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Effect of heating/reheating of fats/oils, as used by Asian Indians, on *trans* fatty acid formation

Swati Bhardwaj [a,b,c,d], Santosh Jain Passi [d,e], Anoop Misra [a,b,c,f,*], Kamal K. Pant [g], Khalid Anwar [g], R.M. Pandey [h], Vikas Kardam [g]

[a] National Diabetes, Obesity and Cholesterol Foundation (N-DOC), C 6/57, SDA, New Delhi 110016, India
[b] Diabetes Foundation (India), C 6/57, SDA, New Delhi 110016, India
[c] Center of Nutrition and Metabolic Research (C-NET), New Delhi 110016, India
[d] Institute of Home Economics, University of Delhi, F-4, Hauz Khas Enclave, New Delhi 110016, India
[e] Public Health Nutrition Div, LSTech Ventures Pvt Ltd., New Delhi, India
[f] Fortis C-DOC Center for Excellence for Diabetes, Metabolic Diseases and Endocrinology, B-16, Chirag Enclave, Nehru Place, New Delhi 110048, India
[g] Department of Chemical Engineering, Indian Institute of Technology (IIT), Hauz Khas, New Delhi 110016, India
[h] Department of Biostatistics, All India Institute of Medical Sciences (AIIMS), Ansari Nagar, New Delhi 110029, India

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ABSTRACT

Heating/frying and reuse of edible fats/oils induces chemical changes such as formation of *trans* fatty acids (TFAs). The aim of this study was to investigate the effect of heating/frying on formation of TFAs in fats/oils. Using gas chromatography with flame ionisation detector, TFA was estimated in six commonly used fat/oils in India (refined soybean oil, groundnut oil, olive oil, rapeseed oil, clarified butter, partially hydrogenated vegetable oil), before and after subjecting them to heating/frying at 180 °C and 220 °C. All six fats/oils subjected to heating/frying demonstrated an increase in TFAs ($p < 0.001$), saturated fatty acids ($p < 0.001$) and decrease in *cis*-unsaturated fatty acids ($p < 0.001$). The absolute increase in TFA content of edible oils (after subjecting to heating/reheating) ranged between 2.30 ± 0.89 g/100 g and 4.5 ± 1.43 g/100 g; amongst edible fats it ranged between 2.60 ± 0.38 g/100 g and 5.96 ± 1.94 g/100 g. There were no significant differences between the two treatment groups (heating and frying; $p = 0.892$). Considering the undesirable health effects of TFA, appropriate guidelines for heating/re-frying of edible fats/oils by Asian Indians should be devised.

1. Introduction

Deep-frying is a popular method of food preparation globally, specifically in the Indian subcontinent, wherein the food is cooked in hot fat/oil, deep enough to cover the food (Pasricha, 1989; Raina, 2001). High temperature used in frying causes lipids to undergo a variety of chemical and physical changes due to thermal decomposition. During deep-frying, the fat/oil is continuously exposed to elevated temperatures in the presence of air and undergoes hydrolysis, oxidation and polymerisation, resulting in deterioration in quality, thereby causing changes in not only the sensory but also the nutritional properties (Zhang, Saleh, Chen, & Shen, 2012). However, such deteriorated fats/oils are often repeatedly used for frying by commercial vendors and homemakers in India in order to decrease costs.

Frying is also considered as a contributory factor leading to *trans* fatty acid (TFA) formation, which is believed to be a product of partial hydrogenation (Chen et al., 2014; Guallar-Castillon et al., 2012). Presence of TFAs in fats/oils and food items is of particular interest, owing to their association with adverse effects on health. There is rapidly escalating research on health effects of TFAs and a significantly growing body of evidence linking TFAs to CHD, highlighting that TFAs may be even more harmful than saturated fatty acids (SFAs). Metabolic studies have shown that TFAs increase low-density lipoprotein cholesterol (LDL-c) and decrease high-density lipoprotein cholesterol (HDL-c) levels, increasing the risk of cardiovascular diseases (Bhardwaj, Passi, & Misra, 2011; Brouwer, Wanders, & Katan, 2013; Mozaffarian, Katan, Ascherio, Stampfer, & Willett, 2006; Nestel, 2014; Yanai et al., 2015). TFA intake, has also been suggested to influence systemic inflammation, and may increase insulin resistance (Micha & Mozaffarian, 2009;

* Corresponding author at: Fortis CDOC Center for Excellence for Diabetes, Metabolic Diseases and Endocrinology, B16 Chirag Enclave, New Delhi, India.
E-mail address: anoopmisra@gmail.com (A. Misra).

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Mozaffarian, 2006). Furthermore, there is a growing concern that the risk for type 2 diabetes also increases with TFA consumption (Bhardwaj et al., 2011; Mozaffarian, 2006).

