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Research Article

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Evaluation of Oil Quality of Selected Street Fried Foods

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ABSTRACT

Objective: As the oil quality of fried food help in understanding the quality of fried food, this study was aimed to analyse the oil quality of selected street fried foods.
Methods: In this study, deep fried snacks such as poori (flattened bread of wheat), samosa (pastry with savoury filling), bread pakora (bread stuffed with potato and coated with gram flour) and chicken pakora (small pieces of chicken with mixture of different spices) were randomly collected from the street vendors of Delhi which are consumed regularly by local population. The fried oils from these snacks was extracted and analysed for lipid oxidation status.
Results: The study revealed that all these extracted oils have high levels of free fatty acids (FFA), peroxide value (PV), and p- anisidine value (p-AV). Although total polar materials (TPM) was not checked in frying oils but the extracted oils was reheated to 50°C and checked for TPM levels, wherein more than 65% of oils were found of unacceptable quality (25.0 > TPM). The fatty acid profiling of oils using gas chromatography depicted the breaking of double bonds into single bonds as Saturated Fatty Acids (SFA) constituted 69.2-73.7% in these extracted oils. Trans Fat (TFA) also constituted 1.57-2.31% of these oils. The FTIR data of the oils corroborated the fact that degree of saturation is more in these extracted oils than in fresh oils.
Conclusions: All the street fried foods, analyzed, had less than the desirable quality. Therefore, it is suggested to educate the street fried food vendors to provide good quality fried foods for public.

Key words: Deep frying, Fatty acids, Lipid oxidation, Oil quality, Street fried foods

Introduction

Fried foods are popular and highly appreciated by consumers worldwide due to their unique sensory properties, such as flavour, colour, palatability and texture. Oils and fats are used as means of heat transfer from the fryer to the food (Andrikopoulos et al. 2003). Deep frying is a continuous process of heating oil at elevated temperature of 165-195°C. It is the process of frying oil uptake by the frying material and mass transfer, involves the loss of carbohydrate, protein, oil and fat, moisture and vitamins and other compounds from fried material (Zhang et al. 2012).

Deep fat frying is a complex process and it depends on several factors including oil composition, storage of oil, nature of frying material and its interaction with frying medium and frying equipment material. The degradation quality of fried food and the frying oil depends on all these factors and their interactions (Bou et al. 2012, Rosseli 1998). The hydrolysis, oxidation and polymerization of oil produce volatile and non- volatile compounds (Choe and Min 2007). Most of the volatile compounds generated during frying, evaporate in the atmosphere with steam and the remaining volatile compounds would undergo further reactions upon heating or may be absorbed by the food fried in that oil (Choe and Min 2007). Initiation

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of lipid oxidation was made by a large number of molecules to form peroxy radicals, these radicals then abstract a hydrogen from fatty acids to form acyl radicals and hydroperoxides, which in turn enhance cholesterol oxidation (Soto-Rodríguez et al. 2008). Many toxic degradation problems are identified in deep fat fried foods in which acrylamide and 4 hydroxy nonenol (HNE) have attracted much more attention because of its high toxicity and concentrations that may pose health concerns. Frying time, temperature, food surface area, types of battering materials, moisture content of food, and frying oil influence the amount of absorbed oil to foods (Moreira, Sun and Chen 1997, Choe and Min 2007). The absorbed oil always accumulates on the surface of fried food during frying and moves to interior during cooling. The quality of oils and fats during the frying process has a major influence on the quality of the fried foods (Andrikopoulos et al. 2003).

The rate of chemical reactions during frying depends on particularly conditions such as temperature, frying time, numbers of frying, type of food, additives, and air blowing (Javad Taghipour Fard ARDEKANI and Taghipour Fard ARDEKANI 2015). Moreover, it also relies on consumed oil features, predominant fatty acid in percent, mono-, and poly- unsaturated fatty acids, as well as produced food composition(Karakaya and Şimşek 2011). Multiple times frying of oil changes the physical characteristics and chemical composition of oils. Therefore, quality of fried foods was also affected, if the frying was done multiple times in the same oil (Flores-Álvarez et al. 2012). It was suggested, to standardize the fried food quality, a suitable frying conditions in each frying cycle should be maintained (Bou et al. 2012).

