Fatty Acids and *Trans* Fatty Acids Profile of Potato Chips and French Fries Marketed in Romania

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The aim of the study was to evaluate the composition in fatty acids (FAi) and trans fatty acids (t-FAi) from potato chips and French fries using gas chromatography coupled with mass spectrometry (GC-MS). The fat sample was extracted with petroleum ether, using the Büchi B-811 automatic extraction unit, the Soxhlet Standard procedure. The extracted fat was saponified with sodium methoxide solution and the fatty acids derivatized into fatty acid methyl esters (FAME) with BF_3 methanolic solution. Six potato chips samples and six French fries samples, coming from 3, respectively 5 brands, were purchased from supermarkets and fast foods in Bucharest, Romania. In potato chips, saturated (SFA), cis-monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) were present between 6.410 - 48.862%, 41.786 - 84.570%, respectively 5.567 - 28.274%, and in French fries ranged between 7.001 - 57.277%, 35.281 – 57.894%, respectively 7.442 – 49.392%. The tested samples showed that the level of total trans fatty acids (TFA) was less than 0.2% (undetectable - 0.124%). It can be concluded that potato chips and French fries marketed in Bucharest, Romania are safe for consumers in terms of TFA content.

Keywords: *potato chips, French fries, GC-MS, SFA, MUFA, PUFA, TFA*

Potatoes (*Solanum tuberosum*) are an important source of carbohydrates, proteins, vitamin C, and natural antioxidants [1, 2]. Potatoes are consumed after thermal processing, and like this the potato starch becomes digestible [3]. Potatoes have a low content of fat (<0.1 g/100 g) [4, 5], but during frying it incorporates fat by absorption in variable amounts, resulting an enrichment in fatty acids. Oil absorption is dependent of the frying time, because during frying the water content of potatoes decreases, and the structural oil penetrates into the potatoes increasing slowly at the initial stage of frying [6]. By studying the oil absorption, Zhang et al. (2018) [6] showed that the total oil content and structural oil of potato chips increased at 40.44%, respectively 6.44% after 2 min of frying.

The fat content, texture, aroma and taste of the final product are influenced by the type of oil used, the potato variety, and technological parameters [7, 8]. The fatty acids composition of potato chips and French fries is dependent of the frying oil used [3, 9], the most popular oils being the vegetables types (sunflower, palm or its fractions, rapeseed oil).

Potato chips started to be more popular among the Romanian consumers in the last years, being eaten at least once a week by one third of population in urban areas. Potato chips are chosen based on their taste, this category representing over 51% of the salty snack category marketed in Romania [10]. These products are often rich in energy, salt or sugar, fats, saturated fatty acids, *trans* fatty acids and have a low content of vitamins, minerals and dietary fiber. Based on World Health Organization (WHO) and Food and Agriculture Organization (FAO) recommendations, the daily intake of fat from the total energy should not exceed 30%, SFA intake should be less than 10%, and TFA should be less than 1% of total calories (2 g TFA per day) for a balanced diet (2000 kcal) [11, 12].

There is a concern regarding the long chain saturated fatty acids (palmitic, stearic) consumption due to the fact that is difficult to be digested and absorbed, creating various digestive problems. The use of saturated fats in the preparation of processed foods helps to extend their freshness, shelf life and appealing appearance in store shelves. Another concern regards the intake of foods containing *t*-FAi due to the negative effects they bring to the human body. Epidemiological studies have shown that high *trans*-FA consumption increases cholesterol and, implicitly, increases risk of cardiovascular disease, diabetes and cancer [13, 14].

Due to the consumption and possible harmful impact on health, the lipid profile of potato products has been investigated in several countries, such as Portugal [15], Spain [16], United Kingdom [17], Serbia [18], Turkey [19], and Pakistan [20]. The results of these studies are important not only for national nutrient data base, but also for assessing the content and consumption of SFA and TFA from these products. Interestingly, several of these studies, especially those from developed countries, have shown that TFA content in food and snacks has declined significantly in recent years [16-18].

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The aim of this study was to investigate the fat content and the fatty acids and *trans* fatty acids (elaidic, *trans*-vaccenic, *trans*-9,12-octadecadienoic) profile of potato chips and French fries produced and marketed in Bucharest, Romania, also the PUFA/SFA and the omega-6/omega-3 ratios. The data obtained could be useful in future in order to estimate the population exposure to the consumption of SFA and TFA in this food category.

Experimental part

Reagents and reference standards

All solvents and reagents used in experiments were of analytical grade: petroleum ether, 40 - 60°C (VWR Chemicals, France), 5.4 M methanolic solution of sodium hydroxide (Acros, New Jersey), 14% methanolic solution of boron trifluoride (Sigma Aldrich, Switzerland), sodium chloride (Sigma Aldrich, Denmark), anhydrous sodium sulphate (LGC Standards, Germany). Methanol picograde and isooctane (2, 2, 4-trimethylpentan) picograde were especially for chromatography (Sigma Aldrich, Germany).

As reference standards were used SRM®2377 (NIST-certified, USA) - a mixture of 26 FAMEs, with NIST certified mass fraction values (mg/g) and F.A.M.E. Mix. C4-C24 - a mixture of 37 FAMEs with mass percent (%) for 37 FAMEs (Bellefonte, PA, USA).

Food matrices

In this study, 6 samples of potato chips purchased from local supermarkets in Bucharest (3 different brands: A, B, C) and 6 samples of French fries purchased from the fast-foods in Bucharest (5 different brands: D, E, F, G, H) were analysed. The potato chips were labeled as fried in vegetable oils (palm/rapeseed/sunflower oil). Based on the nutrition labelling stated by the manufacturer, some products of French fries were also fried in the same vegetable oils. The samples taken into study and some information from the label, according to the manufacturer's nutrition information are shown in Table 1.

