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EFFECT OF FRYING TEMPERATURE/FRYING CYCLES ON *TRANS* FAT CONTENT OF GROUNDNUT OIL

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Abstract

Frying process leads to oxidative deterioration and generation of *trans* fatty acids (TFAs) in fats/oils. Objective of this study was to assess the effect of frying temperatures and the number of frying cycles on TFA content of groundnut oil used for preparing French fries. TFA was estimated by gas chromatography at varying temperatures (160ºC, 180ºC, 200ºC, 220ºC, 230ºC) and frying cycles (1^{st}, 4^{th}, 8^{th} 16^{th} and 32^{nd}). With soaring frying temperatures and progressive frying cycles, mean *cis*-unsaturated fatty acids decreased while mean saturated fatty acids and TFA increased. Temperature variation indicated increase in mean TFA from 0.26±0.05 g/100g (160°C, 32^{nd} cycle) to 5.89±1.25 g/100g (230°C, 32^{nd} cycle) ($p<0.05$). With successive frying cycles, TFA increased from 0.1±0.04 g/100g (1^{st} cycle) to 0.26±0.05 g/100g (32^{nd} cycle) when oil was heated to 160°C; and 2.08±0.89 g/100g (1^{st} cycle) to 5.89±1.25 g/100g (32^{nd} cycle) when oil reached 230°C. TFA increased with elevating frying temperatures and progressive frying cycles. Food safety agencies need to formulate policies, stringent food laws and impose necessary regulations to curb oil abuse during frying. There is a dire need to raise consumer awareness regarding deleterious health effects of TFA and oxidative deterioration of edible oils.

Keywords: frying, *trans* fatty acid, saturated fatty acid, *cis*-unstaurated fatty acid.

Introduction

During deep-frying, heat, moisture and oxygen regulate the kinetics of oxidation-cum-polymerization reactions forming volatile/non-volatile, mono/polymeric and oxidised/non-oxidised components. This cooking procedure involves high temperatures as a result the food components as well as the oil (used for frying) undergo physico-chemical degradation affecting sensory attributes, nutritional quality and thermal/storage stability of the fried products (Firestone and Reina, 1996). Deep frying has been considered to contribute in the production of TFAs (Bhardwaj *et al*., 2016; Chen *et al*., 2014). *trans*-Fats are unsaturated fatty acids having one/more non-conjugated double bond(s) in *trans* orientation. TFAs are generated during hydrogenation/partial hydrogenation of vegetable oils and/or frying procedures. During deep-frying, especially with the reuse of frying oils, there is a significant increase in TFA content of oils/fried foods (Bhardwaj *et al.,* 2016; Aro *et al*., 1998). Research evidence indicates that trace amounts of TFA (~1.0-1.5%), particularly *trans* dienes and trienes, are also produced during refining or deodorization of vegetable oils (List, 2014).

Formation of *trans* fats at elevated temperatures may render the fried foods harmful for consumer health. *trans*-Fat generation during frying has been extensively investigated which highlights that heat treatment of unsaturated lipids (refining/frying) not only leads to their production (Tsuzuki, Matsuoka and Ushida, 2010) but the

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concentration increases with rising temperatures and prolonged heating (Hou, Jiang and Zhang, 2012). Studies document that TFAs are mainly generated under severe frying conditions (Aladedunye and Przybylski, 2009; Bansal *et al*., 2009; Romero, Cuesta and Sanchez-Muniz, 2000).

India's groundnut oil production contributes to nearly 10% of the world's total vegetable edible oil production (FAO, 2018). Owing to high smoke-point, groundnut oil (~230°C) is considered more suitable for deep-fat frying procedures. For frying purposes, in fact groundnut oil is considered even better than soybean oil as over a period of time it develops lesser off flavours (Young, 1996).

The quality of oil that has been used for frying is a matter of serious concern both for the consumers as well as the food safety institutions/organisations, since the degradation products are envisaged to adversely affect the sensory/nutritional quality of these oils. However, Indian data pertaining to TFA content of oils for frying under varying conditions are rather scanty. The present study was, therefore, designed to assess the effect of frying temperatures and number of frying cycles on *trans* fat content of the groundnut oil used for frying.

