.6	**11.6**	7.5	-
Haytowitz et al. (2008) - USA	[58]	Margarines -Data 2002	80	**19.69**	13.3	-

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		Margarines -Data 2006	80	**14.7 (11.2-18.8)**	11.8 (9-15.04)	-
Wagner et al. (2008) - Austria	[17]	Household margarines	80	1.45 ± 1.99	1.16 ± 1.57	-
		Industrial margarines	79.3	7.83 ± 9.97	6.21 ± 7.84	-
Fu et al. (2008) -China	[59]	Margarines	77.29 (25.02-99.81)	5.09 (0-**13.21**)	3.9 (0-10.21)	-
Saunders et al. (2008) – New Zealand	[20]	Margarines and table spreads	64.9 (58.9-72.1)	5.3 (2.7-6.9)	3.4 (1.7-4.5)	32.8
Basol & Tasan (2008) - Turkey	[60]	Shortenings	-	**12.6** (2.7-**23.9**)	-	52.3
		Margarines	-	**11.24** (0-**39.4**)	-	44.94
Albers et al. (2008) - USA	[61]	Margarines	56.4	6.6 ± 10.4	3.7	25.5 ± 11.1
Fernández-San Juan (2009) – Spain	[39]	Margarines		2.8 ± 1.7		
Richter et al. (2009) - Switzerland	[21]	Semi-solid fats	-	3.86 (0.15-**29.3**)	-	-
Cavendish et al. (2010) - Brazil	[62]	Hydrogenated margarines	50	**15.8**	7.91 ± 1.05	39.42
		Hydrogenated margarines	20	**12.3**	2.46 ± 0.39	34.8
		Interesterified margarines	65	1.98	1.29 ± 0.47	27.46
		Interesterified margarines	30	2.17	0.65 ± 0.24	26.07
Kuhnt et al. (2011) - Germany	[63]	Houlsehold margarines	70.6	0.96 (0.11-4.28)	0.7 (0.08-3.0)	33.99
		Industrial margarines	87.8	1.70 (0.05-**14.38**)	1.5 (0.04-12.6)	47.06
Pajin et al. (2011) - Serbia	[64]	Puff pastry margarines	-	7.7 (0.68-**23.77**)	-	53.73
Hernández-Martínez et al. (2011) - Mexico	[65]	Spreadable margarines	95	5.35 (0-**20.66**)	5.12 (0-19.68)	29.35
		Stick margarines		8.71 (0.25-**23.87**)	8.34 (0.24-22.84)	49.63
Meremae et al. (2012) - Estonia	[19]	Margarines	47.6	3.84 (0.04-**34.96**)	1.83	31.38
		Shortenings	70.62	6.11 (0.14-**39.50**)	4.31	48.39
		Blended spreads	65.7	2.97 (1.18-9.08)	1.95	61.64
Roe et al. (2013) - UK	[16]	Margarine hard block	76.4	0.1	0.08	-
		Fat spread (41-62% fat)	59.6 (59.1-60.6)	0.22 (0.19-0.25)	0.13 (0.11-0.15)	-
		Fat spread (26-39% fat)	38.3 (36.9-39.0)	0.28 (0.15-0.38)	0.10 (0.06-0.14)	-
Vucic et al. (2016) - Serbia	[22]	Hard margarines	80	4.5-**28.8**	3.6-23.4	58.8 (57.03-63.84)
		Soft margarines	50 (25-60)	2.28 (0.17-6.89)	0.08-3.4	31.5 (23.33-42.36)
Costa et al. (2016) - Portugal	[66]	Margarines and shortenings	-	0.83 (0.26–2.16)	-	0.56 (0.16–1.57)