Table 1
DESCRIPTION OF THE SAMPLES, INCLUDING NUTRITION LABELLING INFORMATION

No.	Brand	Sample	Sample code	Fat content/SFA (g/100 g product)	Type of oil used to prepare the product
Potato chips					
1	A	Potato chips with salt	P1	Fat: 35 g/100 g SFA (g/100 g product): 3	Sunflower oil
2		Oven baked potato with salt	P3	Fat: 14 g/100 g SFA (g/100 g product): 2	Rapeseed oil
3		Deep ridges with cream and paprika	P5	Fat: 33 g/100 g SFA (g/100 g product): 3	Sunflower oil
4		Deep ridges cheddar & onion	P6	Fat: 33 g/100 g SFA (g/100 g product): 3	Sunflower oil
5	B	Expanded product made of potatoes with salt	P2	Fat: 26 g/100 g SFA (g/100 g product): 12	Palm oil
6	C	Potato crisps with cheese flavour	P4	Fat: 35 g/100 g SFA (g/100 g product): 3.2	Sunflower oil
French fries					
7	D	French fries	P7	Fat: 21 g/100 g SFA (g/100 g product): 2	Vegetable oil
8		Fresh potato wrapped in a crisp layer and soft inside	P8	Fat: 9 g/100 g SFA (g/100 g product): 1	Mixture of non-hydrogenated vegetable oil
9	E	French fries	P9	-	-
10	F	French fries	P10	Fat: 14.29 g/100 g SFA (g/100 g product): 2.58	Vegetable oil
11	G	French fries	P11	-	-
12	H	French fries	P12	-	-

Sample preparation

The food samples were milled in a mixer (Büchi Mixer B-400, Labortechnik AG Switzerland). The homogenized products were stored in closed plastic bottles encoded from P1 to P12 and stored in the freezer at -20°C until analysis.

Fat content

The total fat content of potato chips and French fries samples was determined gravimetrically after extraction with petroleum ether using the Büchi B-811 automated unit (Labortechnik AG Switzerland), the Soxhlet Standard working procedure. The fat was stored at 4°C. Samples were analyzed in triplicate and the results are expressed in %.

Fatty acid methyl esters (FAMEs) preparation

About 0.050 g of extracted fat was esterified with 4 mL of 0.5 M methanolic solution of sodium hydroxide, and FA were derivatized into FAME using 5 mL of 14% methanolic solution of boron trifluoride [21]. The obtained extract was diluted with 3 mL isooctane and transferred to an autosampler vial for GC-MS injection.

GC-MS equipment and operating conditions

For FA determination and quantification there were used several methods but the most used one is gas chromatography (GC) [22-25].

In our study, the FA and TFA composition of food samples analysed was performed by using a gas chromatograph coupled with a mass spectrometer (Trace GC Ultra/TSQ Quantum XLS, Thermo Fisher Scientific, USA). The GC is equipped with a high polarity capillary column, TR-FAME (stationary phase consisting of 70% cyanopropyl and 30% polysilphenyl-siloxane (60 m x 0.25 mm inner diameter and 0.25 μm stationary film thickness), provided by Thermo Fisher Scientific. The oven temperature was programmed at 100°C for 0.2 min, a 20°C/min ramp to 240°C and held for 15 min. Helium was the carrier gas, at a constant flow rate of 1 mL/min. A volume of 0.5 μL extract was injected at 240°C in split mode with a 1:50 split ratio and a 50 mL/min splitting rate. For the applied method, the MS detector was operated in the positive electron impact ionization (EI +) mode, selected ion monitoring (SIM) mode, using 24 segments. The temperature of the ion source was 250°C. Injections were performed in duplicate. Instrument control, data acquisition and processing were performed using the Xcalibur Program.

Identification of chromatographic peaks in the potato chips and French fries samples was achieved by comparing their retention times with those of appropriate FAMEs reference standards, and the mass/charge (*m/z*) ratio characteristic of each component. The fatty acids and *trans* fatty acids content of food matrices studied were calculated based on correction factors (CF) determined from the calibration solutions. CF were determined from both reference standards, SRM®2377 and F.A.M.E. Mix. C4-C24 (23 FAMEs common to both standards, 3 FAMEs specific to SRM®2377 and 14 FAMEs specific to F.A.M.E. Mix C4-C24). The recording time of a GC-MS chromatogram is 85 minutes.

Two samples of each brand were analyzed in parallel (n = 2) and each sample was injected 2 times at GC-MS. The results are expressed as weight of fatty acid in 100 g fat/100 g product or as SFA, MUFA, PUFA, *trans* fatty acid (TFA) in 100 g fat/100 g product and are presented as mean ± standard deviation (n= 2 x 2). It was calculated also the PUFA/SFA ratio which has a minimum recommended value of 0.4 [26], and the omega-6/omega-3 ratio which have an optimal recommended ratio of 3:1 [27].

With the developed method, among omega-6 fatty acids can be identified and quantified C18:2n6, C18:3n6, C20:2n6, C20:3n6, C20:4n6, C22:2n6, and among omega-3 fatty acids, the ones that can be determined are C18:3n3, C20:3n3, C20:5n3, C22:5n3, and C22:6n3.

Statistical analysis

The results for the fat content and the fatty acid profile are expressed as the mean ± standard deviation (SD) obtained for all products analyzed. The results were analyzed by the Tukey test. Values of $p < 0.05$ were considered significant. All analyzes were performed using SPSS (IBM SPSS Statistics 24).

Results and discussions

The fat content, fatty acids (FAi) and trans fatty acids (t-FAi) profile of potato chips samples

Recently there have been made many studies associated with the analysis of fatty acids from chips, French fries and other food products. It has been found that total fat content varies significantly between different product categories as well as between assortments of the same product category.

Potato chips are a category of products, rich in fat. The chips samples taken into study were analyzed for total fat content and composition in individual and total fatty acids (SFA, MUFA, PUFA, TFA). The results obtained are presented in Table 2.

