Turk J Chem
26 (2002) , 705 – 710.

Determination of Fatty Acid Composition and Total *Trans* Fatty Acids in Cereal-Based Turkish Foods

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Received 25.06.2001

The fatty acid composition and *trans* fatty acids of 13 cereal-based foods produced by Turkish companies were analysed by capillary gas-liquid chromatography. The total fat contents of the samples ranged from 1.8 to 37.9%. Traditional Turkish white bread and bulgur had the lowest fat content (1.8% and 2.3% respectively) and wafer the highest (37.9%). The major fatty acids in the samples were $C_{16:0}$, $C_{18:0}$, *trans* $C_{18:1}$, $C_{18:1}$ and $C_{18:2}$. Total unsaturated fatty acid contents varied between 49.0 and 80.3% of total fatty acids, and bulgur had the highest percentage among the samples. Except for bulgur, all the samples contained *trans* fatty acids (weight percentage of methyl esters) ranging from 0.1 to 31.0% of the total. Bulgur did not contain detectable levels of *trans* fatty acids while white bread and corn chips contained trace amounts: 0.1% and 0.7% respectively.

Key Words: Capillary gas-liquid chromatography, cereal foods, fatty acid composition, *trans* fatty acids

Introduction

In order to reduce the saturated fat content of processed foods, the food industry in developed countries has moved progressively from animal fat to vegetable fat sources. The fatty acid composition of hydrogenated fat is complex with monoene fatty acids (*cis* and *trans*) possessing double bonds at positions 4 to 16, depending on the hydrogenation technique. In general, the percentage of unsaturated fatty acids in processed foods containing hydrogenated fat is higher than that of saturated fatty acids. The major fatty acids present in most cereal products, excluding *trans* fatty acids (TFAs), are $C_{16:0}$, $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$[1–3].

TFAs are formed by partial hydrogenation of vegetable oils for manufacture of shortenings and margarines. In general, the concentration of TFAs in a partially hydrogenated oil increases with increasing hydrogenation. Partially hydrogenated oils are now used in place of palm oil in many processed foods and therefore TFAs are found in a wide variety of foods. They are also produced in ruminants via bacterial action, and occur naturally in dairy and other animal fats. Although rare, TFAs have been reported in six species of plants[1,4–7].

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There is concern about the safety of TFAs in the diet, because of a possible relationship between TFA intake and cardiovascular disease. Intake of TFAs has been shown to increase the concentration of low-density lipoproteins in the blood and decrease the concentration of high-density lipoproteins[8−11].

TFAs are found in a wide variety of foods and their amount varies widely within and between different countries. Erp et al.[12] have analysed TFAs in bakery products from 14 European countries. According to their results, levels ranged from less than 1 to 28% while 60% of the 203 cookies and biscuits sampled had TFA contents of 1-10%. Total *trans* fatty acid (TFA) contents in sweet pastries/cakes, croissants, doughnuts, bread and pizza varied between 1 and 33, 4 and 14, 2 and 32, 1 and 8, and 1 and 5%, respectively. Aro et al.[13] have also found that high fat frosted breakfast cereals such as muesli contained high TFA levels (18.9-23.7%) while many savoury snacks were low in TFA. Steinhart and Pfalzgraf[14] have determined the TFA contents of some German foods as follows: shortenings 0.1-31.8%, margarines 0.6-23.5%, cakes and cookies 0-15.5%, crisps and other snacks 0.1-20.2%. In research on the fatty acid composition of imported and domestic cookies, biscuits and crackers available in Japan, the major fatty acid present in all products tested was *trans* $C_{18:1}$. In most imported products, TFAs were present at levels greater than 20%, while in domestic products TFAs were less than 15%[15].