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French Fries						
Aro et al. (1998) - various countries	[44]	French fries	14.3 (11-18)	**12-35** **33.57** in Spain	1.7	-
Wagner et al. (2000) – Austria	[50]	French fries		1.9-18	3	
Stender et al. (2006) - various countries	[45]	French fries	-	1 (Germany, Denmark) 4-**13** (Spain) **28** (South Africa) **42** (Poland)	-	-
Barrado et al. (2008) -Spain	[67]	French fries	35.84 (over dry matter)	2.5	-	31.4
McCarthy et al. (2008) - Australia	[57]	French fries	17.3(11.7-21.4)	2.1 (1.4-3.4)	0.3 (0.3-0.4)	-
Wagner et al. (2008) – Austria	[17]	French fries		1.72 ± 3.04	0.30 ± 0.55 (up to 1.6)	
Fernández-San Juan (2009) - Spain	[39]	French fries	20.4	**20**.9 ± 12.9	4.3	13.1
Fritsche et al. (2010) - Germany	[68]	French fries	22.5	0.2 (0.09-0.3)	0.04	
Tyburczy et al. (2012) - USA	[36]	French fries	14.7 (12.14-17.50)	6.6 (0.6-**12.62**)	0.97	27.53
Chung et al. (2013) – Hong Kong	[69]	Potato products (French fries, wedges, chips)	26 (12-39)	0.5 (0.13-1.46)	0.13 (0.035-0.38)	6.93
Roe et al. (2013) - UK	[16]	Potato chips, takeaway (fish and chips shop)	8.4	2.05	0.17	-
		Potato chips, fine cut, takeaway (fast food outlets)	14.2	0.11	0.01	-
Karim et al. (2014) - Pakistan	[14]	French fries	-	0.11-**24**	-	-
Yildirim et al. (2015) - Turkey	[43]	French fries	-	1.24 (0-7.19)	-	41.43 (24.41-49.33)

- - No data available. In bold, values higher than 10g TFA /100g fat are highlighted.

Table 2. Fatty acid profile (g/100g fat) for the ¾ fat margarines (brands 1, 2 and 3) and for the half-fat margarines (brands 4, 5 and 6) analyzed (mean and standard deviation).

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Fatty Acid	Brand 1		Brand 2		Brand 3		Brand 4		Brand 5		Brand 6	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Caprylic 8:0	0.30	0.02a	0.47	0.0c	0.30	0.02a	0.31	0.03a	0.39	0.02b	0.32	0.02a
Capric 10:0	0.30	0.03a	0.41	0.04c	0.29	0.02a	0.30	0.03a	0.37	0.02b	0.31	0.01a
Lauric 12:0	2.76	0.06c	2.58	0.13b	2.70	0.09bc	2.91	0.21d	2.73	0.03c	2.28	0.03a
