PAPER

ASSESSMENT OF TOTAL POLAR MATERIALS IN FRYING FATS FROM CZECH RESTAURANTS

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ABSTRACT

Deep-frying is commonly used as convenient technique for the preparation of foods. The frying oils and fats are absorbed by fried food and become a part of diet. The content of total polar materials was determined in frying oils and fats in 46 restaurants from South Moravia and the Olomouc regions. Twenty-eight samples were found with total polar materials with limit of rejection over 24%. The highest total polar materials values were observed in cooking fat; the lowest one was in vegetable shortening oil. This conclusion corresponds with frying temperatures, which were highest in cooking fat.

Keywords: deep-frying, fats, oils, restaurant, total polar materials

INTRODUCTION

Fried foods are consumed worldwide with increasing popularity since their unique sensory properties, such as colour, flavour, texture and palatability, are highly appreciated by consumers. Oils and fats are used as means of heat transfer from the fryer to the food. The quality of oils and fats during the frying process has a major influence on the quality of the final product (ANDRIKOPOULOS *et al.*, 2003). Although many studies have dealt with the mechanism and products of fat deterioration under laboratory conditions, relatively little attention has been paid to changes that occur in cooking oils and fats during use in restaurants and other establishments.

In relation to frying operations of fried foods, most of them are conducted at elevated temperatures (160°-195°C) in presence of air, metal container and moisture, resulting in both thermal and oxidative disintegration of the oil (BANSAL *et al.*, 2010b). The thermal treatment of the cooking oils results in oxidative and hydrolytic reactions i.e. hydrolysis, cyclisation or polymerisation. These chemical and physical changes take place and lead to the formation of numerous decomposition products (volatile and non-volatile compounds) (FRITSCH, 1981; FRIEDMAN, 2000).

Furthermore, the extent and nature of these decomposition products are affected by the food being fried, the type of the fat used as well as by the choice of the fryer design and the operating conditions (temperature, oxygen exposure, heating time, turnover rate) (AL KAHTANI, 1991). Regarding the majority of the non-volatile by-products, they are categorized as the total polar materials (TPM). The TPM constituents include dimeric fatty acids, triglyceride monohydroperoxides, polymerized triglycerides (PTG), cyclic fatty acid monomers and aldehydic triglycerides (MÁRQUEZ-RUIZ *et al.*, 1998; GERTZ, 2000).

During the reactions mentioned above, the functional, sensory and nutritional qualities of frying fats are changed and may reach a point where it is no longer possible to prepare high quality fried foods and the frying fat will have to be discarded (VAHČIČ and HRUŠKAR, 1999). The discarding point of the oil that is used repeatedly for frying of food is very closely related to the health issues. The compounds formed during deep-frying e.g. enzyme inhibitors, vitamin destroyers, lipid oxidation products, gastrointestinal irritants and/or potential mutagens are harmful to human health and can therefore become a chemical and physical hazard (SORIANO *et al.*, 2002). There are many studies examining how the quality of frying oils and fats, which are consumed in a diet, influences the health of live animals, especially the rats. Many surveys dealing with the effect of these oils on the growth, liver size, cholesterol or phospholipids in rats showed the relevant negative changes of mentioned parameters by rats fed with oils containing the higher percentage of TPM.

However, no epidemiological or public health investigations have directly proved the effect of abused frying oils on the healthy persons (BILLEK, 2000; BANSAL *et al.*, 2010b). Therefore, it is important to observe the quality of frying oils and fats in view of the fact that they are absorbed by frying food and so become a part of our diet. The uptake of absorbed oil in food ranges in percentage from 4% to 14% of the total weight, depending on the food and the type of frying medium (ANDRIKOPOULOS *et al.*, 2003).

Nevertheless, it is necessary to test the oil quality and establish the cut-off point at which the oil should be discarded in order to protect public health. Since there are health and safety issues related to the reuse of frying oils, several countries have established relevant laws, regulations or recommendations regarding the further use or the discarding of such oils. These countries have set limits for parameters such as frying temperature, acid value, smoke point, polar compounds and polymers (BANSAL *et al.*, 2010b).