So far, limited research has been carried out on TFAs in Turkey. According to various research results, the ranges of TFA contents in some Turkish foods were as follows: hydrogenated sunflower oil 7.31-56.24%[16]; soft margarines 5.6-6.7%, and hard margarines 16.0-18.3%[17]; biscuit types 1.9-30.5%[3]; puff pastries 12.3-16.5%[18,19]; butter 5.81-16.72%[20]. This research extends the data on the fatty acid composition and TFAs of cereal-based foods commonly sold in Turkish shops. The *trans* isomers of the samples were also evaluated in relation to health.

Experimental

The cereal-based food items used as research material were purchased from local supermarkets and bakeries. An attempt was made to select commonly consumed nationally available brands. A total of 13 different cereal based food were analysed twice at three-month intervals. Fatty acid methyl ester (FAME) standards (99% purity) were purchased from Nu-Chek-Prep. Inc. (Elysian, MN).

Extraction of the lipids. Most food items were extracted and submitted to analysis shortly after they were purchased. When the time between purchase and analysis was longer than normally encountered in the home, foods were stored and refrigerated (4°C) or frozen (-20°C) as appropriate for the individual food item. Lipid extraction from the samples was carried out with hexane under the operating conditions specified in ICC Standard No. 136, and expressed as a percentage by mass of the product as received[21].

Preparation of Fatty Acid Methyl Esters (FAMEs). FAMEs were prepared from the fats after alkaline hydrolysis, followed by methylation in methanol with BF_3 as catalyst[22]. The final concentration of FAMEs was approximately 7 mg/mL in heptane.

Capillary Gas-Liquid Chromatography (GLC). Analyses of the FAMEs by capillary GLC were carried out on a Hewlett-Packard 6890 chromatograph, equipped with a flame-ionization detector (FID) on a split injector (Varian Chrompack International, Middelburg, the Netherlands). A fused-silica capillary column (CP^{TM}-Sil 88, 50 m x 0.25 mm i.d., 0.2 μm film) Chrompack was used for FAMEs analysis. The column was operated isothermally at 177°C, and the injector and detector were kept at 250°C. The carrier gas was helium at a flow rate of 1 mL/min.

Results and Discussion

The total fat contents, and *cis* and TFAs isomers of the 13 selected cereal-based foods produced in Turkey are given in the Table. It is clear from the table that their fat contents varied widely. As expected, traditional Turkish white bread and bulgur contained the lowest amounts of fat, 1.8% and 2.3% respectively. The highest amount was found in wafers with 37.9%, and chocolate wafers, doughnuts, oat biscuits, corn chips and puff dough followed this with fat contents of 36.8%, 23.4%, 22.9%, 22.0% and 21.2% respectively. Except for white bread and bulgur, all the analysed samples are rich in fat and mostly hydrogenated oils are used in their production.

The major fatty acids in the samples were $C_{16:0}$, $C_{18:0}$, *trans* $C_{18:1}$, $C_{18:1}$ and $C_{18:2}$, and the other fatty acids except $C_{12:0}$, $C_{14:0}$, *trans* $C_{18:2}$ such as in doughnuts were around 1% or less in the samples. Total unsaturated fatty acid contents ranged from 49.0 to 80.3% of the total fatty acids and the major proportion of them was composed of monounsaturated fatty acids. On the other hand, total unsaturated fatty acid (TUSFA) contents of the white bread and bulgur were relatively high (74.9% and 80.3% respectively) and a large percentage of the unsaturated fatty acids of these two samples was composed of polyunsaturated fatty acids, mainly $C_{18:2}$.

