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Content of Polymerised Triacylglycerols in Fat of Fried Foods

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Abstract

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Polymerised triacylglycerols (TAG) were determined in the fat of 66 industrially produced fried foods (especially frozen pre-fried French fries, potato chips and other fried snacks) and 56 samples of French fries (and other forms of fried potatoes) prepared in restaurants, snack bars, and other catering establishments. All samples were purchased in the Czech Republic, especially in Prague, in the years 2012–2014. Polymerised TAG were determined by HP-SEC with refractive index detection, after the fat extraction with petroleum ether. While in none of the samples of industrially produced fried foods did the content of polymerised TAG in fat exceed the limit value of 12%, in French fries provided by different types of catering establishments this threshold was exceeded in 9 samples (i.e. approximately in 16% of the analysed samples).

Keywords: frying; lipid oxidation; food quality regulation; French fries; potato chips

Frying is a fast and convenient technique producing foods with typical sensory properties (taste, flavour, and texture) that are favoured by consumers. However, a lot of negative effects [e.g. retarded growth of experimental animals (Esterbauer 1993; Chow 2007; Omwamba *et al.* 2010), increased weight of liver and kidneys (Izaki *et al.* 1984; Esterbauer 1993), gut and intestine irritation (Esterbauer 1993), liver damage (Alexander 1981; Totani *et al.* 2008) or cirrhosis (Chow 2007), pathological changes of the heart muscle (Alexander 1981; Chow 2007), kidney damage (Alexander 1981), hypertension (Omwamba *et al.* 2010), atherosclerotic changes (Kubow 1990; Esterbauer 1993), increased tumour incidence (Esterbauer 1993), decreased glucose tolerance and thyroid activity (Omwamba *et al.* 2010) or haemolytic anaemia (Esterbauer 1993)] were observed in some long-term tests with fats and oils after frying (or oxidised fats and oils generally), which become a part of fried foods. Though studies (on after-frying risk assessments of fats and oils) with contradictory results or conclusions can be found (Esterbauer 1993; Chow 2007; Gertz 2014) and the after-frying toxicity of fats and oils is affected significantly by the overall diet composition, in particular the intake of essential fatty acids and vitamin E (Chow 2007), the available data on the level of after-frying possible risks of fats and oils are quite alarming (Réblová & Peprná 2013). Thus, for many decades, an effort to create professional recommendations or legislative limits regulating the quality of fats and oils used for frying, and/or prescribing a reasonably frequent replacement of the frying bath used for repeated frying can be observed (Dobarganes & Márquez-Ruíz 1998; Stier 2013). Currently, the most accepted professional recommendation states that the frying bath must be replaced any time when the content of total polar materials (compounds) reaches the limit of 24% or the content of polymerised triacylglycerols (pTAG) reaches the limit of 12% (Stier 2013; Brühl 2014). Some European Union member countries and some other countries have already adopted the recommendation of the replacement of the frying bath for

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repeated frying according to the respective national legislative regulations; however, it has not yet been regulated either under the joint EU legislation or under the legislation of the Czech Republic.

In connection with the preparation process of the above recommendation adopted in its final form by the delegates at the 3rd International Symposium on Deep-fat Frying in 2000 (Stier 2013), and the process of its general introduction into the public notice and practice, the studies monitoring the quality of fats and oils used for repeated frying (Dobarganes & Márquez-Ruíz 1995; Skrökki 1995; Masson *et al.* 1999; Andrikopoulos *et al.* 2003) and summarising the results of similar previous studies (Dobarganes & Márquez-Ruíz 1998; Saguy & Dana 2003) were done in many countries (Greece, Spain, Finland, Chile, Germany, and others). In most of these studies, a significant proportion of the analysed samples from restaurants, fast food outlets, and other catering establishments did not meet the given criteria (Dobarganes & Márquez-Ruíz 1995, 1998; Skrökki 1995; Masson *et al.* 1999; Andrikopoulos *et al.* 2003; Saguy & Dana 2003).

In the Czech Republic an analogous study that determined pTAG in the fat of French fries prepared in restaurants, fast food outlets, and other catering establishments was implemented in the years 1998 to 2002. It also brought about a significant number of samples (11 out of 40, i.e. approx. 28%) where the adequate limit for the timely replacement of the frying-bath was not met. The results of this study were not published in professional journals, but they were presented at national scientific meetings and used in the training of the industry workers and public educational programs. Now, i.e. approximately 15 years later, this study was repeated. For comparison, the content of pTAG was determined not only in the fat of French fries (and other forms of fried potatoes) offered by restaurants, fast food outlets, and other catering establishments, but also in the fat of different types of industrially produced fried foods.