The analyzed samples, P1, P2, P4, P5 and P6, showed a high fat content ranging between 25.88 to 32.59 g/100 g product, and the P3 sample showed a lower value (12.81%), as shown in Table 2.

Similar results were obtained by Albuquerque et al. (2018) [28] who analysed 47 potato products (chips, fried potatoes) and the average fat content was 25.58 g/100 g food product. Vardavas et al. (2007) [29] studied the fat content of snacks, including potato crisps and the results were between 9.11 and 43.26 g/100 g potato crisp products. Higher fat contents were obtain in a study realized by Timic et al. (2018) [18], who analysed 5 assortments of potato chips, and obtained a fat content of 31.6 - 40.4 g/100 g product.

In the 6 samples of potato chips analysed in our study, 15 to 25 FAi were identified and quantified. Figure 1 shows the chromatogram in FAi and TFAi of the P4 potato chips sample.

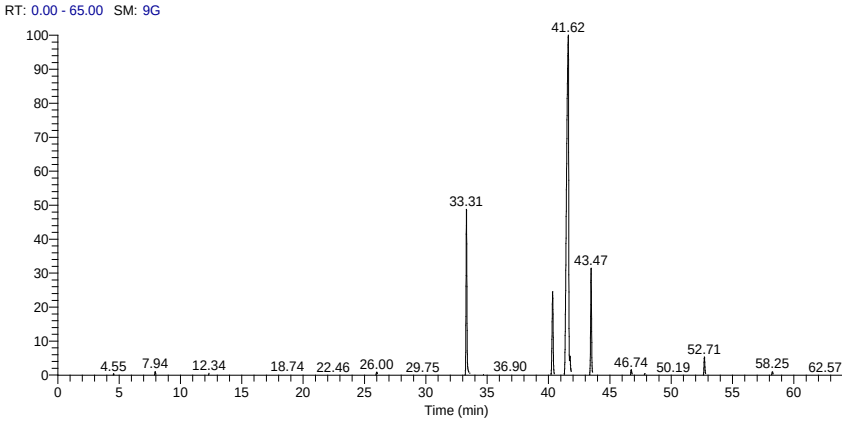

Fig. 1. Chromatogram of the P4 potato chips sample

The SFA, MUFA and PUFA profiles (g/100 g fat or g/100 g product) differ between the assortments of potato chips as it can be seen in Table 1.

The SFA content varied between 6.410 - 48.862 g/100 g fat (0.821 g - 12.646 g/100 g product). For P1, P2, P4, P5 and P6 samples, the content of SFA determined per 100 g product (Table 2) was also confirmed by the manufacturer's labeling declaration (Table 1).

From the saturated fatty acids, palmitic acid (C16:0) predominates, with values ranging from 2.998 to 43.865 g/100 g of fat, the minimum value being recorded for P3 sample, and the maximum value for P2 sample which was fried in palm oil, as stated by the manufacturer. The second saturated fatty acid predominantly from P1-P6 chips samples, was stearic acid (C18:0), with values ranging from 1.303% (P3) to 4.373% (P4). Our results are in accordance with the ones obtained in the study of Cakmak et al. (2011) [19], where palmitic acid was the predominant fatty acid in the potato crisps samples, the value ranging from 24.03 to 40.12 g/100 g fatty acids, followed by stearic acid with a mean value of 4.52 g/100 g fatty acids. Similar results were also obtained in the study of Fu et al. (2008) [30] on potato chips and in the study of Fernandez and Juan (2000) [31] on fried potatoes, where palmitic and stearic acids were the predominant SFA. The other components, identified and quantified in the P1-P6 chips samples, showed values below 1.5%. In P4, P5 and P6 samples in a percent less than 1% were identified the following fatty acids: butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), indicating the presence of dairy products in the manufacturing recipes of the products. The results are also confirmed by the manufacturer's declaration, as ingredients such as cheese, cheddar, and cream are present in the recipe.

Table 2

TOTAL FAT CONTENT AND INDIVIDUAL AND TOTAL FA AND TFA COMPOSITION (%, G/100 G FAT) OF THE POTATO CHIPS SAMPLES ANALYZED

No.	FAi/TFAi components	Code FAi/ TFAi	P1	P2	P3	P4	P5	P6
1	Butanoic/butyric	C4:0	-	-	-	0.037 ± 0.003	0.036 ± 0.003	-
2	Hexanoic/caproic	C6:0	-	-	-	0.020 ± 0.001	0.021 ± 0.002	-
3	Octanoic/caprylic	C8:0	-	-	-	0.092 ± 0.007	0.107 ± 0.009	0.207 ± 0.042
4	Decanoic/capric	C10:0	-	-	-	0.083 ± 0.005	0.086 ± 0.007	0.124 ± 0.025
5	Dodecanoic/lauric	C12:0	-	0.188 ± 0.006	-	0.034 ± 0.002	0.032 ± 0.002	-
6	Tetradecanoic/myristic	C14:0	-	1.003 ± 0.031	0.042 ± 0.002	0.176 ± 0.007	0.186 ± 0.011	0.059 ± 0.010
7	*Cis*-9-tetradecenoic/myristoleic	C14:1n5	-	-	-	0.014 ± 0.001	0.010 ± 0.000	-
8	Pentadecanoic	C15:0	0.016 ± 0.003	0.035 ± 0.000	0.024 ± 0.002	0.027 ± 0.001	0.029 ± 0.001	0.017 ± 0.003
9	Hexadecanoic/palmitic	C16:0	4.455 ± 0.138	43.865 ± 0.467	2.998 ± 0.020	5.328 ± 0.029	5.520 ± 0.265	5.082 ± 0.201
10	*Cis*-9-hexadecenoic/palmitoleic	C16:1n7	0.169 ± 0.008	0.229 ± 0.008	0.304 ± 0.010	0.216 ± 0.012	0.238 ± 0.013	0.206 ± 0.0403
11	Heptadecanoic	C17:0	0.050 ± 0.001	0.101 ± 0.001	0.067 ± 0.000	0.055 ± 0.001	0.061 ± 0.003	0.054 ± 0.010
12	*Cis*-10-heptadecenoic	C17:1n7	-	0.029 ± 0.001	0.075 ± 0.000	0.062 ± 0.001	0.065 ± 0.004	0.064 ± 0.013
13	Octadecanoic/stearic	C18:0	3.944 ± 0.170	3.095 ± 0.075	1.303 ± 0.007	4.373 ± 0.038	4.150 ± 0.171	2.319 ± 0.012
14	*Trans*-9-octadecenoic/elaidic	C18:1n9t	-	-	-	0.031 ± 0.005	-	-

