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FRYING STABILITY ASSESSMENT OF PALM OLEIN BLENDS OF SUNFLOWER AND SOYBEAN OILS HAVING BALANCED FATTY ACID PROFILE

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ABSTRACT

Edible oil blends prepared from palm olein and sunflower/soybean oils (6:4 w/w) with desired fatty acid profile as per American Heart Association (AHA) recommended SFA:MUFA:PUFA ratio of 1:1:1 were used for frying of food products to assess their frying stability against native oils. Frying was carried out with two popular snacks namely, poori and French fries with low and higher moisture content respectively. The oil retention/absorption was more in the snack with high moisture content compared to the snack with low moisture. Physico-chemical parameters like acid value, peroxide value and total polar matter were analyzed for the fried oil samples. The analysis revealed that oxidation occurred more rapidly compared to hydrolysis during deep-fat frying and that blending with palm olein attributed higher stability to oils which were rich in unsaturated fatty acids. The total polar matter of the fried oils was found to be below 25% under the present frying conditions.

Keywords: Blended oils; Fatty acids; Frying; Oil absorption; Palm olein; Oxidative stability

INTRODUCTION

Deep frying is a widely used cooking process which entails cooking the food by immersing in hot edible oil or fat at temperatures ranging from 150 to 200°C. It is popularly used in several food industries and households since long period as it enhances sensory attributes which includes palatability, flavour, colour and texture of the raw material. During frying, the oil undergoes several chemical reactions such as hydrolysis, oxidation and polymerization, cyclization and pyrolysis (**Tynek *et al.*, 2001**). During frying, the food material undergoes several physical and chemical changes consisting of dehydration, starch gelatinization, protein denaturation, aromatizing and colouring via Maillard reaction which can lead to deterioration if frying of the food material is not controlled (**Ziaiifar *et al.*, 2008**). However, the degree of deterioration of fried oils depends on the nature of heating, fatty acids present in the oil and also based on the food material being cooked (**Saeed *et al.*, 2019**). A wide range of oils and fats can be used for frying different varieties of food and the choice of oil for frying is now focused on the quality of the oil used as a nutritionally lower quality oil is considered as one of the main factor for risks of several diseases like cancer, diabetes and heart diseases (Dana and Saguy, 2001). Frying results in a number of degradation products such as free fatty acids, oxides, peroxides, alcohols, etc which are collectively known as polar matter or polar compounds which serve as important indicators for monitoring the quality of the oils used for frying (**Rihana *et al.*, 2019**).
Reports indicate that fried and reused oils fed to Wistar rats showed that there was a change in the size of vital organs showing that the reused oils were toxic causing damage to organs of the experimental animals (**Shastry *et al.*, 2011**). Hence, there is a high demand for healthy oils or blends which are low in *trans* and saturated fatty acids and high in mono and polyunsaturated fatty acids with better oxidative stability. Blending is necessary as no single oil has a balanced fatty acid and hence blending of oils can result in a oil which can have balanced fatty acid profile. In this context palm oil and its products are anticipated to show very good frying oil properties with higher oxidative stability and longer shelf life. Palm olein due to its frying properties and pricing is considered as heavy duty frying oil (**Nallusamy 2006; Che Man *et al.*, 1998**). Due to their good oxidative and thermal stability, palm oil and its fractions are reported to be employed for the preparation of modified lipids for food applications. In addition, palm olein contains balanced saturated and monounsaturated fatty acids along with micronutrients like carotenoids, tocotrienols, phytosterols, coenzyme Q10, squalene, etc which makes it a good choice for blending with other oils (**Feitosa *et al.*, 2019**). Therefore, in the present study, edible oil blends of palm olein with sunflower and soybean oils were prepared in different mass ratios (1:1 and 6:4) to obtain a suitable blend with balanced fatty acid profile as recommended by health organizations. Among these blends, the 6:4 POo:SFO/SBO blends were found to have the fatty acid composition closer to the AHA recommended balanced ratio of 1:1:1 (SFA:MUFA:PUFA) against the native oils (**Sumit *et al.*, 2021**). Hence, the present study also aimed to assess the frying stability studies of the 6:4 POo blends with SFO and SBO against the native oils to assess the frying quality and stability. As poori is a popular food throughout India, it was selected for the study along with another popular snack French fries.