In general, the percentage (%) of TPM in the cooking oil has been shown to be almost identical to the one present in the oil absorbed by the food. Thus, by measuring TPM % in frying oil, the direct content of TPM in the fried food could be reflected. Moreover, most European countries have established the limits for the rejection and replacement of cooking oil in restaurants as the content of TPM% where its maximum values range from 24 to 27% (CALDWELL *et al.*, 2001). The limit 24% for TPM was recommended as the most appropriate for rejection while the limit of 20% TPM (GERTZ, 2000) has been recommended for the replenishment of the oil or fat. The concentration of TPM is so rapidly becoming the most widely accepted parameter for the determination of used frying oil quality (DOBARGANES *et al.*, 2000; GERTZ, 2000).

As to the present study, the TPM% of six different types of cooking oils and fats from 46 restaurants in South Moravia and the Olomouc regions are reported indicating the quality status of these oils and fats used under current catering practice.

MATERIALS AND METHODS

Samples

The quality of frying oils and fats was examined during one month in 46 restaurants and fast-food outlets of various types from South Moravia and the Olomouc regions, in the Czech Republic. The measurements were performed in daily frying operations of these restaurants and were analysed repeatedly for the relevance of results. In total were evaluated 46 samples of

Table 1 - Oils and fats used for deep-frying in 46 selected restaurants and fast-food outlets in South Moravia and Olomouc region, Czech Republic.

Producer (trademark)	Type of oil or fat	n
A	Canola oil	2
B	Canola oil	2
C	Canola oil	6
D	Canola oil	2
E	Canola oil	4
F	Canola oil	2
G	Canola oil	2
H	Canola oil with palmolein	4
I	Canola oil with palmolein	2
J	Palm oil	2
K	Palm oil	2
L	Palm oil	4
M	Sunflower oil	2
N	Sunflower oil	2
O	Vegetable cooking fat	2
P	Vegetable shortening oil	2
Q	Vegetable shortening oil	4
Total		46

oils and fats that were divided according to raw materials. The types of oils and fats used for frying are summarized in Table 1. The most of restaurants used only one type of frying fat during measurements.

Methods

The amount of TPM was determined by using TESTO 270 (Testo Inc., Germany). This instrument has to provide the content of TPM in percentage with accuracy +/- 2% TPM. The samples were analysed by inserting the sensor into oil heated to frying temperature and reading the temperature and the TPM content in percentage from the display after about 30 s. The sensor was calibrated with the calibration oil supplied by the manufacturer before analysing the frying oils. The equipment was cleaned with warm water and neutral detergent and dried well between the measurements. Each test was performed in three times. The limit value for the replacement of frying oils and fats was established on 24% for TPM according to German regulations (BANSAL *et al.*, 2010b).

Statistical analysis

The data obtained were statistically analysed by the analysis of variance (ANOVA) and Tukey's multiple range test for comparison of means. Other functions were calculated using the Unistat, v. 5.1 statistical package and Office Excel® Microsoft 2010.

RESULTS AND DISCUSSION

The mean values, the medians and the range of the parameter studied (total polar materials) for oils and fats used for frying from 46 restaurants are shown in Table 2. The mean values for TPM were determined below 20% in all types of oils and fats and therefore did not reach the limit for rejection. The minimum of TPM observed was about 5% in canola oil and vegetable shortening oil at the 1st day of frying, while the maximum value increased to 33% in vegetable cooking fat after 9 days of frying. The analogous wide range was also found by ANDRIKOPOULOS *et al.* (2003), who mentioned in their papers that the minimum of TPM is about 3% and maximum reaches the level of 40%.

Total polar materials reflect the total level of breakdown products from the frying process. The amount and character of these products are affected by some frying parameters such as fat and food composition, frying conditions (temperature, oxygen exposure, heating time, turnover rate) and the design and material of frying equipment (AL-KAHTANI, 1991; VAHČIČ and HRUŠKAR, 1999).

The reported cases of oils and fats that exceed the TPM limit for rejection (24%) are presented in Table 3. Approximately 60% of all samples (12 samples of canola oil, 6 samples of canola oil with palm olein, 4 samples of palm oil, 4 samples of sunflower oil and 2 samples of vegetable cooking fat) were found over the TPM limit for rejection. In case of canola oil with palm oil, sunflower oil and vegetable cooking fat was found out, that all the average values for TPM were above the limit for rejection. The values above 24% TPM were measured already after 6 days of frying by vegetable cooking fat, 7 days by canola oil with palm olein, palm oil and 9 days by sunflower oil.

Table 2 - The content of TPM in examined frying oils and fats in percentage.