Myristic 14:0	1.28	0.06d	1.37	0.06e	1.13	0.06b	1.20	0.03c	1.16	0.01bc	1.07	0.01a
Palmitic 16:0	18.80	0.44f	18.52	0.13e	12.88	0.31a	15.71	0.10c	14.31	0.12b	18.04	0.23d
t-Palmitoleic 9*t*-16:1	0.02	0.02b	0.01	0.01a	0.01	0.01a	0.00	0.00a	0.00	0.00a	0.00	0.00a
Palmitoleic 9*c*-16:1	0.18	0.01b	0.12	0.01a	0.10	0.00a	0.25	0.05c	0.12	0.00a	0.28	0.01d
Stearic 18:0	2.62	0.10a	3.63	0.16c	3.82	0.07d	3.71	0.05c	3.64	0.03c	3.38	0.04b
Σ *Trans* 18:1	0.37	0.06e	0.22	0.19d	0.10	0.01bc	0.05	0.06a	0.06	0.01ab	0.11	0.01c
Oleic 9*c*-18:1	45.40	0.99f	29.60	0.79c	25.11	1.18a	35.28	0.81d	26.11	0.20b	39.84	0.86e
11*c*-18:1	2.26	0.18c	0.65	0.09a	0.70	0.11ab	0.83	0.05b	0.60	0.04a	0.59	0.23a
t-Linoleic 9*t*,12*t*-18:2	0.00	0.01a	0.00	0.01b	0.01	0.01b	0.00	0.00a	0.02	.0.00b	0.01	0.00b
c-t Linoleic 9*c*,12*t*-18:2	0.12	0.01a	0.26	0.00e	0.16	0.00b	0.13	0.00a	0.19	0.01c	0.23	0.01d
t-c linoleic 9*t*,12*c*-18:2	0.12	0.01ab	0.23	0.01d	0.13	0.01b	0.12	0.01a	0.18	0.01c	0.22	0.01d
Linoleic 9*c*,12*c*-18:2	17.30	1.74a	40.92	0.94d	46.11	1.12d	33.82	0.73c	40.69	.0.11d	32.13	1.01b
Arachidic 20:0	0.43	0.05d	0.17	0.06bc	0.16	0.04b	0.21	0.03c	0.07	0.03a	0.20	0.02bc
γ-linolenic 18:3n-6	0.38	0.07c	0.00	0.00a	0.17	0.04b	0.00	0.00a	0.20	0.06b	0.02	0.02a
Eicosenoic 20:1	0.73	0.21b	0.13	0.01a	0.09	0.01a	0.12	0.02a	0.08	0.01a	0.15	0.02a
α-linolenic 18:3n-3	5.95	0.40d	0.19	0.06a	5.88	0.20d	4.76	0.14c	8.68	0.12e	0.59	0.09b
Eicosadienoic 20:2	ND		ND		ND		ND		ND		ND	
Behenic 22:0	0.25	0.04b	0.44	0.23c	0.50	0.03d	0.41	0.10c	0.45	0.11c	0.02	0.0a
Brassidic 13*t*-22:1	ND		ND		ND		ND		ND		ND	
Erucic 22:1	ND		ND		ND		ND		ND		ND	
Eicosatrienoic 20:3n-3	ND		ND		ND		ND		ND		ND	
Arachidonic 20:4n-6	ND		ND		ND		ND		ND		ND	
Eicosapentaenoic 20:5n-3	ND		ND		ND		ND		ND		ND	
Nervonic 24:1	0.09	0.01b	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a
Docosatrienoic 22:3	0.07	0.00b	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a
Docosapentaenoic 22:5n-6	ND		ND		ND		ND		ND		ND	