MATERIALS AND METHODS

Materials

Palm olein (POo), sunflower (SFO) and soybean oils (SBO), wheat flour, French fries were purchased from nearby local market in Hyderabad, Telangana, India. All reagents and chemicals were purchased from M/S AVRA Chemicals, Hyderabad. TESTO 270 (Cooking oil tester) was procured from M/S TESTO India Ltd. It was used to measure the percentage of total polar material (% TPM) formed in fried oil. Oxidative stability was analysed by using Metrohm 892 Professional Rancimat.

Preparation of POo blends

POo having IV of 56 was used for the preparation of blends with SFO and SBO in order to obtain a suitable blend with balanced fatty acid ratios. The POo-based SFO/SBO blends were prepared by adding SFO/SBO to the pre-heated POo at 70°C under magnetic stirring in 1:1 and 6:4 (wt/wt) ratios. Heating was continued for 20 min in order to obtain a uniform blend and then was allowed to cool to ambient temperature for further use.

Fatty acid composition analysis by GC-FID

All the oils and their blends were converted to fatty acid methyl esters (FAME) by 2%-sulfuric acid methanol reagent following a reported method (Christie, 1982). The fatty acid composition of the edible oils and blends was determined by GC analysis according previously reported method (Ravinder *et al.*, 2017). GC was performed on Agilent 6890 GC equipped with a flame ionization detector (FID) with a capillary column (DB- 225, 30 m × 0.25 mm i.d. × 0.5 µm film thickness). The injector and detector temperatures were maintained at 230°C and 250°C respectively and the oven was programmed for 2 min at 160°C, then increased to 230°C at 5°C min^{-1} and maintained for 10 min at 230°C. Nitrogen was used as carrier gas at a flow rate of 1.5 mL / min. The injection volume was 1 µL, with a split ratio of 50:1. The fatty acids were identified by comparing the retention times with a mixture of standard FAME's, C4-C24 (Supelco, St. Louis, MO). Each sample was analysed in duplicate and the average value is reported.

Food material preparation

To the wheat flour, salt (1%) was added followed by approximate amounts of water and kneaded until smooth dough was formed. From the kneaded dough, about 200 g was taken and was rolled into thin sheets and cut into round shaped pooris.

Frying method

Oil (4 L) was taken in a bench top deep fryer (5 L) and was heated to 185-190˚C (Figure 1). The raw pooris or French fries were subjected to frying once the oil reached the set temperature and fried until the food was properly cooked. The time taken for complete cooking of poori and French fries in a cycle was 1 and 8 min respectively. The time gap between frying of each food item was 2 min to stabilise the temperature of the oil. The process was carried out for five cycles of pooris and French fries, with each cycle having a hold time of 15 min. The samples were drawn after each frying cycle and stored in a refrigerator for further physico-chemical analysis.

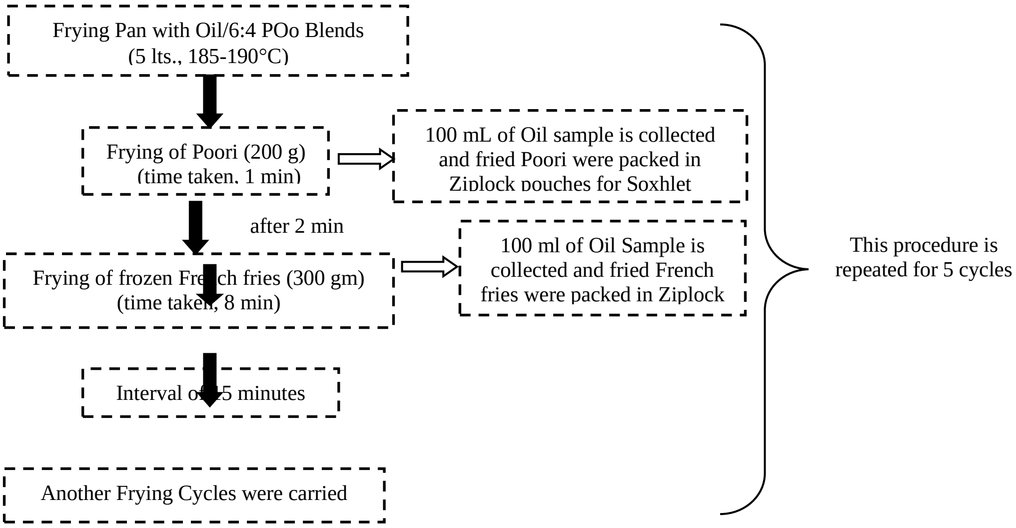

Figure 1 Flow chart for frying of poori and French fries.

