Nutrition and Food Sciences Research Vol 10, No 4, Oct-Dec 2023, pages: 11-18

Original Article

Comparative Study of Total Fat, Trans and Saturated Fatty acids Contents of the Industrial and Guild-fried Foods in Iran

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Received: February 2024 Accepted: June 2024

ABSTRACT

Background and Objectives: The quantity of absorbed oil in fried foods is a concern issue due to the presence of unhealthy trans fatty acids and alteration of nutrients and consequently their effects on public health. Therefore, the aim of the present study was to investigate fat contents of the guild and industrial fried foods in Iran and compare these content values with those of the national standards.

Materials and Methods: In this study, total fat, saturated and trans fatty acid contents of 142 industrial (potato chips, shoestring potatoes and onions) and guiled (potato chips, potatoes, onions and garlics) fried foods from various regions of Iran in two consecutive years were assessed. First, Soxhlet extraction was used to extract fats. Then, all free acids were methyl-esterified and detected using gas chromatography. Compliance of total fat, saturated fatty acid and trans fatty acid contents of each fried food with Iranian national standards (INS) was assessed. Significant differences between the means of fatty acid composition of the fried foods were reported using ANOVA and Duncan post hoc tests ($p < 0.05$).

Results: The mean fat concentrations of industrial (41.30%) and guild potato chips (42.89%) in 2017 and industrial potato chips (38.83%) in 2019 were higher than the Iranian national standards (38% w/w). The mean of saturated and trans fatty acids in the oily phase of guild potato chips was statistically different in 2017 and 2019 ($p < 0.05$). Significant differences were seen between the quantities of saturated fatty acids in the oily phase of shoestring potatoes in 2017 and 2019, while no significant differences were seen between the total fat, saturated and trans fatty acids of guild-fried potatoes in 2017 and 2019 ($p < 0.05$). Furthermore, levels of trans fatty acids in the oily phase of industrial fried onions (2.23%) and guild-fried garlics (2.41%) in 2019 were above the Iranian national standards (2% w/w).

Conclusions: It seems that actions are needed to decrease the absorbed fats by fried products.

Keywords: Fried foods, Total fat, Saturated fatty acids, Trans fatty acids, Iran

Highlights

- In 2019, the fat content of industrial potato chips was higher than the Iranian standard.
- Levels of total fat, SFAs and TFAs in fried onions were relatively high.
- The quantity of total fat, SFAs and TFAs in industrial and guild fried foods depends on the type of oils used to produce these products.

Introduction

Fried products are popularly interested by the consumers and their consumption has increased worldwide (1). This increasing popularity is attributed to the unique characteristics of fried foods such as golden-brown color, crispy texture and favorable aroma (2). However, a considerable issue is absorption of the high oil content during frying, which includes negative effects on human health. Frying is one of the conventional and most popular technologies for preparing various foods, especially potato donuts, fish sticks, French fries, chips and fried chicken

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products (3). Complex chemical reactions occur because of the interactions between the fried foods and frying oil, including Maillard reaction, protein denaturation, dehydration and starch gelatinization, that lead to a series of favorable and unfavorable changes in the final products (4). During frying, mass and heat transfers are between the frying oil and foods where oil is used as an energy transfer agent from the heat source to the products (5). Transfer of moisture and oil are two types of mass transfer, where moisture migration from inside to outside of foods happens at first and then the oil penetrates the food (6). There is a direct strong correlation between absorption of oil and moisture loss. However, food surface area, moisture content of the food, frying time and oil temperature affect quantity of the oil absorption (7, 8).

Oil absorption happens during the cooling of products after frying (9). In a study on the quantity of oil absorption into potato chips through deep fat frying, results indicated that nearly 20 and 80% of the oil were absorbed during the deep fat frying and cooling process, respectively (10). In another study, 35% of the total oil were at the surface and 65% were absorbed by the chips during cooling whereas only 38% of the total oil were absorbed during the deep frying (11). Other studies have reported that oil absorption is majorly during the cooling rime because oil migration is restricted by the rapid evaporation of moisture and formation of a thick crust during deep-frying (12, 13). Pedreschi et al. (2008) observed that the total fat content of French fries reached from 0.2 to 14% after deep frying (14). Hence, fried products include higher lipid contents and calories than those non-fried foods do, owing to oil absorption and nutritional changes (6). Furthermore, carcinogens such as polycyclic aromatic hydrocarbons, heterocyclic amines, acrylamide and trans fatty acids (TFAs) as health risk agents can be generated during frying, which pose potential threats to the safety and quality of foods (15). Thus, consumption of fried foods is a major concern due to the excessive intake of lipids, which increases risks of obesity and other fat-linked diseases such as high blood pressure, high cholesterol and CVDs (CVDs) (16).