Lignoceric 24:0	ND		ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-3	0.00	0.00a	0.04	0.00ab	0.00	0.00a	0.05	0.00a	0.06	0.00a	0.15	0.02c
Docosahexaenoic 22:6n-3	ND		ND		ND		ND		ND		ND	
SFA	26.73	0.64e	27.60	0.16f	21.79	0.47a	24.69	0.36c	23.06	0.11b	25.62	0.23d
MUFA	48.86	1.27e	30.52	0.86b	26.00	1.28a	36.38	0.82c	26.85	0.16a	40.90	1.05d
PUFA	23.77	1.42a	41.16	0.85d	52.17	1.32f	38.64	0.70c	49.63	0.14e	32.92	1.07b
n-3	5.95	0.39d	0.23	0.11a	5.88	0.20d	4.82	0.18c	8.74	0.11e	0.76	0.10b
n-6	17.69	1.67a	40.93	0.95d	46.28	1.13e	33.83	0.71c	40.90	0.12d	32.16	1.02b
n-6/n-3	3.00	0.49a	226.96	119.21b	7.87	0.10a	7.04	0.31a	4.69	0.06a	42.71	4.52a
PUFA + MUFA / SFA	2.72	0.09b	2.60	0.02a	3.59	0.07f	3.04	0.08d	3.32	0.02e	2.88	0.03c
TFA	0.64	0.03e	0.72	0.02f	0.41	0.04b	0.29	0.04a	0.45	0.01c	0.57	0.02d

Different letters in the same row indicate significant differences ($p < 0.05$) among the mean values for the different brands. ND: Not detected
SFA: sum of all saturated fatty acids; MUFA: sum of all monounsaturated fatty acids; TFA: sum of all trans fatty acids

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Table 3. Fatty acid profile (g/100g product) and fat content (g/100g product) for the ¾ fat margarines (brands 1, 2 and 3) and for the half-fat margarines (brands 4, 5 and 6) analyzed (mean and standard deviation).