	Canola oil	Canola oil with palmolein	Palm oil	Sunflower oil	Vegetable cooking fat	Vegetable shortening oil
n	138	50	66	34	18	28
Mean	15.3[a]	18.1[b]	17.9[b]	14.9[a]	19.6[c]	12.3[d]
SD	±6.08	±7.47	±8.41	±7.22	±8.47	±6.06
Minimum	4.5	5.5	6.3	5.0	8.2	5.0
Median	16.0	20.4	15.0	11.8	22.5	10.7
Maximum	26.6	30.8	31.8	27.1	32.5	24.0

n - number of the measurements from the 1st day of frying time to day of used oil replacement.

Table 3 - The summary of examined oil and fat samples that exceed TPM limit for rejection.

Type of oil or fat	n	TPM < 24%	TPM > 24%
Canola oil	20	8	12
Canola oil with palmolein	6		6
Palm oil	8	4	4
Sunflower oil	4		4
Vegetable cooking fat	2		2
Vegetable shortening oil	6	6	
Total	46	18	28

On the other hand, the average content of total polar materials in the samples of vegetable shortening oil was observed below this limit. In the study related to frying oils and fats from 63 restaurants in Athens, Greece were determined only (17%) of all samples over the TPM limit for rejection. The most samples above this limit were observed in vegetable cooking fat (40%) and then in sunflower oil (30%) and palm oil (18%) (ANDRIKOPOULOS *et al.*, 2003). Approximately (41%) of frying oils used in the restaurants in Zagreb, Croatia reached the oil discard level. However, there was no information about the type of frying oils and fats (VAHČIČ and HRUŠKAR, 1999).

The extent of oxidative degradation in frying oils and fats can be reliably determined using the content of total polar materials. The results of this study showed that the content of TPM increased with frying time (Fig. 1). The initial values of the TPM were below 10%. At the end of frying time (the 9th of frying) the content of TPM reached above 24%, which is oil discard level set in many European countries. These values were observed after 5 days of frying at the earliest.

After 6 up to 9 days of deep frying, the final TPM levels were: "19,8"% in vegetable shortening oil, "23,1"% in canola oil, "25,8"% in sunflower oil, "28,8"% in canola oil with palm olein, "31,8"% in palm oil and "32,5"% in vegetable cooking fat (Fig. 1).

The maximum content of TPM in frying oil was accepted as 24%. From this point of view the percentage (%) of TPM in determined oils would be ranged in ascending sequence: vegetable shortening oil > canola oil > sunflower oil > canola oil with palm olein > palm oil > vegetable cooking fat. In the other study the highest amount of TPM in frying oils was established at 27% and was found out that sunflower oil reached lower value for %TPM than palm oil (XU *et al.*, 1999).

There are many factors that impact the amount of total polar content in frying oils and fats. For example the fatty acid composition of oil has marked effects on its frying performance as well as on its physical and chemical behaviour (BRINKMANN, 2000). The formation of polar compounds during repeated frying operations has been shown to increase with the degree of oil unsaturation, both during repeated frying and during the heating of oils (TAKEOKA *et al.*, 1997; ROMERO *et al.*, 1998).

The next significant parameter that influences the formation of polar compounds in heated oils is the ratio of the surface oil area to, oil volume in the fryer. The specific surface also plays an important role in behaviour of oils during frying, as the overall deterioration is an oxidation process rather than an interaction with frying foods according to BRACOO *et al.*, (1981). The differences in temperatures do not cause significant changes in frying oils (JORGE *et al.*, 1996). The