MATERIAL AND METHODS

Samples. In study were analysed 56 samples of French fries (and other forms of fried potatoes) from restaurants, fast food outlets, and other catering establishments, including, for example, occasional kiosks at the Christmas market, etc., and 66 samples of industrially produced fried foods. The industrially produced samples included mainly fried potato chips and similar snacks, such as fried extruded corn and potato snacks (in total 36 samples) and frozen pre-fried French fries (20 samples). The rest (10 samples) included various frozen pre-fried oven-ready foods such as fish fingers, fish fillets, pork and chicken fillets, breaded cheese, potato pancakes, and others.

All analysed samples were purchased and analysed in the years 2012 and 2014, and were selected at random from the general food store offer of the given category. Samples of the industrially produced fried foods were purchased in the shop network in Prague, mostly in large supermarkets with a broad range of foods. Samples of French fries (and other forms of fried potatoes) from restaurants, fast food outlets, and other catering establishments were purchased throughout the Czech Republic, with a slight prevalence of various Prague districts, with the aim to provide samples including fried potatoes prepared in various types of restaurants, fast food outlets, and other catering establishments.

Sample preparation. The fat from the analysed samples was extracted by the procedure mentioned below. In the coated samples of foods (such as frozen pre-fried fish fingers, fish fillets, pork and chicken fillets, and/or breaded cheese) only the mechanically separated breadcrumbs were analysed. Samples were ground and 2 g of each ground sample was extracted with 50 ml of petroleum ether (30 min on a laboratory shaker). Subsequently, the extract was filtered through filter paper and the solvent was evaporated with a rotary vacuum evaporator at a bath temperature of up to 40°C. The final evaporation residue was dissolved in the amount of tetrahydrofuran suitable to provide approximately 50–70 mg of fat in 1 ml of the resulting solution. This resulting solution was dried out by anhydrous sodium sulphate.

Determination of polymerised triacylglycerols. The pTAG were determined using HP-SEC with refractometric detection. The system consisted of an LCP 4000.11 high-pressure pump (Ecom, Prague, Czech Republic), HP 1050 series autosampler and HP 1047A series refractometric detector (Agilent Technologies, Santa Clara, USA). The chromatographic separation was performed at room temperature using a PL gel MIXED-E SEC column (7.5 mm × 300 mm, 3 µm) equipped with a guard column (7.5 mm × 50 mm, 5 µm; Agilent Technologies, USA). Tetrahydrofuran was used as the mobile phase at a flow rate of 0.6 ml/min and 5 µl of the solutions prepared

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at the close of the sample extraction were injected into the column.

The percentage of pTAG was quantified using the area-normalisation method. The only quantified substances were those with a retention time lower than or equal to the retention time of free fatty acids. As pTAG were recognised all substances with the retention time lower than the retention time of monomeric TAG. The obtained result was the content of pTAG in the fat of the analysed food products expressed as a percentage.

Results and discussion

Industrially produced fried foods. As presented in Table 1, none of the analysed samples of the industrially produced fried foods contained in its fat an amount of pTAG that exceeded the limit value of 12% (Stier 2013). This corresponds with the results of analogous studies (Dobarganes & Márquez-Ruíz 1998; Saguy & Dana 2003; Bou *et al.* 2012), which stated that in general the continuous deep-fat frying used in industry produces fried foods of relatively equal and high quality, i.e. foods with a low content of compounds formed in fats and oils during frying. This effect is caused by the high turnover rate of oil in continuous fryers.

Oil turnover is defined as the ratio between the amount of oil in the fryer and the amount of oil added to the fryer per hour (Saguy & Dana 2003), as it is necessary to keep replenishing the frying bath with new oil to replace the oil retained in the product during frying (Dobarganes & Márquez-Ruíz 1998).