In general populations, prevalence of obesity has increased over the past four decades based on the World Health Organization (WHO) reports (17). In a survey in 2011, 27.7 and 14% of the Iranian females and males were obese, respectively (18). If fried oil is used more than once, hazard of atherosclerosis increases because essential fatty acids are lost and TFAs are enhanced. Therefore, it becomes necessary for the consumers to be aware of which type of industrial or guild-fried products generate a fewer food hazard factors and possibly cause less harms to their health. To the best of the authors' knowledge, no comprehensive survey has been carried out on the total fat, TFA and saturated fatty acid (SFA) contents of industrial and guild-fried foods such as potato chips, shoestring potato, fried potato, fried garlics and fried onions in Iran. This study aimed to analyze various fried products and compare their results with the available results. Hence, total fat, saturated fatty acid and TFA contents of common industrial and guild-fried products were assessed first and then their resulted data were compared with the available data and national standards.

Materials and Methods

Materials

Total fat, SFA and TFA contents of 142 samples of common fried foods were investigated, 2017 and 2019. Therefore, 25 samples of industrial potato chips, eight industrial shoestring potatoes, seven industrial fried onions, 16 guild-potato chips, 55 guild-fried potatoes, 20 guild-fried onions and 11 guild-fried garlics were selected from various regions of Iran. Industrial fried foods (brands of large-scale food companies) and guild-fried foods (produced by traditional methods) were purchased from local supermarkets and stores in Iran, respectively. All reference standards, chemicals and reagents were supplied by Sigma Aldrich, St. Louis, MO, USA, with a minimum purity of 99%.

Soxhlet Extraction

Fat was extracted using Soxhlet instrument (Corning, USA). Guild-fried potatoes, onions and garlics and industrial-fried onions were dried at 70 ℃ using vacuum oven (Tel Co., Model 29, USA) and extraction was then carried out. Five grams of each sample were transferred into a cellulose extraction cartridge in the Soxhlet siphon. The Soxhlet instrument was fitted to a distillation flask containing 70 ml of *n*-hexane (99%) and a few boiling glass regulators. Extraction was carried out for approximately 16 h. At the end of the extraction, the achieved oil was recovered by evaporating the solvent (*n*-hexane) using vacuum rotary evaporator (Heidolph, Germany) (19).

Preparation of Fatty Acid Methyl Esters

Based on the ISO procedure (20), methyl-esterified fatty acids were prepared and detected using gas chromatography (GC, Varian, CP3800; USA). Thus, extracted fatty acids were methylated using 2 N methanolic potassium hydroxide and heptane for GC analysis. A specified quantity of methyl ester heptadecanoic acid was used as an internal standard. After stirring for 30 s and setting to separate the two phases, the organic higher phase containing dissolved methyl esters in heptane was stored for injection into GC.

Fat Content

Fatty acid methyl esters (FAMEs) were identified using gas chromatography (Varian, CP3800; USA) equipped with a flame ionization detector (GC-FID). Capillary column HP88 with a length of 100 m, a coating thickness of 0.2 µm and an outer diameter of 25 mm was used to separate the analytes. Helium (99.99%) was used as the carrier gas with

a flow rate of 1 ml min^{-1}. The injector and detector temperatures were set at 280 and 250 ℃, respectively. The GC oven temperature was set to shift from 40 ℃ for 5 min to 140 °C at a rate of 5 °C min^{-1} and then increase to 240 °C at 100 °C min^{-1}. Three injections were carried out for quantification of each fatty acid.

Statistical Analysis

Results were expressed as means of total fat, SFAs and TFAs of the fried foods. Moreover, ANOVA with Duncan post hoc tests were used to assess significant differences between the fatty acid compositions of fried foods in 2017 and 2019. In general, $p < 0.05$ was recorded as the significance level.