Extraction of oil from fried food

About 60 g of fried food sample was subjected for Soxhlet extraction using hexane as solvent for approximately 8 h following a reported method (**Mohan *et al*., 2016**). After extraction, solvent was evaporated and the obtained oil dried under vacuum to remove any traces of solvent.

Physico-chemical analysis

The samples collected were subjected for physico-chemical analysis such as acid value and peroxide value following AOCS methods (AOCS, 2013). All the analysis was performed in duplicate and the average values are reported.

Oxidative stability (OS)

Oxidation stability is an important parameter in the characterization of fats and oils. The OS was determined on the Metrohm Rancimat Model 892 as per the procedure mentioned in the official method of AOCS. Samples were subjected to accelerated oxidative conditions by a Metrohm Rancimat model 892 at an air flow rate of 20 L/h and at 110°C. The conductivity measuring cells contained 60 ml of distilled water. The induction time was automatically determined as the inflection point of the generated plot of conductivity (mS/cm) of the water *versus* time (h). Analysis was performed in duplicate.

Total polar material (TPM)

The estimation of TPM is a widely accepted parameter to decide whether the oil is safe for further use or not. The % of TPM in cooking oil is determined using the hand-held device TESTO-270. The TPM percentage and the temperature were displayed on the screen and it took about 10 s to obtain a stable reading (**Zribi *et al*., 2016**).

Statistical analysis

The results of all the analysis of the samples were expressed as the means of two replicates ± standard deviation. The data were statistically assessed by two way ANOVA without replication with an alpha value of 0.05 and the statistical evaluation of the results was carried out using Microsoft Excel. The statistical significant differences were obtained at 95% confidence level.

RESULTS AND DISCUSSION

This study was designed for the preparation of *trans*-free edible oil blends of POo with SFO and SBO to obtain a suitable blend with desired fatty acid profile and assessment of frying stability of these blends against native oils. The SFO and SBO were rich in polyunsaturated fatty acids (PUFA), whereas POo has almost equal amounts of saturated and monounsaturated fatty acids. POo was blended with SFO and SBO in 1:1 and 6:4 mass ratios and fatty acid composition was analyzed to determine the percentages of SFA, MUFA and PUFA. The blends which were found to be closer to the recommended ratios suggested by health organizations were shortlisted for frying study (**WHO 2008**). The fatty acid composition of the edible oils and their blends prepared are given in Table 1.
It was observed that among all the blends prepared, the 6:4 blends of POo with SFO and SBO were found to have the desired fatty acid composition profiles closed to AHA and WHO recommended SFA:MUFA:PUFAS ratios of 1:1.5:1 and 1:1:1 respectively (Table 1). Hence, these blends were selected for frying studies to assess their frying performance in terms of oxidation and thermal stability over the native oils. In the present study, continuous frying method (Figure 1) was adopted as it was reported that the intermittent frying method involving heating and cooling of oils leads to higher deterioration of oils as the oxygen solubility increases in the oil during the cooling of oil (**Clark and Serbia, 1991**).

The physico-chemical properties like acid value (AV), peroxide value (PV), colour, oxidative stability (OS) and total polar material (TPM) were determined for the fried oil samples collected after each cycle and also for the oils extracted from the fried food materials (poori and French fries). The free fatty acids are formed due to hydrolysis and the acid value variation for individual oil of POo, SFO, SBO and their blends is shown in Figure 2. As the two snacks which were fried involved moisture in them, an increase in the acid value is anticipated in the fried oil samples. It can be observed that the acid value increase was very marginal in the oil samples (individual oils and POo blends) collected after each cycle of frying of poori (Figure 2a & c) compared to French fries (Figure 2b & d). This may be due to the presence of high content of moisture in French fries compared to poori. In general, it is reported that the foods that have higher moisture tend to increase the hydrolysis of the oil during frying (**Cho *et al*., 2007**). Moreover, in the initial oils, the acid value was more in POo followed by SBO and SFO which could be the reason for the higher acid values of their blends.