Table 1. Content of polymerised triacylglycerols (pTAG) in the fat of analysed samples (%)

	Fried foods	
	industrially produced	prepared in catering establishments
Number of samples	66	56
Minimum	0.39	0.98
Maximum	11.76	18.56
Average	3.22	7.67
Median	1.90	7.28
Number of samples with content of pTAG higher than 12%	0	9
Proportion of samples with content of pTAG higher than 12%	0	16.1

During the industrial production of fried foods the average oil turnover time ranges between 5 h and 14 h (Saguy & Dana 2003; Bou *et al.* 2012), which usually maintains the good quality of the frying bath fat or oil (i.e. the fat or oil with a low content of oxidation and other reaction products of lipids) without the use of some control tests and regulation mechanisms (Dobarganes & Márquez-Ruíz 1998; Ferreira *et al.* 2014). Under continuous deep-fat frying, the level of oxidation products (for example polar compounds) reaches a constant value typically below the limit value and, only exceptionally, the oil has to be replaced (Dobarganes & Márquez-Ruíz 1998).

However, as we can see from the comparison of polymerised TAG content in the fat of chips and similar fried snacks, and in the fat of pre-fried French fries (Figure 1), quite significant differences can be found between the various groups of industrially produced fried foods. These differences are probably related to different fat content of these foods (i.e. on average 31.4% in chips and similar snacks versus 7.6% in pre-fried French fries; Saguy & Dana 2003), and the related different turnover rate of oil in the production of these product groups. The lower turnover rate of oil typical of the production of lower-fat products (e.g. frozen pre-fries) leads to a higher content of pTAG and other reaction products of lipids in the fat of these foods (Ferreira *et al.* 2014). On that account, limits ensuring the timely replacement of frying bath (Stier 2013) and related supervisory and regulatory frameworks should be introduced also into the fried

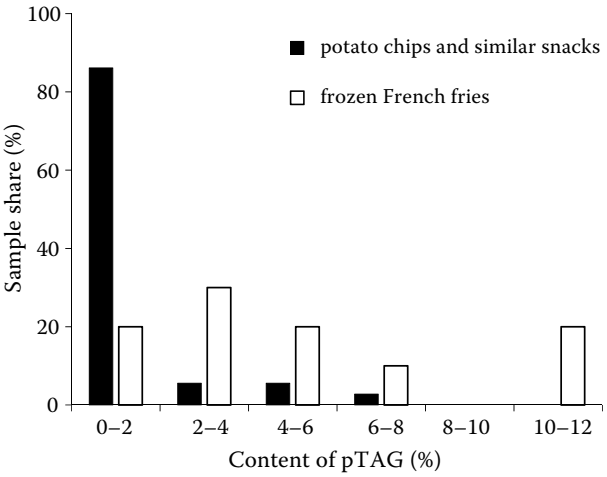

Figure 1. Content of polymerised triacylglycerols (pTAG) in the fat of potato chips and similar fried snacks, and in the fat of frozen pre-fried French fries (relative frequency histogram)

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food industrial production. Besides, many industrially fried foods are ready-to-cook products, which are thus subsequently re-fried (or currently more often baked) at home at temperatures often above 200°C, especially in the case of baking. Therefore, open to debate is the question whether in this case the limits appointed for the content of total polar materials and the content of pTAG should not be lower than those appointed for the preparation of fried foods in catering establishments (i.e. 24 and 12% respectively; Stier 2013).

Fried foods prepared in restaurants, snack bars, and other catering establishments. The situation concerning this type of fried food production differs significantly from the industrial production of fried foods (Dobarganes & Márquez-Ruíz 1998). Here, discontinuous fryers are generally used and in many cases the oil cools down and is subsequently reheated or keeps heating for a relatively long period without presence of any heated food between individual fryings. The oil turnover rate is therefore significantly lower and the turnover time can reach up to 100 h or more (Dobarganes & Márquez-Ruíz 1998; Saguy & Dana 2003). These conditions in themselves do not bring either the sufficient quality of the frying bath (as opposed to the industrial production of fried foods – see above) or the quality of the fried foods (in terms of the content of oxidation and other reaction products of lipids) and it is therefore necessary to have an appropriate control and management framework guaranteeing the frequent and timely replacement of oil (frying bath). It is, however, accompanied by technical and economic problems: unlike the industrial establishments, most of the catering establishments do not have access to laboratory facilities to check when the frying oil should be replaced, while, on the other hand, an unnecessarily frequent replacement of the frying bath increases groundlessly the production costs (Dobarganes & Márquez-Ruíz 1998).