15	*Cis*-9-octadecenoic/oleic	C18:1n9	77.527 ± 1.031	40.982 ± 0.273	60.713 ± 0.037	80.865 ± 0.318	81.148 ± 0.634	83.157 ± 0.770
16	*Cis*-11-octadecenoic/vaccenic	C18:1n7	0.825 ± 0.041	0.390 ± 0.010	2.438 ± 0.022	0.935 ± 0.008	0.892 ± 0.032	0.865 ± 0.040
17	*Cis*-9,12-octadecadienoic/ linoleic	C18:2n6	10.793 ± 0.517	9.155 ± 0.172	19.954 ± 0.117	5.443 ± 0.145	5.581 ± 0.203	5.650 ± 0.161
18	*Cis*-6,9,12-octadecatrienoic	C18:3n6	-	-	-	0.024 ± 0.001	0.022 ± 0.002	0.028 ± 0.006
19	*Cis*-9,12,15-octadecatrienoic/α- linolenic	C18:3n3	0.141 ± 0.008	0.197 ± 0.005	8.249 ± 0.022	0.100 ± 0.001	0.176 ± 0.014	0.150 ± 0.012
20	Eicosanoic/arachidic	C20:0	0.403 ± 0.012	0.430 ± 0.007	1.196 ± 0.022	0.457 ± 0.007	0.224 ± 0.008	0.517 ± 0.109
21	*Cis*-11-eicosenoic/gondoleic	C20:1n9	0.288 ± 0.008	0.156 ± 0.003	1.282 ± 0.115	0.263 ± 0.005	0.240 ± 0.016	0.278 ± 0.014
22	Heneicosanoic	C21:0	0.007 ± 0.000	-	0.028 ± 0.000	0.007 ± 0.000	0.008 ± 0.000	-
23	*Cis*-11,14-eicosadienoic	C20:2n6	-	-	0.071 ± 0.000	-	-	-
24	Docosanoic/behenic	C22:0	0.896 ± 0.073	0.053 ± 0.002	0.499 ± 0.000	0.938 ± 0.031	0.804 ± 0.022	0.803 ± 0.022
25	*Cis*-13-docosenoic/erucic	C22:1n9	-	-	0.292 ± 0.001	-	-	-
26	Tricosanoic	C23:0	-	0.012 ± 0.000	0.031 ± 0.002	0.049 ± 0.000	0.052 ± 0.004	0.052 ± 0.011
27	Tetracosanoic/lignoceric	C24:0	0.360 ± 0.038	0.081 ± 0.002	0.223 ± 0.003	0.371 ± 0.017	0.312 ± 0.008	0.355 ± 0.033
28	*Cis*-15-tetracosenoic/nervonic	C24:1n9	-	-	0.212 ± 0.002	-	-	-
29	*Cis*-7,10,13,16,19-docosapentanoic	C22:5n3	0.125 ± 0.013	-	-	-	-	0.013 ± 0.001
Fat content (g/100 g product), n =3			28.24 ± 0.15	25.88 ± 0.13	12.81 ± 0.07	32.59 ± 0.04	27.05 ± 0.45	26.19 ± 0.11
SFA (g/100 g fat)/(g/100 g product)			10.131/2.861	48.862/12.646	6.410/0.821	12.047/3.926	11.628/3.146	9.589/2.511
MUFA (g/100 g fat)/(g/100 g product)			78.810/22.256	41.786/10.814	65.316/8.367	82.386/26.850	82.593/22.34	84.570/22.149
PUFA (g/100 g fat)/(g/100 g product)			11.059/3.123	9.352/2.420	28.274/3.622	5.567/1.814	5.779/1.563	5.841/1.530
TFA (g/100 g fat)/(g/100 g product)			-/-	-/-	-/-	0.031/0.01	-/-	-/-

Results are given as mean ± standard deviation (n = 2); SFA - saturated fatty acids; MUFA - monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; TFA – total *trans* fatty acids

Our results are in agreement with the ones obtained by Albuquerque et al. (2018) [28], where the values determined for SFA in the 47 potato products analyzed (chips, fried potatoes) were between 0.82 - 19.59 g/100 g product.

MUFA content varied between 41.786 to 84.570 g/100 g fat (8.367 - 26.850 g/100 g product). Oleic acid (C18:1n9) was the predominant acid in the analyzed chips samples, with values ranging between 40.982 to 83.157 g/100 g fat.

P1, P4, P5 and P6 samples at which the highest values of oleic acid (over 77%) were recorded indicates that they were fried in sunflower oil, as confirmed by the labeling declaration of the manufacturer. Similar results on MUFA content were obtained by Albuquerque et al. (2018), where MUFA values of the potato products analyzed ranged between 2.41 - 25.43 g/100 g food product.

Except for the P2 sample, which had a higher SFA content (48.862 g/100 g fat) versus MUFA (41.786 g/100 g fat), the other samples had a much lower content of SFA, ranged between 6.410 to 12.047 g/100 g fat, compared to MUFA, which had a level of 65.316 to 84.570 g/100 g fat.