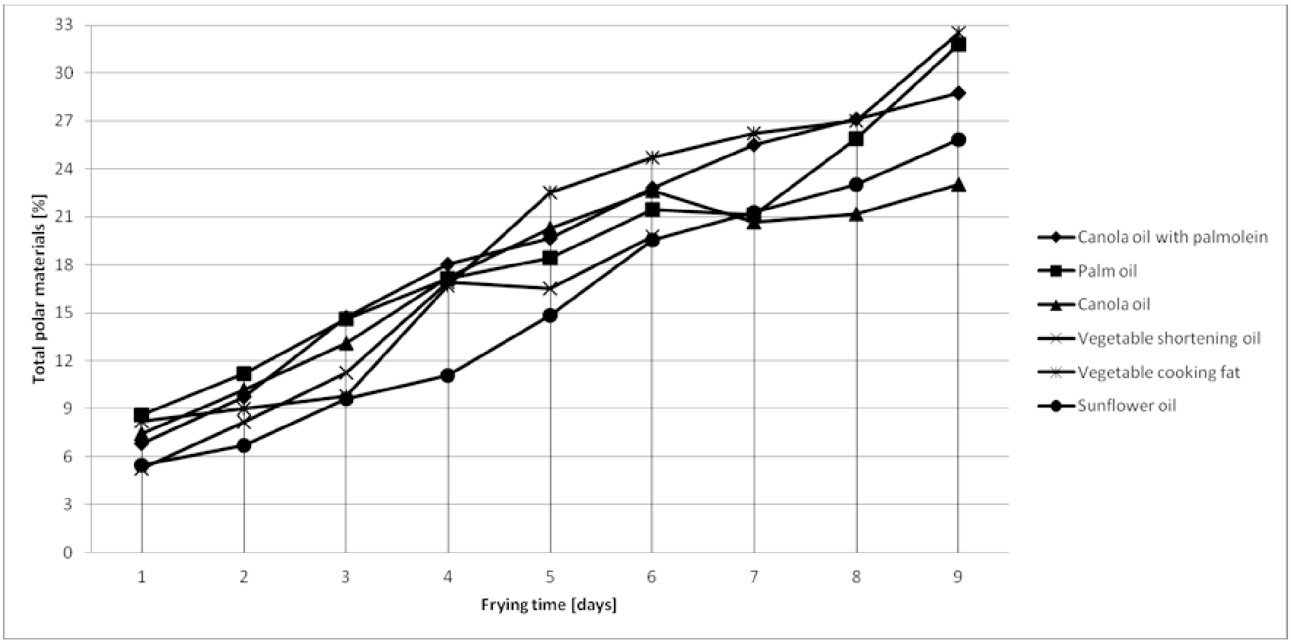

Fig. 1 - The content of total polar materials during frying in examined types of oils and fats

Table 4 - The temperature of examined frying oils and fats during deep-frying [°C].

	Canola oil	Canola oil with palmolein	Palm oil	Sunflower oil	Vegetable cooking fat	Vegetable shortening oil
n	138	50	66	34	18	28
Mean	154.6[a]	158.5[a]	167.3[b]	136.8[c]	173.6[d]	124.1[e]
SD	±42.54	±38.62	±57.71	±45.18	±32.26	±27.29
Minimum	156.4	162.1	147.0	152.6	161.8	94.0
Median	171.0	176.2	166.0	165.4	168.3	132.5
Maximum	186.3	189.5	173.5	174.6	180.5	161.2

n - number of the measurements from the 1st day of frying time to day of used oil replacement.

oil alteration depended on the frying procedure mainly as a result of different surface area to volume ratios and specific areas because pan-frying caused more marked changes than deep-frying on all the parameters studied including the content of total polar materials (ANDRIKOPOULOS *et al.*, 2002).

The next important factor is the temperature which should be in the range of 160 - 180°C for frying operations (SORIANO *et al.*, 2002). In this research the highest temperatures were observed for vegetable cooking fat (173.6°C) while the lowest temperatures were examined for using vegetable shortening oil (124.1°C) (Table 4). Similar conclusion was found also by ALADEDUNYE and PRZYBYLSKI (2009), who mentioned in their paper that the extent of oxidative deterioration, as measured by the TPM formation, was faster during frying at 215°C compared to 185°C. SORIANO *et al.*, (2002) recommended the continuous heating as the intermittent heating is much deleterious due to an increased rate of oil breakdown. Their team was concerned with the daily oil turnover too which should be ranged between 15 to 25 weight per cent in food service kitchens. This suggestion was determined with regard to much longer turnover periods influenced by fluctuations in the demand for fried foods. In our study only 40% of restaurants replenished the frying oils and fats. The replenishment of frying medium was made between the 4th and the 7th day of using. The average volume of replenished oil was 1.5litres. Our finding about catering practice in examined restaurants showed, too, that oils and fats were replaced after 9 days of using while the content of TPM reached the oil discard level already on the sixth day (Fig. 1).

CONCLUSION

Among 46 restaurants, the samples of oils and fats over the rejection limit comprise a relatively high part of samples examined (60% regarding TPM). There was observed higher content of total polar materials with increasing frying temperature. The catering practice in Czech restaurants as such has some lacks, like the turnover rate or the late replacement of used oils and fats, too. From all the findings of the presented study it appears, that it is necessary to survey the conditions of the usage of frying oils and fats more in detail. In addition, more frequent controls and the application of strict regulations by food authorities are important as well.

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