The majority of samples contain TFAs and the level ranged from 0.1 to 31.0% of the total fatty acids. The highest amount of TFAs was determined in doughnuts (31.0%). Foods such as muesli, wafers, chocolate wafers, oat biscuits, petit beurre biscuits, puff dough and fruit cake contained more than 15% of the total fatty acids. The predominant *trans* isomer found in all samples except bread and bulgur was *trans* $C_{18:1}$ monounsaturated fatty acid and ranged between 0.4 and 28.1% of the total fatty acids (Figure). Ronald et al.[23] also reported that *trans* monounsaturated fatty acids with 18 carbon atoms (*trans* $C_{18:1}$) are typically abundant in hydrogenated vegetable oils. As *trans* polyunsaturated fatty acids, *trans* $C_{18:2}$ was detected in the majority of samples, varying between 0.3 and 2.4%. However, *trans* $C_{18:3}$ was only found in doughnuts and white bread at levels of 0.5% and 0.1% respectively. If we ignore the 0.1% level of TFAs, luckily bread and bulgur, basic foods of Turkish people, did not contain TFAs. We may also put corn chips into the same category. Food processing, except for hydrogenation, did not substantially alter the fatty acid composition. Significant differences in total fat and TFAs levels among the analysed samples can be attributed to the amount and composition of the shortening used in production. Our results are similar to those determined by Erp et al.[12], Aro et al.[13], Steinhart and Pfalzgraf[14] and Ochi et al.[15].

In recent years, there has been concern about the safety of TFAs in the diet. Intake of foods which are significant sources of TFAs (margarine, cake, cookies, doughnuts, puff dough etc.) is associated with higher coronary heart disease risk. TFAs, created by the partial hydrogenation of vegetable oils, can affect the ratio of high density lipoprotein to cholesterol. The intake of TFAs from an average diet could be high enough to negate the serum cholesterol lowering effect of a decreased intake of saturated fat[1,24]. TFAs may increase coronary heart disease risk by raising the serum cholesterol level and inhibiting delta 6 desaturase activity, which converts linoleic acid into the long chain polyunsaturated fatty acid. Results suggest that *trans* linolenic acid has a negative impact in that it decreased the good cholesterol and raised the ratio of total cholesterol to good cholesterol[25].

TFAs from partially hydrogenated oils have been a component of the human diet since the early 20^{th} century. Their content in foods is not given in most nutrient data banks, which makes it difficult to obtain

Table. Total fat percentages and fatty acid composition of selected cereal-based Turkish foods (weight percentage of methyl esters)

Fatty acids	bulgur	chocolate wafer	corn chips	cocoa cake	cracker	doughnut	fruit cake	muesli	oat biscuit	petit beurre	puff dough	wafer	white bread
Total fat (%)	2.3	36.8	22.0	18.5	14.3	23.4	16.6	19.0	22.9	13.0	21.2	37.9	1.8
$C_{8:0}$	-	0.1	0.3	0.1	-	0.7	0.1	-	-	0.1	0.1	0.2	-
$C_{10:0}$	-	0.1	0.2	0.1	-	0.6	0.1	-	0.1	0.1	0.1	0.2	-
$C_{12:0}$	-	0.3	0.3	0.4	0.5	5.4	0.3	0.3	0.2	0.2	0.4	1.4	-
$C_{14:0}$	0.1	0.9	0.9	0.8	1.1	2.6	0.6	0.6	0.5	0.5	0.8	1.1	0.1
$C_{16:0}$	18.2	26.5	37.4	31.2	44.2	15.4	23.4	21.3	24.7	30.2	30.3	28.1	23.3
$C_{16:1}$	0.9	0.6	0.3	0.5	0.3	0.3	0.4	0.2	0.3	0.4	0.2	0.2	0.7
$C_{18:0}$	0.8	8.3	4.1	5.9	4.8	8.1	7.5	10.3	6.5	8.1	8.0	8.5	1.1
$C_{18:1}$ *trans*	-	21.2	0.4	4.1	1.8	28.1	14.2	26.0	18.8	17.2	14.3	24.2	-
$C_{18:1}$	18.3	36.6	41.6	31.4	37.2	27.9	34.0	33.1	37.9	32.1	27.2	28.4	13.2
$C_{18:2}$ *trans*	-	0.6	0.3	0.5	0.3	2.4	1.2	1.0	1.5	1.8	2.0	2.4	-
$C_{18:2}$	56.8	3.7	13.5	24.1	9.1	6.2	16.7	6.4	8.4	8.3	14.3	4.9	57.3
$C_{18:3}$ *trans*	-	-	-	-	-	0.5	-	-	-	-	-	-	0.1
$C_{18:3}$	4.1	0.1	0.3	0.4	0.2	0.2	1.0	0.3	0.3	0.3	1.5	0.1	3.3
$C_{20:0}$	0.4	0.7	0.3	0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.5	0.3	0.4
$C_{20:1}$	0.2	0.1	0.1	0.1	0.1	-	-	0.1	0.2	0.1	-	-	0.3
$C_{20:2}$	-	-	-	-	-	0.5	-	-	0.1	0.1	-	-	-
$C_{22:0}$	0.2	0.2	-	0.1	-	0.5	0.2	-	0.2	0.1	0.3	-	0.2
$C_{22:1}$	-	-	-	-	-	0.2	-	-	-	-	-	-	-
TSFA	19.7	37.1	43.5	38.9	51.0	33.7	32.5	32.9	32.5	39.7	40.5	39.8	25.1
TMUSFA	19.4	58.5	42.4	36.1	39.4	56.5	48.6	59.4	57.2	49.8	41.7	52.8	14.2
TPUSFA	60.9	4.4	14.1	25.0	9.6	9.8	18.9	7.7	10.3	10.5	17.8	7.4	60.7
TUSFA	80.3	62.9	56.5	61.1	49.0	66.3	67.5	67.1	67.5	60.3	59.5	60.2	74.9
TTFA	-	21.8	0.7	4.6	2.1	31.0	15.4	27.0	20.3	19.0	16.3	26.6	0.1
TUSFA/TSFA	4.1	1.7	1.3	1.6	1.0	2.0	2.1	2.0	2.1	1.5	1.5	1.5	3.0