Materials and Methods

Keeping in mind thermal stability of the oils used for frying, groundnut oil was selected for the study. A fresh batch of refined groundnut oil was procured from the local market (*Kotla Mubarakpur,* New Delhi). Frying trials using groundnut oil were carried out at Amity University - Noida Campus (Uttar Pradesh). However, fatty acid profiling including TFA content of oils was carried out at the Department of Biochemistry, All India Institute of Medical Sciences, New Delhi.

100g freshly cut potato strips (10×10×70mm) using French fry cutter were fried in groundnut oil (750 mL) in a thick aluminium *karahi.* Frying process was carried out at varying temperatures (160ºC, 180ºC, 200ºC, 220ºC, 230ºC) uptil 32 frying cycles so as to obtain golden brown coloured French fries (visual assessment). At each temperature range, the frying process was initiated with 750 mL of oil starting from the 1st till the 32nd frying cycle. Further, at each of these temperatures, 30 mL of the oil sample was drawn after the 1st, 4th, 8th 16th and 32nd frying cycle without replenishing the oil for subsequent frying cycles. The oil samples so drawn (30 mL) were cooled to room temperature, filtered (using Whatman No. 4) and stored in sterilised air-tight glass bottles at -20ºC till further analyses.

These oil samples were analysed (in duplicates) for fatty acid profile including TFA content. For the present study, analytical grade reagents - fatty acid methyl ester/reference standards as well as other chemicals and solvents were obtained from NuChek, Merck and Sigma. For analyzing the fatty acid profile of oil samples, fatty acid methyl ester 40 component mix (GLC-607) and individual fatty acid esters (arachidonic acid, behenic acid, eicosatrienoic acid, linoleic acid, linolenic acid, oleic acid, myristelaidic acid, palmitelaidic acid, C18:1t, C18:1tΔ6, C18:1tΔ9, C18:2t) were procured from NuChek Prep, Inc (Waterville, Maine) and Supelco.

For studying the effect of frying on fatty acid profile, unheated groundnut oil (control) was also analysed for its fatty acid composition. Undecanoic methyl ester (C11:0) was used as the internal standard.

Analytical Assessments

Fatty acid composition (including TFA) weas determined as per the official methods given by the American Oil Chemists' Society (AOCS).

The oil samples were brought to room temperature and fatty acid methyl esters (FAMEs) were prepared by AOCS official method Ce 1h-05 (2005). The FAMEs were analysed in the Agilent 7890B series gas chromatograph equipped with flame ionization detector (FID) and a fused silica capillary SP-2560 column (100 m × 250 µm internal diameter × 0.20 µm) coated with cyanopolysiloxane (Supelco Inc., Bellefonte, Pennsylvania). The oven temperature was programmed from initial 140°C (hold time: 5 min; ramp: 1°C/min) to 235°C (hold time: 5 min) making the total run time of 105 minutes. The injector and detector port were at 225°C and 260°C respectively. Nitrogen was used as the carrier gas (1 mL/min) -cum-makeup gas (35 mL/min) and hydrogen (20 mL/min) as well as air (200 mL/min) the flame gases. A split ratio of 1:10 was used and 1 µL was injected in the GC for analysis. The fatty acid profiling was done by comparing the retention times of equivalent chain length fatty acids with those obtained by running the known standards (FAMEs from Supelco and NuChek). The peaks were manually integrated, identified and quantified (by computing area under the specific peak using AIMIL software (Nucon Technologies). Thus, concentration of the individual fatty acid was assessed on the basis of per cent under peak in relation to that of the total area.

Statistical Analysis

For all the above parameters, data have been reported as mean±SD and these were subjected to Pearson correlation, ANOVA analyses and Tukey's Honestly Significant Difference Test using SPSS version 21.0 and Microsoft Excel. Graphs were prepared using Origin Pro9 64-bit software.

Results and Discussion

Fatty acid composition is a key parameter for assessing quality of oils since thermic parameters profoundly affect the sensory, physicochemical and nutritional attributes of the oils. Groundnut oil-being high in oleic acid, possesses greater thermal stability. Its oxidative degradation is also slower as compared to other high PUFA containing oils like sunflower, safflower oil etc. (Abdulkarim *et al*., 2007; Young, 1996). Due to high smoke point (~230°C) and neutral taste, groundnut oil is considered more suitable for frying foods.