Similar results were also found in the study of Wijesunder et al. (2007) [32] which showed a lower SFA content of 7.9-46.7 g/100 g fat potato chips than the MUFA content of 39.2-83.2 g/100 g fat. Also, Elias and Innis (2002) [33], found in potato chips the SFA values (27.8 g/100 g fat) intermediate to the results of our study.

The PUFA content of chips samples ranged from 5.567 to 28.274 g/100 g fat (1.530 - 3.622 g/100 g product). Linoleic acid (C18:2n6) is the predominated PUFA with values ranging between 5.443 - 19.954 g/100 g fat followed by α-linolenic acid (C18:3n3), with values between 0.100 - 8.249 g/100 g fat, the maximum value being obtained for P3 sample which was fried in rapeseed oil. It is known that the fatty acid composition of thermally treated potatoes reflects the oil in which was cooked [3], and in the case of P3 sample which was cooked in rapeseed oil, the composition in linoleic, linolenic acids, SFA, and MUFA is similar with the one reported by Chira et al. (2016) [22] who studied the fatty acids composition of rapeseed oil. Higher values of PUFA content than in our study were obtained in the study of Albuquerque et al. (2018) [28], where the average PUFA content of the potato products analysed was 7.15 g/100 g product.

From the 6 potato chips samples taken into study, only in P4 sample was identified and quantified, in a small percentage (0.031 g/100 g fat and 0.01 g/100 g product) *trans*-9-octadecenoic/elaidic acid (C18:1n9t). Elaidic acid is considered to develop hypercholesterolemia and increase the risk of coronary heart disease [34]. This TFA content is below the recommended or regulated values of some European countries of 2 g/100 g fat (Austria, Denmark, Iceland, Hungary, Sweden, etc.) [35].

These results are comparable to those reported by Cakmak et. (2011) [19] who found in potato crisps a TFA content ranged from 0.02 to 1.35 g/100 g fatty acids, with a mean value of 0.37 g/100 g fatty acids, of which, elaidic acid (C18:1n9t) had values ranging from 0 to 0.93 g/100 g fatty acids. In the study of Costa et al. (2016) [15], the TFA content of the potato chips and French fries analyzed was higher than the values of the present study but less than 2 g/100 g fat.

Low values of TFA (below 1%) were also obtained in the study realized by Albuquerque et al. (2018) [28], where the TFA content of the potato products analysed varied between 0 and 0.43 g/100 g product.

Higher values of the TFA content of potato chips ranging from 0.11 to 2.05 g/100 g fat were obtained in the study realized by Roe et al. (2013) [17], of which elaidic acid (C18:1n9t) showed values between <0.02 - 0.97 g/100 g fat.

In P3 sample, in addition to oleic (60.713 g/100 g fat), linoleic (19.954 g/100 g fat) and α-linolenic (8.249 g/100 g fat) acids which are present in a significant percentage comparing to the other samples, vaccenic acid (2.438 g/100 g

fat) and erucic acid (0.292 g/100 g fat), are also present, acids characteristic of the rapeseed oil composition. The results obtained are confirmed by the manufacturer's labeling declaration, which states as an ingredient the use of rapeseed oil in the chips preparation.

Although P1 (A), P4 (C), P5 (A), P6 (A), come from two different suppliers (A, C), there is no significant difference in the fat content and in the composition of SFA, MUFA and PUFA. All these samples are fried in the same type of oil, sunflower oil. There are significant differences between P2 and P3, since there were fried in palm oil, respectively rapeseed oil.

The variability in SFA, MUFA, PUFA in a food category is more influenced by the type of oil used in the technological process than the fat from the ingredients used, such as flour, potatoes, flavors used, etc. [5]. The differences observed between potato chips analyzed with respect to the fat content and fatty acid profile may be given in particular by the type of oil used in the production process (sunflower oil, rapeseed oil, palm oil or other combinations of hydrogenated or non-hydrogenated oils).

All chips samples were also examined for PUFA/SFA ratio (Figure 2) and omega-6/omega-3 ratio (Figure 3). With the exception of P2 sample, the chips analyzed showed a favorable PUFA/SFA ratio, ranging between 0.462 to 4.411 (Figure 2), falling within the WHO/FAO minimum recommended value of 0.4 for a balanced diet [26, 36].

The P2 sample had an unfavorable PUFA/SFA ratio (0.191), due to the fact that the SFA content had the highest values of 48.862 g/100 g fat. Regulation (EU) no. 1169/2011 [37] states that SFA consumption for certain types or category of foods should be up to 20 g/day.

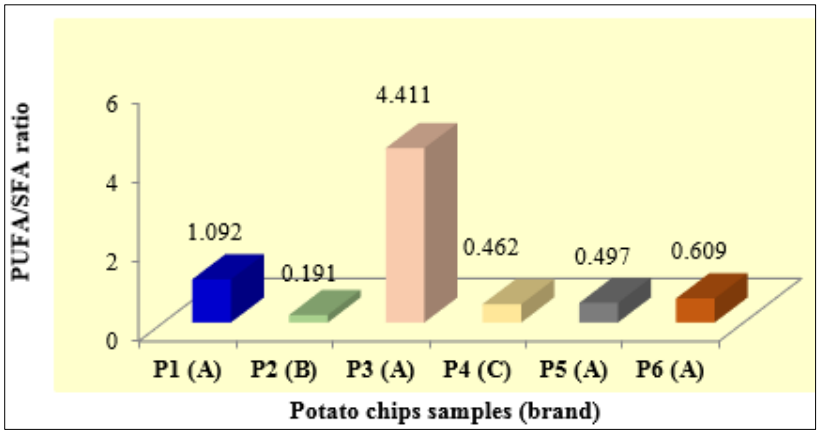

Fig. 2. PUFA/SFA ratio of potato chips analysed

In terms of omega-6/omega-3 ratio, P1, P2, P4, P5 and P6 samples showed a high content of omega-6 (5.467-20.256 g/100 g fat) and a low content of omega-3 (0.100 - 0.226 g/100 g fat), resulting in high ratio of 32 - 55 (Figure 3), exceeding the maximum value of 3 [27].