Results

Based on the Iranian National Standard for potato chips, the maximum allowable level of absorbed oil is 38% (w/w) (21). The mean fat contents of industrial potato chips were 41.30 and 38.83% in 2017 and 2019, respectively. Nearly 45.45 and 57.14% of the samples of industrial potato chips in 2017 and 2019 complied with the Iranian national standard, respectively (Figure 1). Results in Tables 1 and 2 show that the mean total fat and SFA contents of potato chips in 2017 and 2019 were statistically different ($p < 0.05$). The total fat content of guild potato chips complied with the Iranian National Standard in 2019 while nearly 33% of the guild potato chips in 2017 did not (Figure 1). The means of SFAs and TFAs in the oily phase of guild potato chips were statistically different in 2017 and 2019 (Table 2). Based on the serving size of potato chips (28 g), the average daily per capita intakes of total fat, SFAs and TFAs in industrial potato chips were 10.87, 4.39 and 0.05 g, respectively (Table 3).

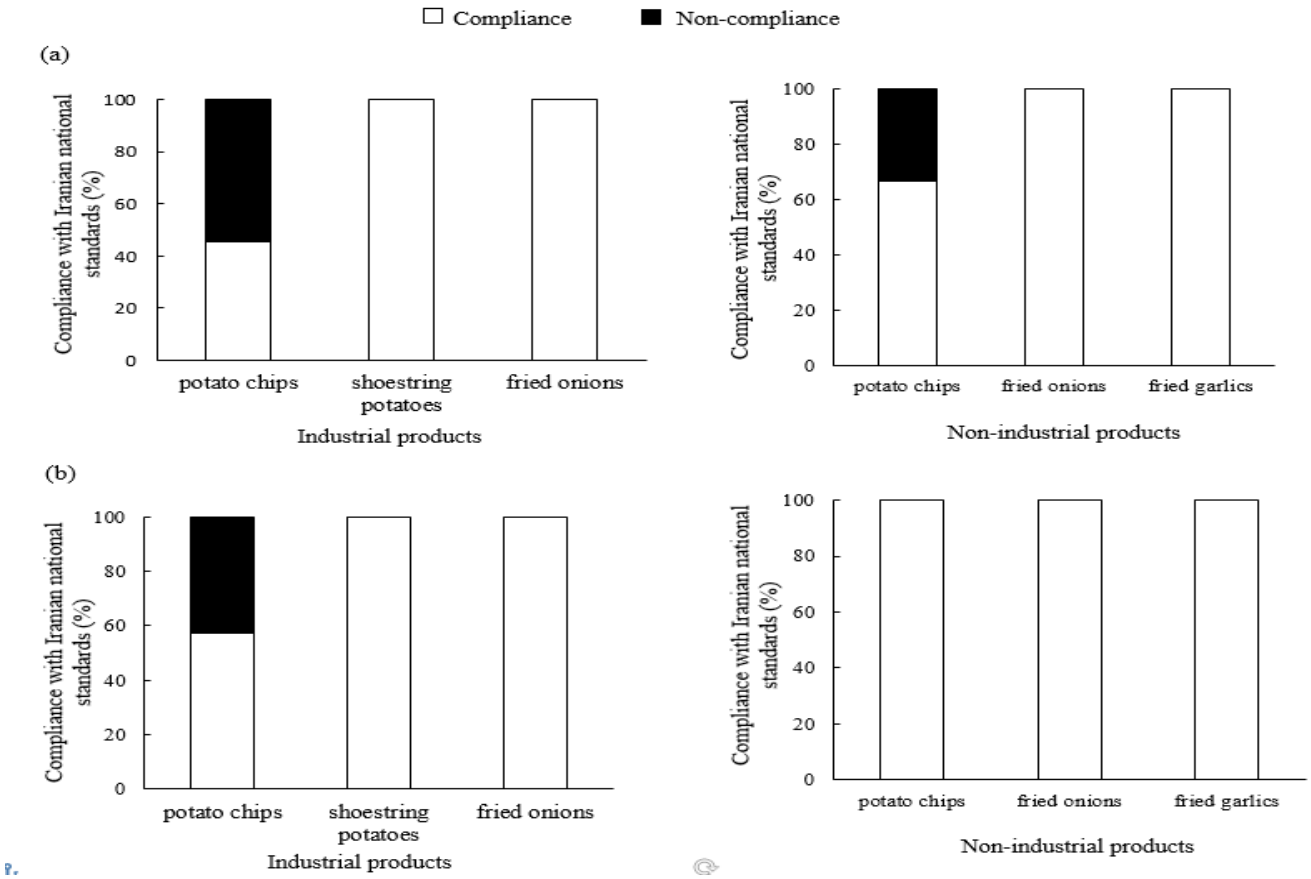

Figure 1. Compliance (%) of fat contents in industrial and non-industrial fried foods with the Iranian National Standards of a) 2017 and b) 2019.