Fatty Acid	Brand 1		Brand 2		Brand 3		Brand 4		Brand 5		Brand 6	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Caprylic 8:0	0.18	0.01b	0.29	0.03c	0.18	0.01b	0.12	0.01a	0.16	.0.01b	0.13	0.01a
Capric 10:0	0.18	0.01c	0.25	0.02d	0.17	0.01b	0.12	0.01a	0.16	0.01b	0.12	0.00a
Lauric 12:0	1.67	0.04c	1.56	0.08c	1.61	0.06c	1.18	0.09b	1.14	0.01b	0.90	0.03a
Myristic 14:0	0.77	0.03d	0.83	0.04e	0.67	0.02c	0.49	0.02b	0.48	0.02b	0.42	0.01a
Palmitic 16:0	11.39	0.37e	11.23	0.07e	7.69	0.22d	6.40	0.23b	8.98	0.05a	7.15	0.25c
t-Palmitoleic 9*t*-16:1	0.01	0.01b	0.01	0.00b	0.01	0.00b	0.00	0.00a	0.00	0.00a	0.00	0.00a
Palmitoleic 9*c*-16:1	0.11	0.02d	0.07	0.00b	0.05	0.01a	0.10	0.02c	0.05	0.00a	0.10	0.01c
Stearic 18:0	1.58	0.05b	2.20	0.09d	2.28	0.05c	1.51	0.02b	1.52	0.01b	1.34	0.05a
Σ *Trans* 18:1	0.22	0.04e	0.13	0.01d	0.06	0.01c	0.02	0.02a	0.03	0.00ab	0.04	0.00bc
Oleic 9*c*-18:1	27.52	0.96e	17.93	0.46d	14.99	0.81b	14.33	0.33b	10.92	0.08a	15.78	0.61c
11*c*-18:1	1.37	0.12c	0.39	0.05b	0.42	0.07b	0.34	0.02b	0.25	0.01a	0.23	0.09a
t-Linoleic 9*t*,12*t*-18:2	0.00	0.00a	0.00	0.00a	0.01	0.01b	0.00	0.00a	0.01	0.00b	0.01	0.00ab
c-t Linoleic 9*c*,12*t*-18:2	0.07	0.00c	0.16	0.00e	0.09	0.00d	0.05	0.00a	0.08	.0.00b	0.09	0.00d
t-c linoleic 9*t*,12*c*-18:2	0.08	0.01c	0.14	0.00d	0.08	0.01b	0.05	0.01a	0.08	0.00b	0.09	0.00c
Linoleic 9*c*,12*c*-18:2	10.47	0.90a	24.80	0.60e	27.53	0.83f	13.78	0.29c	17.05	0.04d	12.70	0.42b
Arachidic 20:0	0.26	0.30c	0.10	0.03b	0.10	0.03b	0.09	0.01b	0.03	0.01a	0.08	0.01b
γ-linolenic 18:3n-6	0.23	0.05c	0.00	0.00a	0.10	0.02b	0.00	0.00a	0.09	0.02b	0.01	0.01a
Eicosenoic 20:1	0.48	0.04d	0.08	0.00c	0.05	0.01b	0.05	0.01ab	0.03	0.00a	0.06	0.01bc
α-linolenic 18:3n-3	3.61	0.29c	0.11	0.04a	3.51	0.15c	1.93	0.06b	3.63	0.05c	0.23	0.03a
Eicosadienoic 20:2	ND	ND	ND	ND	ND	ND						
Behenic 22:0	0.15	0.02b	0.27	0.03d	0.30	0.02e	0.17	0.01bc	0.19	0.00c	0.01	0.03a
Brassidic 13*t*-22:1	ND		ND		ND		ND		ND		ND	
Erucic 22:1	ND		ND		ND		ND		ND		ND	
Eicosatrienoic 20:3n-3	ND		ND		ND		ND		ND		ND	
Arachidonic 20:4n-6	ND		ND		ND		ND		ND		ND	
Eicosapentaenoic 20:5n-3	ND		ND		ND		ND		ND		ND	
Nervonic 24:1	0.05	0.04b	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a
Docosatrienoic 22:3	0.05	0.01b	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a	0.00	0.00a
Docosapentaenoic 22:5n-6	ND		ND		ND		ND		ND		ND	
Lignoceric 24:0	ND		ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-3	0.00	0.00a	0.02	0.00b	0.00	0.00a	0.02	0.00b	0.02	0.00b	0.06	0.00c
Docosahexaenoic 22:6n-3	ND		ND		ND		ND		ND		ND	
SFA	16.19	0.48d	16.72	0.10e	13.01	0.33c	10.05	0.15b	9.66	0.06a	10.15	0.33b
MUFA	29.65	1.14e	18.49	0.52d	15.53	0.87bc	14.83	0.34b	11.25	0.08a	16.18	0.65c
PUFA	14.34	0.64b	24.95	0.54e	31.15	0.98f	15.73	0.29c	20.79	0.06d	13.01	0.42a
n-3	3.64	0.24d	0.14	0.07a	3.51	0.15d	1.96	0.07cb	3.66	0.05d	0.30	0.04b
n-6	10.70	0.86a	24.80	0.60e	27.64	0.84f	13.78	0.27c	17.14	0.04d	12.71	0.42b
TFA	0.39	0.02e	0.44	0.01f	0.25	0.03d	0.12	0.02a	0.19	0.01b	0.22	0.01c
Total fat content	61.50	5.15b	60.60	1.37b	59.71	1.44b	40.74	1.69a	41.82	0.8a	40.29	3.29a