Among fatty acids, in potato chips samples, the predominant omega-6 was linoleic acid (C18:2n6), followed in some samples by small amounts of octadecatrienoic (C18:3n6) and eicosadienoic (C20:2n6) acids, while the predominant omega-3 fatty acid was linoleic acid (C18:3n3), and in some samples was found a small amount of docosapentanoic acid (C22:5n3).

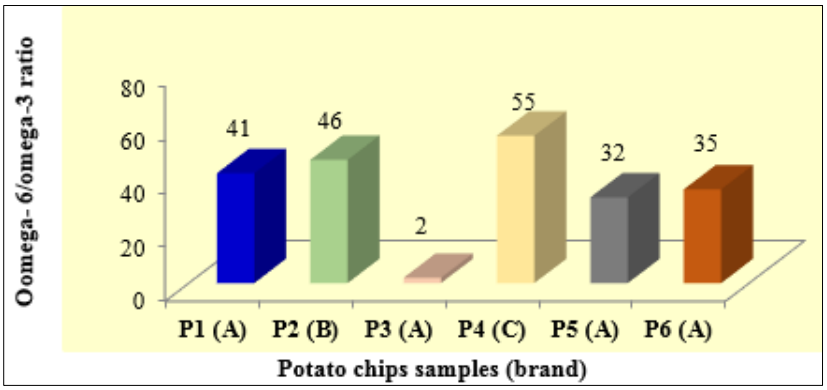

Fig. 3. Omega-6/omega-3 ratio of potato chips samples analyzed

Of the 6 analyzed products, only the P3 sample had a favorable omega-6/omega-3 ratio, and the sample could be considered as a source of polyunsaturated fatty acids. The good omega-6/omega-3 ratio of about 2 may be due, on the one hand, to the technological process of frying, and on the other hand, on the use of rapeseed oil, which is an important source of omega-3 and omega-6 polyunsaturated fatty acids.

The fat content, fatty acids (FAi) and trans fatty acids (t-FAi) profile of French fries samples

The total fat content also the individual and total SFA, MUFA, PUFA and TFA composition of French fries assortments analyzed, expressed in g/100 g fat, respectively 100 g product are presented in table 3. P11 sample presented a lower fat content (6.62 g/100 g product) compared to the other five samples which had a fat content between 11.49 - 17.54 g/100 g product.

In the case of P9 sample, similar results were obtained in the study realized by Santos et al. (2018) [5], where a fat content of 11.2% was found in fried potatoes samples prepared in rapeseed oil.

In the French fries samples were identified and quantified from 16 to 23 FAi as shown in Table 3. Figure 4 shows the chromatogram of FAi and TFAi of the P7 French fries sample.

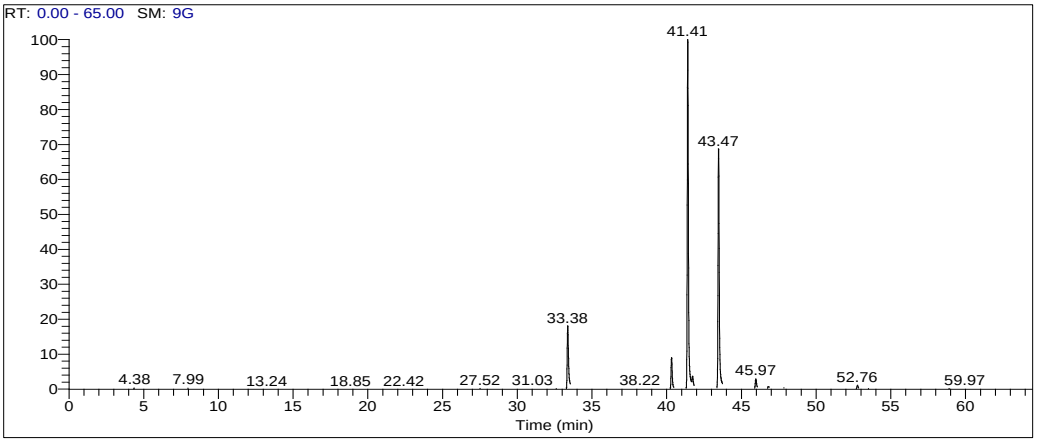

Fig. 4. Chromatogram of the P7 French fries sample

The SFA, MUFA and PUFA (g/100 g fat) profiles differ between the French fries assortments.

The SFA content of the six French fries samples ranged between 7.001 - 57.277 g/100 g fat, the predominant acids being palmitic and stearic acids and in the case of P8 sample compared to the other saturated fatty acids was obtained a high percent of lignoceric acid (4.205%). The other SFA components, identified and quantified in French fries samples, showed values below 1%. The lowest values of SFA content were recorded for the P10 (7.001%), P7 (9.610%) and P8 (10.937%) samples, the rest of it being characterized by a higher SFA content of more than 39 g/100 g fat. The obtained SFA content (0.987 - 6.581 g/100 g product) is similar to the one reported by Albuquerque et al. (2018) [28], where the mean SFA content was 5.57 g/100 g product.

In the case of P9 sample, our results are in accordance with those of Li et al. (2017) [9], who obtained a similar fatty acids composition of French fries prepared in palm oil, thus considering that the P9 sample was fried in palm oil.

The MUFA content of the six French fries samples ranged between 35.281 - 57.894 g/100 g fat, respectively 2.699 - 9.353 g/100 g product. The monounsaturated fatty acids predominant were oleic and vaccenic acids.

Li et al. (2017) [9] studied the fatty acid profile of potatoes fried in palm oil, and the MUFA content obtained had values of 47.55 g/100 g fat and much lower MUFA values were obtained for potatoes fried in coconut oil, 10.57 g/100 g fat. Lower MUFA values were recorded in the study reported by Albuquerque et al. (2018) [28], yielding the highest MUFA values of 25.43 g/100 g product.