Table 1 Fatty acid composition (%) of the edible oils and blends

Fatty Acid	Edible Oil			POo Blends			
				POo:SFO Blends		POo:SBO Blends	
	POo	SFO	SBO	1:1	6:4	1:1	6:4
14:0	0.9	ND	ND	0.5	0.6	0.5	0.5
16:0	38.2±0.1	6.3±0.1	10.8±0.1	22.3±0.1	26.4±0.2	25.4±0.6	26.6±0.7
16:1	0.1	0.1	ND	0.1	0.2	0.2	0.2
18:0	4.6±0.1	3.2	4.4	4.0	3.7	4.4	4.3
18:1	43.2±0.1	28.8±0.4	22.2±0.1	35.2±0.3	37.2±0.6	32.7±0.3	32.8±0.5
18:2	12.1±0.2	60.3±0.4	54.4±0.9	36.7±0.3	31.1±0.4	32.7±0.6	30.8±0.8
18:3	0.2	ND	7.3±0.1	0.1	0.1	3.4±0.1	3.2
20:0	0.4	0.2	0.1	0.3	0.3	0.4	0.3
20:1	0.1	0.1	0.2	0.2	0.1	0.1	0.1
20:2	ND	ND	ND	ND	ND	ND	ND
22:0	0.1	0.7	0.4	0.4	0.3	0.2	0.2
22:1	ND	ND	ND	ND	ND	ND	ND
24:0	ND	0.3	0.2	0.2	ND	ND	ND
SFA	44.2±0.2	10.7±0.1	15.9±0.5	27.7±0.2	**31.3±0.7**	30.9±0.6	**31.9±0.7**
MUFA	43.5±0.3	29.0±0.4	22.4±0.4	35.5±0.6	**37.5±0.7**	33.0±0.9	**33.1±0.4**
PUFA	12.3±0.2	60.3±0.3	61.7±0.8	36.8±0.5	**31.2±0.4**	36.2±0.5	**34.0±0.4**

POo: Palm olein, SFO: Sunflower Oil, SBO: Soybean Oil. SFA: saturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid. Data are shown as means of two replicates ± standard deviation; Results are valued (±) 0.01 or unless otherwise stated; ND – Not Detected.