In the freshly procured unheated groundnut oil (kept at room temperature), TFA was undetectable while mean SFA was 19.42±0.8g/100g and *cis*-UFA 80.58±0.7g/100g. With rising frying temperatures and successive number of frying cycles, the mean *trans* fat increased from 0.26±0.05g/100g (at 160°C, 32nd cycle) to 5.89±1.25g/100g (at 230°C, 32nd cycle), mean SFA increased from 25.28±1.45g/100g (at 160°C, 32nd cycle) to 43.29±1.89g/100g (at 230°C, 32nd cycle) but the *cis*-unsaturated fatty acids decreased from 74.46±1.59g/100g (at 160°C, 32nd cycle) to 50.82±1.26g/100g (at 230°C, 32nd cycle). While there was more than 22 fold increase in the TFA concentrations, SFAs increased by nearly 71%, the *cis*-UFAs decreased by nearly 31% (Fig. 1).

Elevating frying temperatures indicated a significant positive correlation with TFA as well as SFA concentrations but a negative correlation with *cis*-unsaturated fatty acids ($p<0.01$, Table 1). Our study findings are in agreement with Sanibal and Mancini-Filho (2004), who reported that during deep-fat frying of potatoes in soybean oil/partially hydrogenated soybean oil at 180±5°C, *cis*-PUFA decreased while SFA and TFA increased significantly ($p<0.001$). Similar findings have been documented by Bhardwaj *et al.*, 2016 and Aladedunye and Przybylski, 2009). A study by Chen *et al.,* 2014) inferred that deep-fat frying procedures at extreme temperatures and/or prolonged durations induce thermal degradation coupled with TFA formation in the oil and that their concentrations are directly proportional to the frying temperatures and/or duration of frying. At the end of 15th frying cycle, TFAs were found to increase from 0.14% (fresh oil) to 0.30% (Çaglar, Duman and Özcan, 2012; Aladedunye and Przybylski, 2009) also reported an increase in TFA levels of the canola oil used for frying the French fries for a period of one week (~3.3% at 185°C, 5.9% at 215°C). Almost similar findings have also been documented for corn oil (Yang *et al.*, 2012; Wolff, 1993) reported that vacuum heating of flaxseed oil at varying temperatures led to an increase in

Table 1: Pearson correlation coefficients w.r.t. fatty acid profile across individual frying temperatures and varying frying cycles.

Chemical parameter /frying temperature	SFA	*cis*-UFA	TFA
160ºC	0.987**	0.988**	0.980**
180ºC	0.978**	0.977**	0.889*
200ºC	0.976**	0.979**	0.987**
220ºC	0.991**	0.990**	0.939**
230ºC	0.968**	0.968**	0.931**

†SFA: saturated fatty acid, *cis*-UFA: *cis*-unsaturated fatty acid, TFA: *trans* fatty acid. Correlation: *significant at 0.05 level, **significant at 0.01 level.