Table 1. Mean fat, trans fatty acid and saturated fatty acid contents of the fried-food products, 2017 and 2019.

Fried foods*	Fat (%w)		Saturated fatty acids (%w)		Trans fatty acids (%w)	
	2017	2019	2017	2019	2017	2019
Industrial potato chips	41.30^{bA}	38.83^{bB}	13.35^{cD}	15.71^{aC}	0.18^{dE}	0.18^{dE}
Industrial shoestring potatoes	33.77^{cA}	33.67^{dA}	15.18^{bB}	15.75^{aB}	0.17^{dC}	0.18^{dC}
Industrial fried onions	48.21^{aA}	42.65^{aB}	19.35^{aC}	13.86^{bD}	0.59^{bF}	0.98^{aE}
Non-industrial fried onions	47.41^{aA}	39.94^{bB}	16.03^{bC}	9.23^{dD}	0.80^{aE}	0.59^{bF}
Non-industrial fried garlics	26.29^{dA}	21.6^{eB}	8.56^{dC}	5.41^{eD}	0.36^{cF}	0.58^{bE}
Non-industrial fried potatoes	15.18^{eA}	14.19^{fA}	4.69^{eB}	4.47^{eB}	0.10^{eC}	0.17^{dC}
Non-industrial potato chips	42.89^{bA}	36.17^{cB}	12.30^{cC}	11.41^{cC}	0.16^{dE}	0.40^{cD}

*Means shown with different small and capital letters represent significant differences ($P < 0.05$) in the same columns and rows, respectively.

Table 2. Mean trans fatty acid and saturated fatty acid contents in oily phase of the fried-food products, 2017 and 2019.

Fried foods*	Saturated fatty acids (%w)		Trans fatty acids (%w)	
	2017	2019	2017	2019
Industrial potato chips	41.27^{bB}	42.90^{aA}	0.55^{cC}	0.51^{eC}
Industrial shoestring potatoes	45.27^{aA}	43.10^{aB}	0.51^{cC}	0.50^{eC}
Industrial fried onions	38.68^{cA}	31.86^{bB}	1.44^{aD}	2.23^{bC}
Non-industrial fried onions	34.39^{dA}	22.66^{eB}	1.57^{aC}	1.54^{cC}
Non-industrial fried garlics	32.38^{eA}	26.18^{dB}	1.34^{aD}	2.41^{aC}
Non-industrial fried potatoes	33.25^{deA}	28.83^{cB}	0.76^{bC}	1.16^{dC}
Non-industrial potato chips	32.88^{eA}	31.04^{bB}	0.46^{dD}	1.07^{dC}

*Means shown with different small and capital letters represent significant differences ($P < 0.05$) in the same columns and rows, respectively.

Table 3. Daily per capita intakes of fried foods and their average fat, saturated fatty acid and trans fatty acid intakes based on the contents of these components in each fried product, 2019.

Fried foods	Daily serving size per person, g	Fat		saturated fatty acids		trans fatty acids	
		Mean, g/100 g	Daily per capita intake, g	Mean, g/100 g	Daily per capita intake, g	Mean, g/100 g	Daily per capita intake, g
Industrial potato chips	28	38.83	10.87	15.71	4.39	0.18	0.05
Industrial shoestring potatoes	28	33.67	9.42	15.75	4.41	0.18	0.05
Industrial fried onions	20	42.65	8.53	13.86	2.77	0.98	0.19
Non-industrial fried onions	20	39.94	7.98	9.23	1.84	0.59	0.11
Non-industrial fried garlics	10	21.60	2.16	5.41	0.54	0.58	0.05
Non-industrial fried potatoes	76	14.19	10.78	4.47	3.39	0.17	0.12
Non-industrial potato chips	28	36.17	10.12	11.41	3.19	0.40	0.11

The fat contents of all industrial shoestring potatoes samples complied with the Iranian National Standard (38% w/w) in 2017 and 2019 (Figure 1). Significant differences were seen between the quantities of SFAs in the oily phase of shoestring potatoes in 2017 and 2019 ($p < 0.05$) (Table 2). No reported standard is available for the fat content of guild-fried potatoes; however, assessment of total fat, SFA and TFA contents of the fried potatoes showed no significant differences between the quantities of total fat, SFAs and TFAs in 2017 and 2019 ($p < 0.05$) (Table 1). The highest quantity of SFAs was detected in the oily phase of industrial shoestring potatoes (45.27%).