Bhardwaj et al. (2016) studied the effect of deep fat frying through formation of trans fatty acids at commercial and household levels in India. The result of this study demonstrated presence of high levels of TFA and SFA in fats/oils when frying was subjected to high temperature heating/re-heating. A recent study on frying oils of selected street fried foods in India reveled the increased trans fatty acid and total polar material (Kumar et al., 2020, Kumar et al., 2021). It was only in December 2014 that Food Safety and Standards Authority of India (FSSAI) regulations revised the limit of trans-fat content to 5% in partially hydrogenated vegetable oils (PHVOs) like Vanaspati (Prasad 2016). Moreover, in September 2016, FSSAI amended the limit of total polar material in edible oil to 25%. However, in a study (Gupta et al. 2016) on the oil used by 44 street vendors in two low-income villages in Haryana and an urban slum in Delhi, it was found that the oil constituted 25-69 % saturated fats and 0.1-30 % trans fatty acids. Though FSSAI clearly states that oil should not be reused more than 2-3 times, restaurants and street vendors often reuse oil, particularly for deep frying, to cut costs. In India's capital, street fried foods are very popular and commonly available at all public places like busy markets, parks, road side etc. Street food vendors may use cheaper quality cooking oils, repeatedly frying the foods in the same oil for several times. As the frying oil gets absorbed into the fried foods, therefore targeting to study the quality of the extracted oil from fried snacks would give better picture of the oil quality of street fried foods in and around Delhi.

Materials and Methods

Materials

A sample of 80 comprises poori, bread pakora, chicken pakora and samosa was procured from all the four corners of Delhi and stored for further analysis. Chemicals for fatty acid profiling were purchased from Sigma supelco (FAME standard C4-C24). All the other AR grade chemicals are procured from SRL chemicals, India.

Extraction of fried food oil

The oil from fried food samples were extracted by Soxhlet Method, (AOAC, 2005). The 50 g fried food samples were taken in the thimble and kept in Soxhlet apparatus and 300 ml of n-hexane was used to extract the oil at the condensation rate of 5 or 6 points per second for 4 hours at a temperature of 70˚C. Then the rotary evaporator was set at 40˚C to evaporate the solvent to dryness (Shaker 2015).

Measurement of oil colour

The oil samples colours were determined by Hunter Lab digital colorimeter. The degree of lightness or darkness of the sample was indicated through L* value and this value extended from 0 (black) to 100 (white). The degree of redness to greenness indicated by a* positive to negative value, whereas b* positive to negative value indicates degree of yellowness to blueness (Nayak, Dash and Rayaguru 2016a).

Determination of peroxide value and free fatty acids (FFA)

The extracted oil peroxides oxidises potassium iodide to iodine and quantified titrimetrically using 0.1N sodium thiosulphate and starch indicator. The peroxide value expressed as milliequivalents of oxygen per kilogram of oil

(Debnath et al. 2012). Titration was done in Auto Titrator using Metrohm 848 Titrino plus with pH sensor electrode 6.0262 Metrohm.

AOCS Official Method, 2002 was used to analyse the free fatty acid (FFA) content of the oils extracted from fried foods. The extracted oil was neutralized with alcohol and allowed to boil. The solution was titrated against 0.1N sodium hydroxide using phenolphthalein as an indicator. The free fatty acids values were expressed as % of oleic acid (Debnath et al. 2012).

Determination of p-Anisidine value(p-Av)

p-AV was determined according to 1998, AOAC official method. The complete method explained by (Germain 2015), was considered to analyse p-AV from the extracted oil samples.

Total polar materials of oil

The amount of TPM was determined by using TESTO 270 (Testo Inc., Germany). This instrument provide % TPM with the accuracy of +/- 2% TPM. This sensor based instrument was inserted into the oil sample and it will display the % TPM in 30 seconds. First sensor was calibrated with the calibration oil supplied by the manufacturer before analysing the frying oils. Then, the equipment was cleaned with warm water and neutral detergent and dried well between the measurements (Mlcek et al. 2015). The FSSAI amended the limit of total polar material in edible oil to 25%.