The formation of TFAs during food frying is closely related to the temperature and the number of times the same oil is used (Li, Ha, Wang, Li, & Li, 2012; Moya Moreno, Mendoza Olivares, Amezquita Lopez, Gimeno Adelantado, & Bosch Reig, 1999). According to Tsuzuki (2011), fresh purified edible oils contain low levels of TFAs (Hou, Wang, Wang, Xu, & Zhang, 2012), which may increase when used for cooking and frying. Further, data also showed an increase in the concentrations of *trans* isomers with increase in temperature and duration of heating (Martin, Milinsk, Visentainer, Matsushita, & de-Souza, 2007). Based on these data, several European countries have recommended that the frying oil temperature must not exceed 180 °C and even have regulations against the use of deteriorated frying oils (Martin et al., 2007). The traditional cooking practice adopted in India involves the cooks, food vendors and homemakers heating and reheating fats and oils in a large *karahi* (a thick, circular, and deep cooking pot, similar in shape to a wok, used for open-air deep frying) or fryers at varying temperatures, for long hours with intermittent cooling and reuse of such oils to cut costs. Recently, Dixit and Das (2012) analysed the TFA content in edible oils and fats, and its probable intake in the Indian population. However, there is a shortage of Indian studies highlighting the generation of TFA during heating of fats/oils or whether the traditional/commercial cooking practices adopted in India may result in formation of TFAs, and if so, to what extent. The present study was designed to evaluate formation of TFAs when oils/fats as used in Indian cooking, are constantly heated at high, varying temperatures to carry out frying, with intermittent episodes of cooling, with the experimental design closely formulated on the basis of deep-fat frying practices adopted at commercial and household levels in the Indian subcontinent. In view of the lack of guidelines on *trans* fatty acids available in India to curb the practices of using degenerated fats/oils at commercial levels, it is important to highlight the same using experiments based on day-to-day cooking/frying practices.

2. Materials and methods

2.1. Sampling

There is a wide variety of fats/oils used in India; therefore, to identify the most commonly used fats/oils (for frying) and the deep fat frying practices, a survey was carried out among 402 female respondents and 42 commercial food establishments, including restaurants, fast food joints (both Indian and western), and roadside vendors. Thereafter six different types of fats/oils commonly used in north India were selected for the study; refined soybean oil (RSO), refined groundnut oil (RGO), refined olive oil (ROO), refined rapeseed oil (RRO), clarified butter (CB; *ghee*) and partially hydrogenated vegetable oil (PHVO; *vanaspati*). For each fat/oil three different samples were used for analysis. All the analysis was conducted in duplicate. Further, to study the formation of TFA in fats/oils during heating/reheating and frying in heated/re-heated fats/oils, two temperatures, each representing a lower (180 °C) and a higher (220 °C) cooking temperature were selected based on previous studies (Bansal, Zhou, Tan, Neo, & Lo, 2009; Martin et al., 2007; Moreno, Olvares, Lopez, Adelantado, & Reig, 1999). Heating/frying of the selected oil samples was carried out at the Foods Laboratory at Institute of Home Economics, New Delhi. The analyses of TFA content of oils were carried out at the Department of Chemical Engineering of the Indian Institute of Technology, New Delhi. A custom made digital hot plate, which can generate temperatures from 50 to 400 °C, with temperature sensors, thermostat and digital temperature display, was used.

2.2. Standardisation

Standardisation of oil quantity and duration of frying was done using commercially blended vegetable oil containing refined edible rapeseed oil (70%) and refined edible sunflower oil (30%). Pre-frozen French fries (PFFF; McCain brand, purchased from a local supermarket, used for all experiments) were selected as the standard test food for frying, due to their standard composition, measurement and easy availability. Prior to initiating the frying protocol, the complete fatty acid profile of pre-fried PFFF was analysed. The fatty acid profile of PFFF as obtained after analysis and that from nutrition labels (and website) are presented in Table 1 (McCain, 2014). The fat was extracted using the Soxhlet method, which is recognised by the Association of Analytical Chemists (AOAC) as the standard method for crude fat analysis (AOAC, 1990). After converting to fatty acid methyl esters (FAMEs), they were analysed using gas chromatography (GC) with flame ionisation detectors (FID), to identify the fatty acid (FA) peaks (AOAC method 969.33) against those of standards (AOAC, 2000). In each case PFFF were fried to obtain a golden brown colour as judged by visual appearance. The fatty acid profile of 100 g of PFFF (Table 1) showed that they were free of TFAs (0.0 g/100 g) (McCain., 2014).

2.2.1. Heating protocol (Fig. 1)

For each fat/oil sample, a karahi (a thick, circular, and deep cooking pot, similar in shape to a wok, used for open-air deep frying) containing 500 mL of the fat/oil sample was taken. The fat/oil temperature was recorded and heating was initiated till the temperature of the fat/oil reached 180 °C. The temperature of fat/oil was maintained at 180 °C for 30 min; thereafter, 30 mL oil were removed in clean and pre-dried, pre-coded glass bottles and stored in a cool box. The subsequent heating cycle was performed on the same fat/oil sample by continuing heating and maintaining the sample for half an hour at 220 °C, and then it was allowed to cool for 60 min. Subsequently, the same sample was reheated, and the entire process was repeated.

2.2.2. Frying protocol (Fig. 1)

To study the effect of formation of TFAs in heated/reheated fats/oils used for frying, a similar process as described above was carried out, wherein, a *karahi* containing 500 mL of the fat/oil sample was taken, and, after the initial heating-up process and maintaining the fat/oil temperature at 180 °C for 30 min, a first frying cycle was started. During each frying cycle, 50 g PFFF were fried. The subsequent frying cycle was performed after continuing heating and maintaining the same oil sample for half an hour at 220 °C, and then sample was allowed to cool for a period of 60 min.

Table 1
Fatty acid profile of pre-fried French fries.*

Fatty acid profile	Pre-fried French fries (g/100 g)	
	Laboratory analysed values	Nutrition label and website [10]
Total fat	7.83 ± 0.70	7.25
Saturated fatty acid (SFA)	4.80 ± 0.56	3.76
cis-Monounsaturated fatty acid (MUFA)	1.70 ± 0.53	1.40
cis-Polyunsaturated fatty acid (PUFA)	1.33 ± 0.35	2.09
cis-Unsaturated fatty acid (UFA)	3.03 ± 0.21	3.49
trans Fatty acid (TFA)	UD	0.00

* Test food used for frying, UD; undetectable.