The permitted level of total fat for fried onions is 60% (w/w) based on the Iranian National Standard (22). The mean fat contents of industrial and guild-fried onions were 48.21 and 47.41% in 2017, respectively. In 2019, all samples of industrial and guild-fried onions complied with the Iranian National Standard (Figure 1) and quantities of fat, SFAs and TFAs of the guild-fried onions were lower than those of the industrial-fried onions (Table 1). Differences between the industrial and guild onions in the quantities of SFAs and TFAs were statistically significant ($p < 0.05$). In 2019, guild-fried onions included the lowest mean SFA content in the oily phase (Table 2). Based on the serving size of fried onions (20 g), the average daily per capita intakes of fat, SFAs and TFAs through industrial and guild-fried onions were 8.53–7.98, 2.77–1.84 and 0.19–0.11 g, respectively (Table 3).

Based on the Iranian national standard for fried garlic (23), the minimum permissible level of fat content in fried garlic is 5% (w/w). Therefore, quantities of fat in guild-fried garlics in 2017 and 2019 complied with the Iranian National Standard (Figure 1). In 2019, the mean TFA content (2.41%) in the oily phase of guild-fried garlics was more that allowed by the Iranian National Standard since the permissible level of TFAs in frying oil maximally includes 2% (w/w). In addition, guild-fried garlics included the highest mean TFA content in the oily phase within the products (Table 2). Based on the serving size of fried garlics (10 g), the average daily per capita intake of TFAs via consumption of guild-fried garlics was 0.05 g (Table 3).

Discussion

These findings showed that guild potato chips included a higher quantity of TFAs, compared to industrial potato chips in 2019. Potato chips included a lower rate of compliance with the Iranian National Standard, compared to other fried products. Therefore, excessive consumption of potato chips was a risk factor for health because these fried products contained high oil concentrations and toxic compounds such as TFAs (24). Potato chips are widely consumed as a snack in Iran, especially by children and adolescents, which can lead to health problems such as cancers and CVDs in adulthood (25). Moreover, the current frequency of overweight and obesity in communities can be attributed to food habits because the rate of valueless food intake with high quantities of fats (e.g. fried potatoes) is higher than that of healthy ones. Bastami *et al*. reported quantities of cheese puffs and potato chips in rural and urban regions of Iran as 25.8 and 20.3%, respectively (26). Pimentel *et al.* investigated the total fat and TFA contents of industrial potato chips in Brazil, 2005–2018. They reported that the mean content of SFAs in potato chips increased, while the mean content of TFAs in potato chips decreased (4.2 to 1.8) (27). In another study, range of TFA content in 25 samples of potato chips and French fries collected from the Portuguese markets was reported as 0.17–1.26 g/100 g (28). Hewavitharana *et al.* declared that the total fat content of fast foods collected from the Sri Lankan markets ranged 7.8–14.5% and a comparatively high quantity of TFAs was detected in French fries and devil chicken pizza (29). Alzaa *et al*. used extra virgin olive, canola and grape seed oils for frying of potato chips. They stated that extra virgin olive oil decreased TFAs in the chips, whereas grape seed and canola oils increased TFAs in the chips (30). Generally, it seems that the quantity of total fat, SFAs and TFAs in fried foods depends on the type of oils used in the production of these products.

In the present study, the total fat, SFA and TFA concentrations of industrial shoestring potatoes in 2019 were 33.67, 15.75 and 0.18 g/100 g, respectively. Lima Dias *et al*. reported that SFA and TFA contents of shoestring potatoes purchased from supermarkets in Rio de Janeiro, Brazil, were 17.81 and 0.21 g/100 g (31). When comparing quantities of SFAs and TFAs in the present study with those reported by Lima Dias *et al*., shoestring potatoes in Iran included lower concentrations of SFAs and TFAs. In another study, shoestring potatoes produced from Arizona and Caruso cultivars in the South-West region of Minas Gerais State, Brazil, included the highest (48.90%) and the lowest (42.21%) absorbed fats, respectively (32).