Determination of fatty acid composition in oil

The fatty acid profiles of the oil extracts were determined using the method explained elsewhere (Karn, Ann Abraham and Ramakrishnan 2013). The known fatty acid methyl esters standard from SUPELCO was used to determine the fatty acids composition. The area under the chromatogram peak was calculated using NUCHROME (Nucon Technologies) software. The individual fatty acid concentration was expressed as % of total area under the peak.

Spectra studies of oil

FTIR spectroscopy has significant advantages over chemical analytical techniques; it is a fast and simple method that requires no sample preparation (Zhang et al. 2015). The functional group changes in the extracted oils of fried foods were studied using BRUKER made FTIR spectrometer. The procedure to acquire the FTIR spectra was adopted from the method explained by (Rohman and Man 2010).

Statistical analysis

The data obtained were statistically analysed with the help of IBM, SPSS Statistics, version 23. The statistical technique ANOVA has applied and presented in tables.

Results

Colour of fried food oil

Colour of oils is a physical indicator of oil deterioration caused by polymerization and oxidation. The photograph of oil samples extracted from street fried foods is shown in Figure 1. Hunter colorimetric studies were performed in extracted oil of selected street fried food samples. The L*, a* and b* colour values of oils extracted from different street fried foods are shown in Table 1. Oil extracted from chicken pakora exhibited decreased lightness (L*) as compared to other fried food oil extraction samples. a* values of poori oil was -2.17±0.01 while chicken pakora oil was -3.42±0.01, indicating increase in greenness in chicken pakora oil. The yellowishness (b*) of oils extracted form poori, samosa, bread pakora and chicken pakora were found to be in the increasing order values.

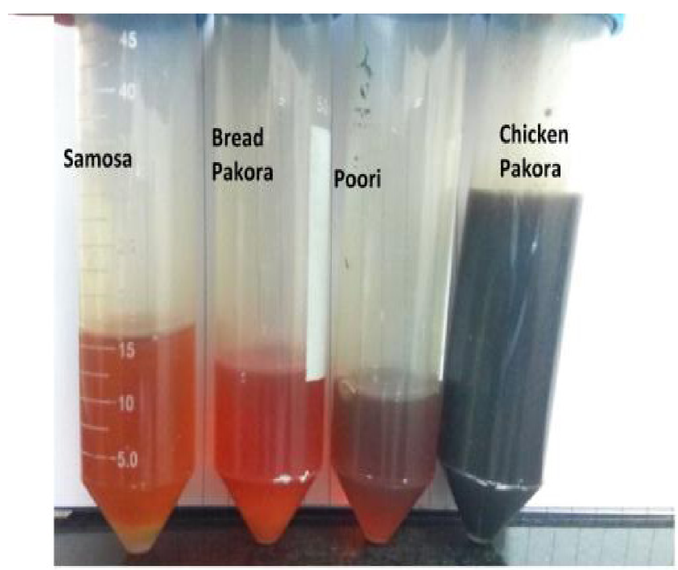

Figure 1. Colours of oil extracted form street fried foods

Table 1. Colour values of extracted oils from street fried foods

Colour	Poori	Samosa	Bread pakora	Chicken pakora
L*	86.02± 0.09[a]	84.99±0.1[b]	88.67±0.1[c]	83.89±0.05[d]
a*	-2.17±0.01[a]	-2.46±0.01[b]	-3.38±0.02[c]	-3.42±0.01[d]
b*	7.07±0.02[a]	9.48±0.01[b]	10.48±0.01[c]	11.55±0.01[d]

L* - Degree of lightness to darkness, a* - Degree of redness to greenness and b* - Degree of yellowness to blueness. All the data are expressed as mean ± SD. Means with the different superscript letters in a row are differ significantly (P<0.05)