TSFA = total saturated fatty acid; TMUSFA = total monounsaturated fatty acid; TPUSFA = total polyunsaturated fatty acid;
TUSFA = total unsaturated fatty acid; TTFA = total *trans* fatty acid

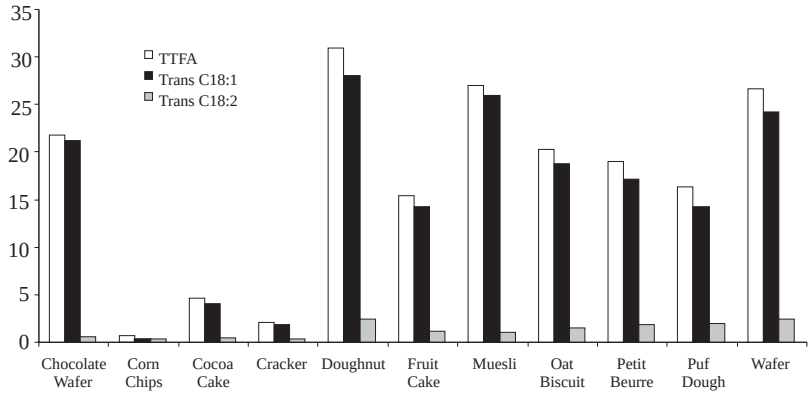

Figure. Total and major TFAs percents of total fatty acids in some cereal based foods

a reliable estimate of current intake. Based on published data, the estimated intake of *trans* $C_{18:1}$ in Western countries varies between 2 and 12 g per day or 5-7% of total fatty acids. The variation in intake between individuals is also very large[23]. The available information is not sufficient to give any particular consumption rate of TFAs for Turkish people. However, it is clear that traditional nutrition habits depending on homemade cereal foods have already been replaced by Western-style nutrition in industrialised regions of the country.

Conclusion

The results of this study indicate that the samples analysed, except for white bread and bulgur, contain considerable amounts of fat and TFAs. Of the 13 selected cereal based food items, only bulgur did not contain measurable levels of TFAs. There were wide variations in either total fat or TFAs percentages among the samples. It is obvious that it attention should be paid to the consumption of cereal foods when considering the health aspects of TFAs. On the other hand, future regulations on the nutritional labelling of foods related with TFAs contents will provide better knowledge for the consumer.

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