Different letters in the same row indicate significant differences ($p < 0.05$) among the mean values for the different brands. ND: Not detected; SFA: sum of all saturated fatty acids; MUFA: sum of all monounsaturated fatty acids; TFA: sum of all trans fatty acids

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Table 4. Fatty acid profile of French fries (g/100g fat) for the 5 fast food outlets analyzed (mean and standard deviation).

Different letters in the same row indicate significant differences ($p < 0.05$) among the mean values for the different brands. ND: Not detected;

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Caprylic 8:0	0.14	0.01a	0.16	0.02a	0.14	0.02a	0.23	0.11b	0.12	0.00a
Capric 10:0	0.65	0.52a	0.10	0.02ab	0.09	0.01a	0.14	0.07b	0.09	0.00ab
Lauric 12:0	0.04	0.01ab	0.09	0.01c	0.07	0.01c	0.05	0.02b	0.02	0.00a
Myristic 14:0	0.07	0.01a	0.31	0.04c	0.28	0.06c	0.19	0.05b	0.07	0.00a
Palmitic 16:0	5.08	0.35a	15.48	1.73d	13.44	2.37c	10.81	0.10b	5.27	0.22a
t-Palmitoleic 9*t*-16:1	ND		ND		ND		ND		ND	
Palmitoleic 9*c*-16:1	0.11	0.00a	0.14	0.01b	0.14	0.01b	0.13	0.02b	0.14	0.02b
Stearic 18:0	3.48	0.09b	4.01	0.01c	3.92	0.04c	4.31	0.06d	3.21	0.23a
Σ *Trans* 18:1	0.21	0.05ab	0.30	0.05b	0.25	0.02ab	0.28	0.20ab	0.19	0.02a
Oleic 9*c*-18:1	63.45	3.24a	63.59	0.74ab	66.18	2.12b	30.08	3.04c	63.30	0.84a
11*c*-18:1	0.83	0.02a	0.81	0.02a	0.83	0.02a	0.78	0.06a	0.92	0.07b
t-Linoleic 9*t*,12*t*-18:2	0.01	0.01a	0.01	0.00a	0.01	0.00a	0.04	0.01b	0.01	0.00a
c-*t* Linoleic 9*c*,12*t*-18:2	0.14	0.01bc	0.12	0.01ab	0.11	0.00a	0.30	0.03d	0.16	0.02c
t-*c* linoleic 9*t*,12*c*-18:2	0.14	0.00b	0.13	0.01ab	0.11	0.00a	0.27	0.04c	0.15	0.02b
Linoleic 9*c*,12*c*-18:2	24.79	2.52b	13.12	1.43a	12.70	0.51a	51.03	5.35c	24.66	0.83b
Arachidic 20:0	0.19	0.03a	0.27	0.03b	0.28	0.01b	0.15	0.11a	0.18	0.02a
γ-linolenic 18:3n-6	ND		ND		ND		ND		ND	
Eicosenoic 20:1	0.18	0.01c	0.16	0.01b	0.18	0.01c	0.12	0.01a	0.18	0.01c
α-linolenic 18:3n-3	0.19	0.01a	0.27	0.00d	0.24	0.03bc	0.25	0.03cd	0.22	0.00b
Eicosadienoic 20:2	ND	ND	ND	ND	ND					
Behenic 22:0	0.55	0.41a	0.64	0.06ab	0.72	0.07ab	0.61	0.11ab	0.77	0.04c
Brassidic 13*t*-22:1	ND		ND		ND		ND		ND	
Erucic 22:1	ND		ND		ND		ND		ND	
Eicosatrienoic 20:3n-3	ND		ND		ND		ND		ND	
Arachidonic 20:4n-6	ND		ND		ND		ND		ND	
Eicosapentaenoic 20:5n-3	0.30	0.03cd	0.25	0.02b	0.27	0.02bc	0.21	0.05a	0.33	0.01d
Nervonic 24:1	ND		ND		ND		ND		ND	
Docosatrienoic 22:3	ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-6	ND		ND		ND		ND		ND	
Lignoceric 24:0	ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-3	ND		ND		ND		ND		ND	
Docosahexaenoic 22:6n-3	ND		ND		ND		ND		ND	
SFA	9.62	0.78a	21.08	1.74d	18.96	2.43c	16.50	2.04b	9.74	0.06a
MUFA	64.58	3.27b	64.70	0.73bc	67.33	2.11c	31.12	3.10a	64.54	0.85b
PUFA	25.29	2.54b	13.65	1.43a	13.21	0.50a	51.48	5.32c	25.20	0.83b
n-3	0.49	0.04ab	0.52	0.02bc	0.51	0.02bc	0.45	0.06a	0.55	0.02c
n-6	24.79	2.52b	13.12	1.42a	12.71	0.51a	51.03	5.35c	24.65	0.83b
n-6/n-3	50.63	4.93b	25.04	2.29a	25.07	1.81a	114.96	28.64c	45.00	2.43b
PUFA + MUFA / SFA	9.40	0.85c	3.75	0.39a	4.33	0.69a	5.10	0.83b	9.21	0.06c
TFA	0.51	0.06a	0.58	0.06a	0.49	0.02a	0.89	0.28b	0.51	0.05a

SFA: sum of all saturated fatty acids; MUFA: sum of all monounsaturated fatty acids; TFA: sum of all trans fatty acids

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Table 5. Fatty acid profile (g/100g product) and fat content (g/100g product) of French fries for the 5 brands analyzed (mean and standard deviation).