Table 2. Analysis of street fried food extracted oils quality

Quality Parameters	Poori	Samosa	Bread pakora	Chicken pakora
FFA (% Oleic acid)	1.54 ± 0.28[a]	1.79 ± 0.19[b]	1.98 ± 0.24[c]	2.12 ± 0.63[d]
PV (mEq/Kg)	17.80 ± 0.48[a]	18.72 ± 1.12[b]	19.73 ± 1.48[c]	32.19 ± 2.17[d]
p-AV	19.89 ± 3.50[a]	20.11 ± 3.28[b]	21.51 ± 0.45[c]	21.79 ± 0.76[d]

Quality studies

Free Fatty acid (FFA) Peroxide Value (PV) and p-Anisidine value (p-AV) of oil samples extracted from the selected street fried food items to determine the quality. The result of these quality parameters are detailed in Table 2. Each value in the table represents the triplicate average value of quality parameters studied for selected fried foods. Poori samples had least FFA value (1.54 ± 0.28 %), while chicken pakora had higher FFA value of (2.12 ± 0.63%). Peroxides are the primary oxidation products of the lipid oxidation. Initial formation of hydroperoxides by oils in a normal or deep frying condition is a good indicator of lipid oxidation (Diop et al. 2014). All the samples analysed had higher PV in which chicken pakora samples showed highest PV (32.19 ± 2.17 mEq/ kg). Higher peroxide values which corresponds to very poor quality of fat (Reshma et al. 2012). p-Anisidine values indicate the oxidative degradation of fat in the food samples. The p-AVs were also in the higher side like PVs in these extracted oils. The p-anisidine values were similar in the oils extracted from the four samples ranging from 19.89 ± 3.5 in poori samples to 21.79 ± 0.76 in chicken pakora samples.

FFA – Free Fatty acid, PV – Peroxide Value, p-AV – para Anisidine value. All the data are expressed as mean ± SD. Means with the different superscript letters in a row are differ significantly (P<0.05)

Total polar materials

Total Polar Materials (TPM) analysed in the oils extracted from the street fried foods of Delhi are shown in Figure 2. The percentage of TPM in the extracted oil was found to be in the range of 24.29 – 27.97 %. Most of the European countries have established the maximum range limit of TPM as 23-27% for the rejection and replacement of cooking oil in restaurants (Mlcek et al. 2015, Caldwell, Cooke and Greer 2011, Andrikopoulos et al. 2003). Recently, FSSAI amended the TPM limit in edible oils to 25%. The limit 24% for TPM was recommended as the most appropriate for rejection while the limit of 20% TPM has been recommended for the replenishment of the oil or fat (Gertz 2000, Mlcek et al. 2015, Andrikopoulos et al. 2003).

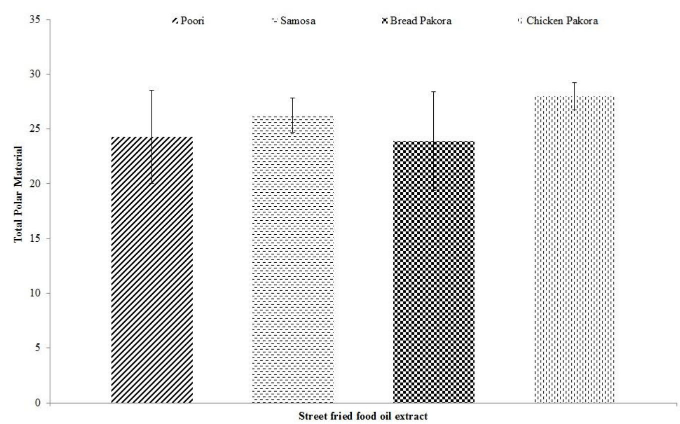

Figure 2. Total polar material mean percentage of street fried food oils

Fatty acid profiling of oils

Total fatty acid profiles of oil samples extracted from street fried foods were analysed and results are presented in Table 3. Saturated fatty acids were found highest in chicken pakora (73.76±2.125) followed by Samosa (73.06±1.32), bread pakora (70.88 ± 0.21) and poori samples (69.2 ± 1.21). Of all the saturated fatty acid analysed in extracted oil samples, stearic acid was predominantly found. The results were similar to a study (Wasti and Rafique 2013) where in the oils extracted from fried fish, chicken and French fries,