P9 and P11 samples had a higher content of SFA than MUFA. In the case of P7, P8 and P10 samples, the SFA levels were significantly lower, ranging from 7.001 to 10.937 g/100 g fat compared to MUFA which ranged from 43.607 to 57.894 g/100 g fat. For P12 sample the SFA content was almost equal to the MUFA content (around 40 g/100 g fat).

The PUFA content of the six fried potato samples varied between 7.442 - 49.392 g/100 g fat and 0.578 - 6.964 g/100 g product. From PUFAs, linoleic acid predominates in all French fries sample, the value ranging from 7.226% (P9) to 46.896% (P10).

Although the manufacturer's nutrition labeling statement does not specify the type of vegetable oil used to fry the potatoes, the presence of erucic acid (0.155%), the content of oleic acid (51%) and linoleic acid (34%) in the sample

P7, suggests the possibility that the sample was fried in a mixture of sunflower oil and rapeseed oil. P8 and P10 samples had a high content of oleic (42 - 56%) and linoleic acid (28 - 47%), leading

to the conclusion that these samples were possibly fried in sunflower oil, and samples P9, P11 and P12, had a high content of palmitic acid (35 - 51%), which means that it were possibly fried in palm oil.

The values found are below the recommended value of 2 g/100g fat [36, 38]. Low values of TFA were also obtained in the studies realized by Costa et al. (2016) [15] and Albuquerque et al. (2018) [28], where the TFA content of the potato products analyzed were lower than 2 g/100 g fat).

Table 3
TOTAL FAT CONTENT AND INDIVIDUAL AND TOTAL FA AND TFA COMPOSITION (%, G/100 G FAT) OF THE FRENCH FRIES SAMPLES

No.	FAi/t-FAi components	Code FAi/TFAi	P7	P8	P9	P10	P11	P12
1	Octanoic/caprylic	C8:0	0.047 ± 0.006	-	-	-	-	-
2	Dodecanoic/lauric	C12:0	0.012 ± 0.001	-	-	-	0.510 ± 0.091	0.171 ± 0.003
3	Tetradecanoic/myristic	C14:0	0.055 ± 0.006	-	1.546 ± 0.403	-	2.519 ± 0.396	0.890 ± 0.028
4	Pentadecanoic	C15:0	0.017 ± 0.002	0.016 ± 0.002	0.059 ± 0.015	0.021 ± 0.008	0.085 ± 0.015	0.032 ± 0.001
5	Hexadecanoic/palmitic	C16:0	3.883 ± 0.345	3.469 ± 0.003	51.306 ± 0.420	4.065 ± 0.033	42.854 ± 0.203	35.098 ± 0.099
6	*Cis*-9-hexadecenoic/palmitoleic	C16:1n7	0.199 ± 0.014	0.165 ± 0.021	0.200 ± 0.047	0.243 ± 0.113	0.414 ± 0.092	0.248 ± 0.012
7	Heptadecanoic	C17:0	0.047 ± 0.003	0.041 ± 0.006	0.137 ± 0.028	0.058 ± 0.021	0.205 ± 0.050	0.082 ± 0.002
8	Octadecanoic/stearic	C18:0	3.997 ± 0.292	1.902 ± 0.015	3.547 ± 0.044	1.902 ± 0.012	3.030 ± 0.009	3.001 ± 0.088
9	*Trans*-9-octadecenoic/elaidic	C18:1n9t	0.084 ± 0.003	0.055 ± 0.010	0.100 ± 0.025	-	-	-
10	*Trans*-11-octadecenoic/vaccenic	C18:1n7t	-	-	0.024 ± 0.005	-	-	-
11	*Cis*-9-octadecenoic/oleic	C18:1n9	50.994 ± 4.050	55.933 ± 0.515	33.826 ± 0.277	41.729 ± 0.307	39.656 ± 0.515	39.064 ± 0.079
12	*Cis*-11-octadecenoic/vaccenic	C18:1n7	1.054 ± 0.114	0.943 ± 0.018	0.980 ± 0.173	1.155 ± 0.017	0.349 ± 0.047	0.976 ± 0.001
13	*All trans* 9,12-octadecadienoic/ linoelaidic	C18:2n6t	0.028 ± 0.001	0.027 ± 0.003	-	0.024 ± 0.006	-	-
14	*Cis*-9,12-octadecadienoic/linoleic	C18:2n6	34.245 ± 2.904	28.140 ± 0.377	7.226 ± 0.124	46.896 ± 0.091	8.160 ± 0.253	19.375 ± 0.238
15	*Cis*-9,12,15-octadecatrienoic/α-linolenic	C18:3n3	2.778 ± 0.168	3.002 ± 0.289	0.216 ± 0.048	2.472 ± 0.019	0.575 ± 0.090	0.230 ± 0.005
16	Eicosanoic/arachidic	C20:0	0.482 ± 0.032	0.496 ± 0.038	0.516 ± 0.112	0.245 ± 0.024	0.995 ± 0.173	0.364 ± 0.001
17	*Cis*-11-eicosenoic/gondoleic	C20:1n9	0.772 ± 0.054	0.798 ± 0.068	0.151 ± 0.030	0.407 ± 0.063	0.352 ± 0.066	0.151 ± 0.002
18	Heneicosanoic	C21:0	0.012 ± 0.001	-	-	-	-	-
19	*Cis*-11,14-eicosadienoic	C20:2n6	0.015 ± 0.001	-	-	-	-	-
20	Docosanoic/behenic	C22:0	0.749 ± 0.060	0.780 ± 0.056	0.068 ± 0.013	0.333 ± 0.024	0.112 ± 0.019	0.175 ± 0.010
21	*Cis*-13-docosenoic/erucic	C22:1n9	0.155 ± 0.010		-	-	-	-
22	Tricosanoic	C23:0	0.036 ± 0.001	0.028 ± 0.000	-	0.035 ± 0.011	0.011 ± 0.000	0.013 ± 0.000
23	Tetracosanoic/lignoceric	C24:0	0.274 ± 0.029	4.205 ± 0.405	0.098 ± 0.022	0.341 ± 0.120	0.172 ± 0.034	0.130 ± 0.013
24	*Cis*-15-tetracoseinoic/nervonic	C24:1n9	0.066 ± 0.001		-	0.073 ± 0.032	-	-
Fat content (g/100 g product), n =3			17.54 ±0.21	15.24 ± 0.40	11.49 ± 0.06	14.10 ± 0.16	6.62 ± 0.28	14.27 ± 0.14
SFA (g/100 g fat)/(g/100 g product)			9.610/1.686	10.937/1.667	57.277/6.581	7.001/0.987	50.493/3.343	39.956/5.702
MUFA (g/100 g fat)/(g/100 g product)			53.324/9.353	57.894/8.823	35.281/4.054	43.607/6.148	40.771/2.699	40.439/5.771
PUFA (g/100 g fat)/(g/100 g product)			37.066/6.501	31.169/4.750	7.442/0.855	49.392/6.964	8.736/0.578	19.605/2.798
TFA (g/100 g fat)/(g/100 g product)			0.112/0.019	0.082/0.012	0.124/0.014	0.024/0.003	-/-	-/-