The results obtained in this study correspond with these general facts. As presented in Table 1, in French fries (and other forms of fried potatoes) from restaurants, fast food outlets, and other catering establishments, in a significant proportion of samples (about 16%) the fat of these foods contained more than 12% pTAG (Stier 2013). This in general corresponds with the earlier studies conducted in different countries at the turn of the century, i.e. when the current recommendations regarding the exchange of frying baths originated and were gradually put into practice (see Introduction; Dobarganes & Márquez-Ruíz 1995, 1998; Skrökki 1995; Masson *et al.* 1999; Andrikopoulos *et al.* 2003; Saguy & Dana 2003), and also with the more recent available studies (Camilo *et al.* 2010; Freire *et al.* 2013), implemented with sufficient delay from the publication of relevant professional recommendations regarding the timely replacement of frying bath (Stier 2013). In both groups of these studies there also appeared a significant number of samples (8–60%) exceeding the limits determining the need of frying bath replacement (i.e. content of total polar materials of 24% and/or pTAG content of 12%; Stier 2013), although in these studies fats and oils (frying bath) were analysed more often than the fried foods and the content of polar compounds was usually determined (Dobarganes & Márquez-Ruíz 1995, 1998; Skrökki 1995; Masson *et al.* 1999; Andrikopoulos *et al.* 2003; Saguy & Dana 2003; Camilo *et al.* 2010; Freire *et al.* 2013).

In the earlier studies, the proportion of samples non-compliant with the limits for the early exchange of frying bath ranged between 17 and 60% (Dobarganes & Márquez-Ruíz 1995, 1998; Skrökki 1995; Masson *et al.* 1999; Andrikopoulos *et al.* 2003; Saguy & Dana 2003), whereas the figures of the more recent studies range between 8 and 26% (Camilo *et al.* 2010; Freire *et al.* 2013). This is a sign of improvement, all the more so since the countries in which the recent studies were conducted did not include the limits for the early exchange of frying baths in their legislative regulations (Camilo *et al.* 2010; Freire

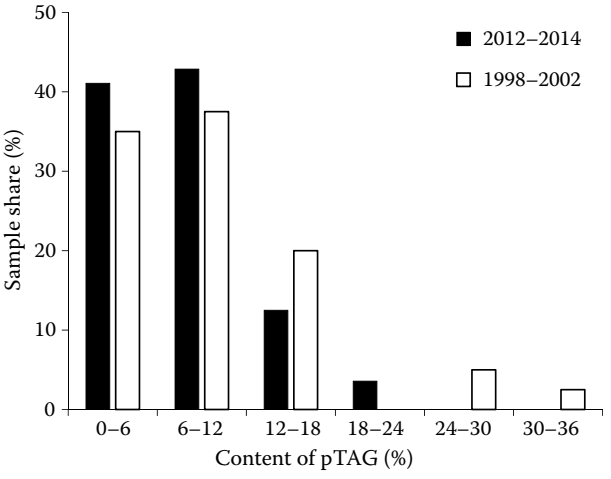

Figure 2. Content of polymerised triacylglycerols (pTAG) in the fat of French fries purchased in various catering establishments in the years 2012–2014 and 1998–2002 (relative frequency histogram)

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et al. 2013; Stier 2013; Ferreira *et al.* 2014). The improvement probably took place primarily due to public enlightenment and awareness-raising, as also seen in the Czech Republic (Figure 2).

However, despite the observed improvements, it is necessary to evaluate the current status as still unsatisfactory. Besides, its further improvement through public enlightenment and information campaigns cannot be expected. That is why the limits for the timely exchange of frying bath (i.e. the content of total polar materials up to 24% and the maximum pTAG content of 12%; Stier 2013) should be promptly implemented into the appropriate legislation of the Czech Republic and/or the EU. However, at the same time it is also necessary to seek means helping the owners and operators of catering services to comply with these limits without excessive economic costs caused by the need of involving commercial laboratories in the sample analyses. A suitable solution might be either development of truly reliable and universally applicable rapid tests for assessing the fat and frying oil quality (Bansal *et al.* 2010) or for instance the formulation of clear recommendations for the handling of frying bath, and the frequency of its replacement in various types of food services (with a varying range of the fried food production) using various types of fats and oils for various types of fried foods, etc.

CONCLUSIONS

The main conclusions drawn from the findings of this study can be summarised as follows: it is necessary to use all means to press for the establishment of limits determining the timely replacement of frying baths into the relevant legislation of the Czech Republic and/or the EU. This applies especially to frying that takes place in catering services. At the same time it is also necessary to provide the owners and operators of catering services with adequate expert support, so that they can ensure compliance with the introduced limits.

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