Table 3. Fatty acid profiling of street fried food extracted oils

Samples	Saturated fatty acids	Mono Unsaturated fatty acids (MUFA)	Poly Unsaturated fatty acids	Trans fatty acids (Elaidic acid) C18:1n9t
Poori	69.2 ± 1.21^{a}	17.27 ±0.02^{a}	2.22 ± 0.203^{a}	1.57 ± 0.03^{a}
Samosa	73.06 ± 1.32^{b}	15.82 ± 0.05^{b}	2.61 ± 0.2^{b}	1.97 ± 0.20^{b}
Bread pakora	70.88 ± 0.21^{c}	20.20 ±1.2^{c}	1.75 ± 1.32^{c}	1.56 ± 0.03^{a}
Chicken pakora	73.76 ±2.125^{d}	13.77±1.21^{d}	4.15 ± 1.24^{d}	2.31 ± 0.05^{d}

the concentration of saturated fatty acid (stearic acid) was found higher than MUFA. The main trans fatty acid i.e., Elaidic acid is found in all the fried food extracted oil samples was ranging from 1.5 – 2.3%. The highest trans fatty acid content was detected in chicken pakora. However, the levels of trans fatty acid content of take away chicken pakora from deprived areas of Scotland (Food Standards Agency 2014) was found to be 12 times less than that of chicken pakora collected form Delhi streets.

Saturated fatty acids (C15:0, C16:0, C17:0, C18:0, C20:0); MUFA (C14:1, C15:1, C16:1, C18:1n9c); PUFA (C18:2n6, C20:2, C20:3n) All the data are expressed as mean ± SD. Means with the different superscript letters in a column are differ significantly (P<0.05)

FTIR spectra analysis of street fried food oil extract

The changes in the functional groups of fried oil can be determined through the analysis of FTIR spectra (Innawong 2001). The FTIR spectra of fresh palm oil and oil extracted from chicken pakora samples are shown in Figure 3. Similarly to the earlier studies on frying oil samples (Innawong 2001, Rohman and Man 2010), similar spectra was obtained in the case of extracted oils from fried food samples, i.e. the strong bands at 2922, 2852 1743, 1459 and 1160 cm^{-1} that correspond to asymmetrical, symmetrical C-H stretching vibrations of CH_2 groups, C=O (ester) stretching, C-H bending (scissoring), and C-O stretching, bending, respectively. Fried oil generates oxidation end products which were normally observed in the region (3800–3200 cm^{-1}). OH group stretching vibration of hydroperoxide is associated with a peak of 3471-3473 cm^{-1} and the formation of FFA is being indicated through a weaker shoulder region at 3300 cm^{-1} (Goburdhun, Jhaumeer-Laulloo and Musruck 2001, Innawong 2001). A peak was observed in the region 3471-3473 cm^{-1} indicating the decreased presence of hydroperoxide in the oil extracted from the fried food samples.

Discussion

The dark colour of the oil extracted from chicken pakora sample indicates development of α-, β-unsaturated carbonyl and nonvolatile decomposition compounds during thermal decomposition and oxidation of fatty acids (Nayak et al. 2016b). Further the lowest L* values obtained in case of oil from chicken pakora supports the established fact that darkened frying oil samples exhibit lower L* values. Parallelly, it was also established in the earlier studies (Sunisa et al. 2011) by comparing different time and temperature of frying conditions, viz., frying the marinated chicken at 190°C for 15-21 min and at 180°C for 21 min caused darker products. Therefore it may be concluded that chicken pakora collected from streets of Delhi might have been fried in the temperature range of 180-190°C. It was also found in the same study that increasing frying time resulted in slightly increase in yellowness (b*) of oil. Similarly in our study also it was observed highest yellowness in chicken pakora oil than any other oil samples of fried foods which also suggests that chicken pakora might have been fried for longer time or the same pakora might have been re-fried a number of times.