Fatty Acid	Brand 1		Brand 2		Brand 3		Brand 4		Brand 5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Caprylic 8:0	0.02	0.00b	0.01	0.00ab	0.01	0.00a	0.03	0.01c	0.01	0.00a
Capric 10:0	0.01	0.01a	0.01	0.00a	0.01	0.00a	0.02	0.01b	0.01	0.00a
Lauric 12:0	0.00	0.00a	0.01	0.00b	0.01	0.00b	0.01	0.00b	0.00	0.00a
Myristic 14:0	0.01	0.00a	0.03	0.00c	0.02	0.00b	0.02	0.01b	0.01	0.00a
Palmitic 16:0	0.74	0.43d	1.45	0.23b	1.10	0.12a	1.32	0.20b	0.55	0.01c
t-Palmitoleic 9*t*-16:1	ND		ND		ND		ND		ND	
Palmitoleic 9*c*-16:1	0.02	(0.00c	0.01	0.00ab	0.01	0.00a	0.02	0.00c	0.01	0.00b
Stearic 18:0	0.51	0.00c	0.37	0.02b	0.33	0.03a	0.53	0.03c	0.34	0.04a
Σ *Trans* 18:1	0.03	0.01ab	0.03	0.00ab	0.02	0.00ab	0.03	0.02b	0.02	0.00a
Oleic 9*c*-18:1	9.25	0.58c	5.91	0.27bc	5.52	0.78b	3.68	0.25a	6.59	0.32c
11*c*-18:1	0.12	0.00d	0.07	0.00b	0.07	0.01a	0.09	0.00c	0.09	0.00c
t-Linoleic 9*t*,12*t*-18:2	ND		ND		ND		ND		ND	
c-t Linoleic 9*c*,12*t*-18:2	0.02	0.00	0.01	0.00	0.01	0.01	0.04	0.00	0.02	0.00
t-c linoleic 9*t*,12*c*-18:2	0.02	0.00d	0.01	0.00b	0.01	0.00a	0.03	0.00e	0.02	0.00c
Linoleic 9*c*,12*c*-18:2	3.61	0.32c	1.21	0.08a	1.06	0.16a	6.28	0.89d	2.57	0.17b
Arachidic 20:0	0.03	0.00ab	0.02	0.00ab	0.02	0.00ab	0.02	0.01a	0.02	0.00a
γ-linolenic 18:3n-6	ND		ND		ND		ND		ND	
Eicosenoic 20:1	0.03	0.00c	0.01	0.00a	0.01	0.00a	0.01	0.00a	0.02	0.00b
α-linolenic 18:3n-3	0.03	0.00c	0.02	0.00b	0.02	0.00a	0.03	0.00d	0.02	0.00b
Eicosadienoic 20:2	ND		ND		ND		ND		ND	
Behenic 22:0	0.08	0.06a	0.06	0.00a	0.06	0.01a	0.07	0.01a	0.08	0.01a
Brassidic 13*t*-22:1	ND		ND		ND		ND		ND	
Erucic 22:1	ND		ND		ND		ND		ND	
Eicosatrienoic 20:3n-3	ND		ND		ND		ND		ND	
Arachidonic 20:4n-6	ND		ND		ND		ND		ND	
Eicosapentaenoic 20:5n-3	0.04	0.00c	0.02	0.00a	0.02	0.00a	0.02	0.00a	0.03	0.00b
Nervonic 24:1	ND		ND		ND		ND		ND	
Docosatrienoic 22:3	ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-6	ND		ND		ND		ND		ND	
Lignoceric 24:0	ND		ND		ND		ND		ND	
Docosapentaenoic 22:5n-3	ND		ND		ND		ND		ND	
Docosahexaenoic 22:6n-3	ND		ND		ND		ND		ND	
SFA	1.40	0.11b	1.96	0.26cd	1.56	0.11bc	2.01	0.19d	1.01	0.06a
MUFA	9.42	0.59d	6.01	0.28b	5.61	0.78b	3.80	0.26a	6.72	0.31c
PUFA	3.68	0.32c	1.26	0.07a	1.10	0.17a	6.33	0.89d	2.63	0.17b
n-3	0.07	0.00d	0.05	0.00b	0.04	0.00a	0.06	0.01c	0.06	0.00c
n-6	3.61	0.32c	1.21	0.07a	1.06	0.16a	6.28	0.89d	2.57	0.17b
TFA	0.07	0.01b	0.05	0.00a	0.04	0.00a	0.11	0.03c	0.05	0.00a
Total fat content	14.58	0.28e	9.29	0.50b	8.32	1.04a	12.26	1.05d	10.42	0.70c

Different letters in the same row indicate significant differences ($p < 0.05$) among the mean values for the different brands.
ND: Not detected
SFA: sum of all saturated fatty acids; MUFA: sum of all monounsaturated fatty acids; TFA: sum of all trans fatty acids