Results are given as mean ± standard deviation (n = 2); SFA - saturated fatty acids; MUFA - monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; TFA – *trans* fatty acids

Higher levels of TFA, between 0.10 and 3.65 g/100 g fat, compared to the results of the present study, were obtained by analyzing French fries samples collected from eight food service retailers from the Honolulu market [39]. The use of hydrogenated fats for frying leads to an increase in TFA values in fried potatoes. Thus, the choice of fat type is important for the formation of TFA in food during the frying process.

All French fries samples were also examined for PUFA/SFA ratio (Figure 5) and omega-6/omega-3 ratio (Figure 6).

The ratio between PUFA and SFA was favorable for samples P7, P8, P10 and P12, ranging from 0.491 to 7.054, falling within the recommended value of at least 0.4 for a balanced diet [26, 36]. For P9 and P11 samples, this ratio was below 0.4 due to the high SFA content given by palmitic acid values. SFA are generally labeled as the cause of cancer and coronary heart disease, and therefore the WHO [40] recommends that their caloric intake to be <10% of the energy value of the product.

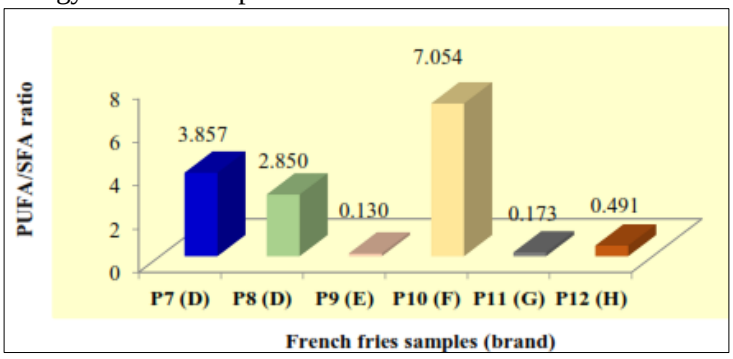

Fig. 5. PUFA/SFA ratio of French fries samples analyzed

For all French fries samples, the high content of omega-6 (7.226 - 34.260 g/100 g fat) and very low content of omega-3 (0.216 - 3.002 g/100 g fat) determined a high omega-6/omega-3 ratio, ranging from 9 to 84, exceeding the recommended maximum value of 3 (Figure 6).

In French fries samples, the predominant omega-6 fatty acid was linoleic acid (C18:2n6), followed in P7 sample by a small amount of eicosadienoic (C20:2n6) acid, while the predominant omega-3 fatty acid was linoleic acid (C18:3n3).

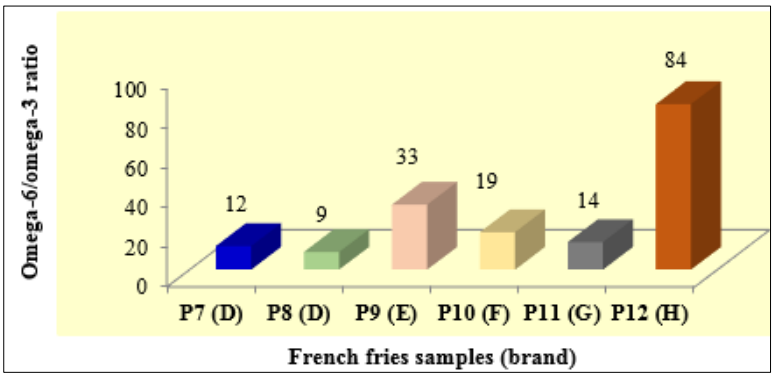

Fig. 6. Omega-6/omega-3 ratio of French fries samples analyzed

Of the 6 products analyzed, no sample is in the PUFA/SFA ratio recommended, the French fries samples making no nutritional intake to consumers from the point of view of polyunsaturated fatty acids.

Conclusions

This study provides an overview of the fatty acids and *trans* fatty acids composition of chips and French fries marketed in Bucharest, Romania. The results showed that variations in fat content, SFA, MUFA, PUFA and TFA within the same food category or between different brands of the same food product were recorded between the samples.

Samples of potato chips and French fries were free of *trans* fats or, in some samples, the *trans* fats were very low, less than 0.2 g/100 g fat, which means below the 2% recommended by some European countries, thus it can not be considered a public health problem.

The content of SFA, MUFA and PUFA, expressed as g/100 g fat, varied between the potato chips and French fries samples analyzed. The predominant acids in chips and fried potato samples were palmitic, oleic and linoleic acid.

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