Off-flavour in oils and fried products are developed due to the hydrolysis of fats to produce FFAs. Therefore analysis of free fatty acids (FFA) content is still considered to be an indicator to understand oil and fried food quality. Moisture content of the fried products accelerates the hydrolysis of oil to form a combination of mono and diacylglycerols, glycerol and free fatty acids and this could be the reason for increase in FFA content of oil extracted from all the selected street fried foods. In deep fat frying it is difficult to differentiate FFA formed by oxidation or by hydrolysis. Therefore in the assessment of the oil degradation by frying, FFA is not very reliable parameter (Diop et al. 2014, Ramadan, Amer and Sulieman 2006).

Increased peroxide values of oil extracted from all the selected street fried food was a useful indicator of initial oxidation and it was related to the formation and breakdown of oxidation products but not related to the frying

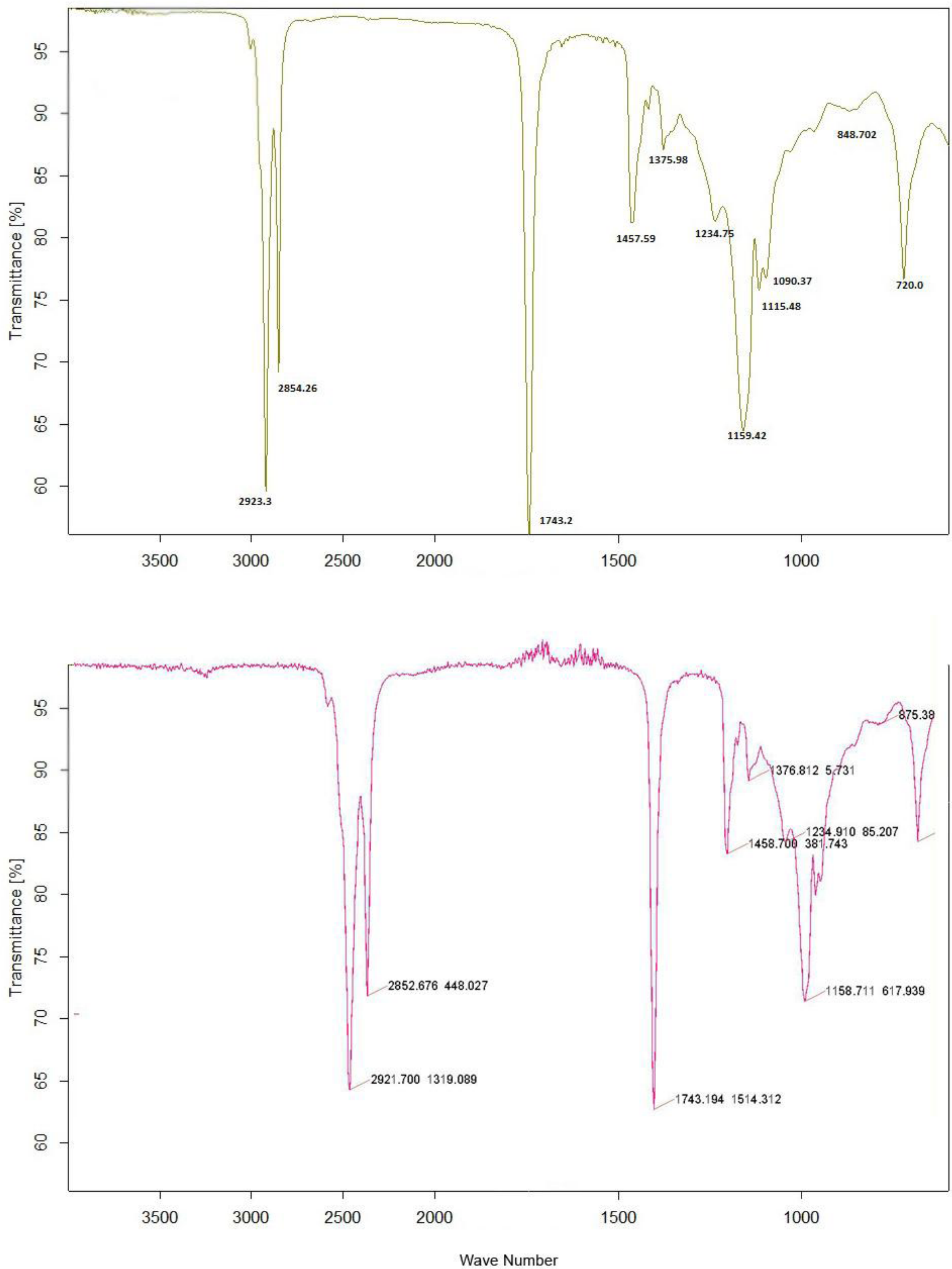

Figure 3. FTIR spectra of fresh palm oil (top) and oil extracted form chicken pakora (bottom)