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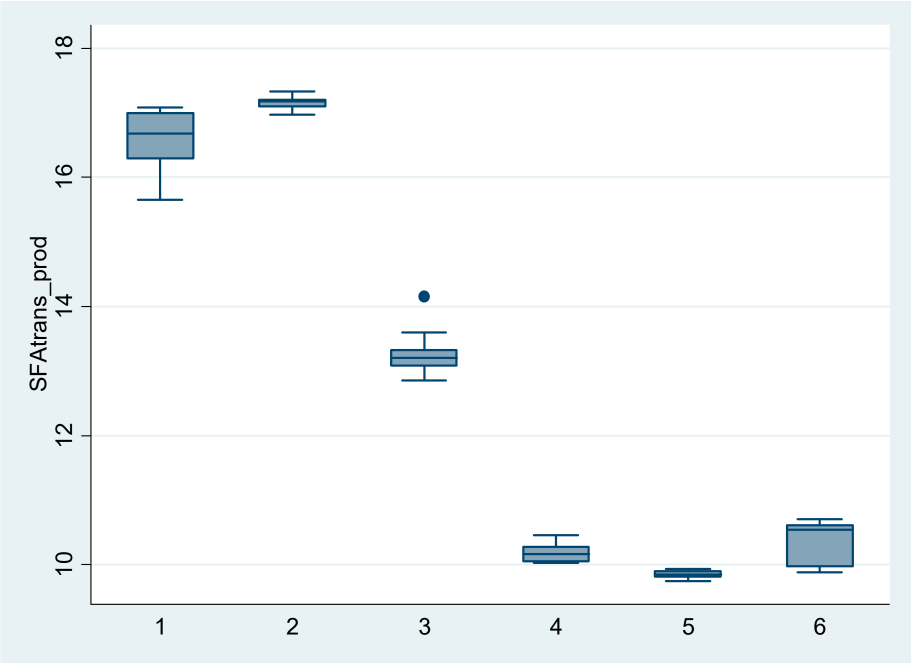
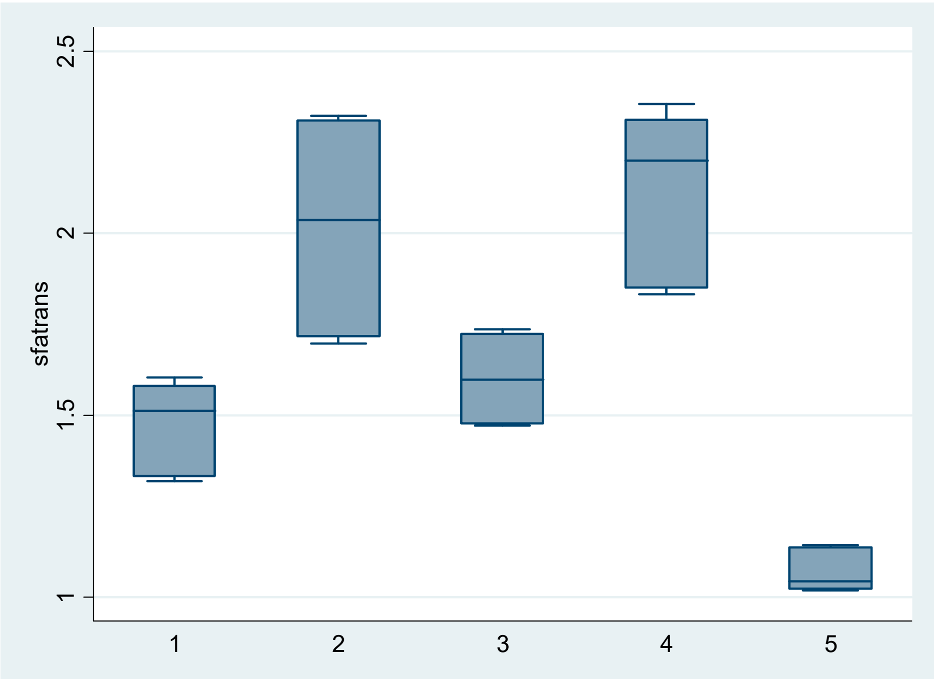
Fig 1. Boxplot for the sum of SFA+Trans (g/100g product) for all samples analyzed.
A) Margarines



B) French fries



Median, 25 and 75 quartiles, maximum and minimum values are represented.
SFA: sum of saturated fatty acids