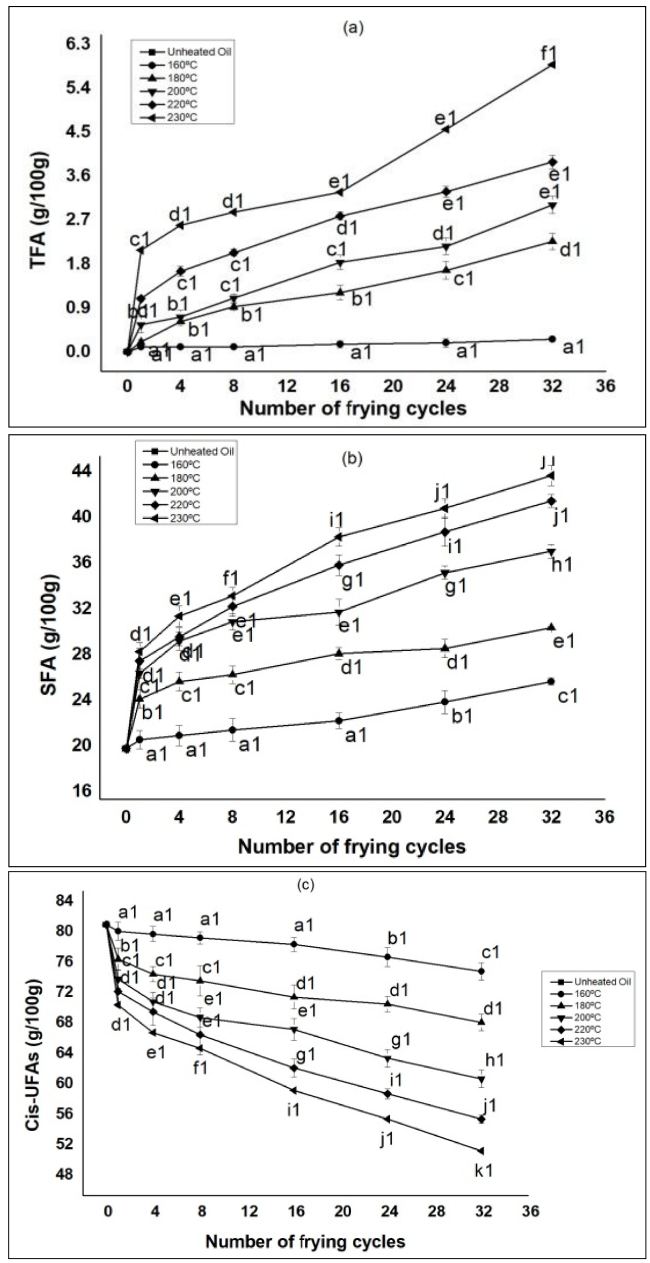

Fig. 1: TFA (*trans* fatty acid; a), SFA (saturated fatty acid; b) and *cis*-UFA (*cis*-unsaturated fatty acid; c) of groundnut oil subjected to varying frying temperatures and frying cycles.

†All values represent mean of two independent analyses (g/100 g), errors bars indicate standard deviation.

trans linolenic acid from 0.2% (fresh oil) to 1.3% (190°C), 9.5% (220°C) and 28.8% (245°C). Frying in soybean oil also led to an increase in TFA content from 1.7% (170°C) to 2.6% (190°C) (Tyagi and Vasishtha, 1996). Heating of olive oil, sunflower oil, corn oil and lard at 80°C to 300°C indicated that regardless of the type of oil, with rising temperatures -*trans* isomers registered a consistent increase. Martin *et al.*, (2007) also endorsed that TFA formation is closely associated with the frying temperatures and time of usage. Irrespective of the type of oil or method of estimation, Bansal *et al.,* (2009) reported a direct association between the degree of isomerization and the number of frying cycles.

Greater palatability and higher acceptability of fried products coupled with convenience and time-saving are some of the reasons for high popularity of the deep-fat frying procedures. During frying, edible oils/fats are subjected to rather high temperatures causing numerous chemical changes like oxidation, hydrolysis, isomerization, polymerization coupled with the generation of TFAs which are known to pose detrimental health effects. The results indicate that there was a steady increase in the SFA and TFA content of groundnut oil used for frying the potato strips at varying temperatures (160°C to 230°C) as well as the number of frying cycles (uptil 32nd cycle) with a concomitant decrease in *cis*-unsaturated fatty acids. The findings indicate that frying greatly affects the oil quality by producing *trans* fats and other degradation products which can pose adverse health effects.

Since multiple factors are associated with TFA generation during frying, the fats/oils should not be subjected to high temperatures or heated for too long. Further, the oil used for frying should not be reused for frying purposes rather it should be utilized for cooking by absorption method so that the left-over fat/oil is not subjected to further degradation. Although, laws/ regulations regarding mandatory TFA labelling exist, authorities yet need to formulate effective policies, stringent food laws and impose necessary regulations to curb fat/oil abuse during the process of frying. It is envisaged that the inclusive data generated in this study would greatly help during the formulation of Indian food safety guidelines for curbing TFA content of oils used for frying.

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