duration. At frying temperature peroxides are unstable and decompose (Diop et al. 2014). The fried foods' peroxide values may increase after it has been taken out from the fryer. Hence, to determine deterioration of frying oil quality peroxide value is generally not a very dependable parameter (Warner and Gupta 2003, Diop et al. 2014). Therefore the secondary oxidation compounds are quantified through p-Anisidine value.

The oils extracted from all the four categories of the street fried foods collected from Delhi exhibited higher p-Anisidine value indicating that these foods would have been prepared with increased frying temperature and time. This may have resulted due to the accumulation of aldehyde compounds produced from less stable primary oxidative hydroperoxides (Sunisa et al. 2011).

Oxidized and other polar lipids enters the fried material relatively more easily than original frying oil (Pokoryn and Dostalova 1999). Oil extracted from samosa and chicken pakora found to have higher percentage of TPM. Therefore, oil extracted from these fried food is always more oxidized than the frying oil which remains in the fryer (Pokoryn and Dostalova 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 (Mlcek et al. 2015, Brinkmann 2000). Both repeated frying and heating of oils led to the production of polar compounds that has been shown to increase the degree of oil unsaturation (Takeoka, Full and Dao 1997, Romero, Cuesta and Sánchez-Muniz 1998, Mlcek et al. 2015).

The occurrence of increased saturated fatty acids in the street fried food extracted oil may be due to the use of mixture of oils (used and fresh) by street vendors as they practice to add fresh oil of different brands in used fried oils without discarding the old frying oils. This is to be noted that the daily value for saturated fatty acids (on a 2000 calorie diet) is 15% and the study revealed 69.2 to 73.76 % which is not securely under the allowable limit (Wasti and Rafique 2013). The Scientific Advisory Committee on Nutrition (SACN) advises that no more than 2% daily food energy should be provided by trans fatty acids (TFAs) (Food Standards Agency 2014). Among all the street fried food analysed extracted oil from chicken pakora was found to have higher amount of trans fatty acid. The increase in trans fatty acids in the oil from chicken pakora sample may be due to repeated use of oils by street vendors, as it had been suggested by earlier studies that repeated use of oils could result in an increased level of TFA (Food Standards Agency 2014).

It was noticed that after deep frying, the used and fresh oils (fresh oil spectra from the earlier work of the same group) showed very similar FTIR spectra. However, some specific peak heights were different among the used and unused oils indicating the difference in the quantity of compound of interest (Innawong 2001). The observance of transmittance at 3471-3473 cm^{-1} in the extracted oil from the fried food samples indicated the decrease in the amount of hydroperoxides due to its decomposition into other compounds (Zahir et al. 2014).

Conclusion

The lowest lightness L* value of the oil extracted from chicken pakora sample indicates that these samples might have developed more pigments through oxidation and thermal decomposition compared to other samples. The quality parameters (FFA, PV, p-Anisidine values) also indicate that the oil is of poor quality which was absorbed by the most of the street fried foods. The higher percentage of TPM in the oil extracted from samosa and chicken pakora infers that oxidized and other polar lipids might have entered in these fried materials. The study has shown that the oils used in repeated frying technique can have a large impact on the amount of TFA and SFA within foodstuffs that are deep fried. In order to reduce intakes of saturated fat, switching to liquid oils that are lower in saturated fats (such as vegetable), cooking at the correct temperatures and practices such as changing oils frequently could significantly reduce the saturated fat content of these street fried foods. It is recommended to conduct awareness programmes for street vendors for the benefit of public health.

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