Based on data shown in Tables 1 and 2, levels of total fat, SFAs and TFAs in fried onions and their oily phase were relatively high. However, higher SFA (44.75%) and lower TFA (0.123%) contents were reported by Zaki *et al*. in fried onions (33). The mean fat content of fried onions was in the range of 39.94–48.21% in this study, which was nearly similar to that of Nikzad *et al*. in canola, sesame and frying oils. Moreover, Nikzad *et al*. reported similar data for SFA concentrations of fried onions in canola and sesame oils (34). Differences between the industrial and guild frying in the mean fat concentrations of industrial and guild potato chips and onions could be attributed to the types of frying oil, time and frequency used in industrial foods, compared to the guild ones. In a survey by Li *et al*., food type (fish nuggets, chicken nuggets and French fries) included less effects on the formation of polar compounds, compared to oil type (sunflower, canola, soybean, palm and cottonseed

oils) (35). In addition, Manzoor *et al.* (2023) detected that the TFA contents of fried products (peas, potato chicken and fish) increased with increasing frying time and TFAs (18:1) included greater levels (0.87–2.41%). The TFA content of soyabean oil was higher than that of mustard oil. After 50 frying cycles, preserved content of TFAs in fried fish was 3.98%. They declared that the fatty acid composition of oils and fried foods included significant effects on the generation of TFAs during frying (36). Based on the previous studies, repeated use of oil for a prolonged time could be another reason for the differences in the generation of TFAs in industrial and guild frying methods as common street vendors, households and fast-food restaurants use the same oil for a long time to minimize costs (36). Jain *et al.* recorded that the total fats of mathri, bread pakora, potato chips, poori and French fries were higher in the frying cycle of 32, compared to the first frying cycle (37).

Garlic is largely used worldwide due to its strong antioxidant and antimicrobial characteristics (38). However, during frying, its health-promoting characteristics may be lost and high concentrations of fat can penetrate into the garlic. In the present study, the mean fat concentration of guild-fried garlics was in the range of 21–26%. Similarly, Arisseto *et al*. investigated the quantity of fat absorption by fried garlic samples in corn oil. They detected 0.16 and 17.7 g/100 g fat in raw and fried garlic samples, respectively (39). Other researchers reported oil content of fried garlics via vacuum frying as 32.6% (40). Although the TFA concentration of all fried foods was in accordance with the Iranian National Standard, results of this study revealed that the level of TFAs in all samples except industrial potato chips and guild-fried onions increased from 2017 to 2019. In a survey by Otite *et al*., they assessed 16 categories of TFA-containing foods collected in US supermarkets, 2007–2011, and verified decreases in TFA concentration of the products (41). Therefore, the present findings emphasize continuous monitoring of the fried foods to encourage people to consume healthier foods and decrease the harmful effects of fried foods on their health.

Conclusion

Results of this study showed that the highest concentration of TFAs was associated to industrial fried onions (0.98%) and the oily phase of non-industrial fried garlics (2.41%). Differences between the industrial and guild potato chips in their fat content, SFAs and TFAs were significant in 2019 while no significant differences were observed between these parameters of foods in 2017 ($p < 0.05$). In addition, significant differences were seen between the industrial and guild onions in quantities of SFAs and TFAs ($p < 0.05$). Comparison of data indicated that the quantity of absorbed fat decreased in all fried products in 2019, compared to 2017, showing increased public awareness as well as efficiency of approvals of laws and regulations. Furthermore, this study demonstrated that total fat contents of all fried food products were less than the acceptable limits except for guild potato chips in 2017 and industrial potato chips. As daily per capita intake of fried products is relatively high, especially in teenagers, decreases in oil absorption may play vital roles in the prevalence of various associated cancers and CVDs. This study has verified that regular monitoring of industrial and guild-fried foods is important because increasing the level of consumer awareness can be effective in improving the health level of society. However, further studies are necessary to investigate the effects of oil type, frying time and frying frequency used by the industrial processes, street vendors and fast-food restaurants on the absorption of oils by fried foods.

Acknowledgement

We gratefully thank from the National Nutrition and Food Technology Research Institute (NNFTRI) of Shahid Beheshti University of Medical Sciences for the efforts in promoting the knowledge and implementation, as well as financially supported by Food and Drug Administration of Iran.

Financial disclosure

The authors declared no financial interest.

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