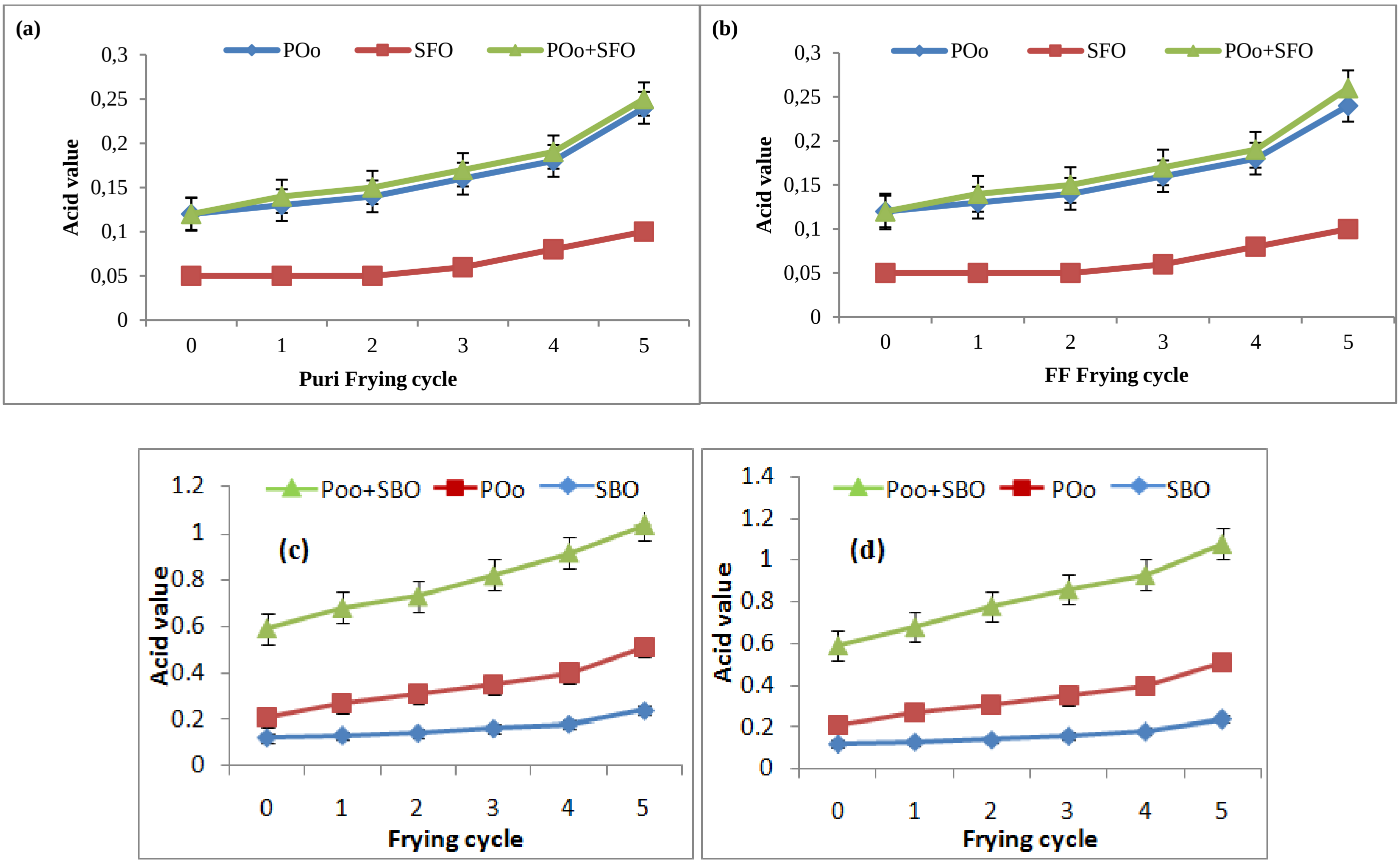

Figure 2 AV of Poori fried Oil in (**a**) POo, SFO and 6:4 POo:SFO blend, (**c**) POo, SBO and 6:4 POo:SBO blend. AV of FF fried Oil in (**b**) POo, SFO and 6:4 POo:SFO blend, (**d**) POo, SBO and 6:4 POo:SBO blend. Results are expressed as average of two measurements ± standard deviation. FF = French fries.

The changes in the PV in the fried oils of 6:4 blends of POo:SFO and POo:SBO after 5 cycles of frying of poori and French fries were found to be significant when compared to native SFO and SBO (Table 2). Similar observations were reported where it was found that the PV of SBO blends were higher compared to SFO during frying (**El-Ghonamy *et al*., 2015**). This can be due to the higher amounts of PUFA in SBO, which are known to oxidise rapidly compared to other fatty acids. The colour of all the fried oil samples was found to be increased compared to the starting oils and their initial blends which is naturally due to the exposure of the oil to heat. It was reported that the frying of binary blends of palm oil with corn, RBO and SMO had shown that the blend of corn oil was having balanced fatty acids and was stable with respect to oxidation and hydrolysis compared to other blends (**Azimah *et al*., 2017**).

Table 2 Changes in peroxide values (PV) of the fried oils and blends after 5th cycle of frying

Cooking Oil	PV (meq/kg)		
	Initial Oil	Fried Oil of Poori	Fried Oil of FF
POo	0.40	2.70	2.38
SFO	2.69	3.12	3.97
6:4 POo:SFO Blend	2.50	3.20	3.25
SBO	2.84	7.36	7.88
6:4 POo:SBO Blend	2.08	3.73	3.84

Data are shown as average of two measurements. FF = French fries.

The oxidative stability of the oils also changed greatly with frying. The oxidative stability of starting oils and the blends along with their fried oil samples drawn during 5 cycles of frying are shown in Figure 3. It was observed that the oxidative stability index of fried oils was decreased compared to their initial oils. In general, thermal treatment of oil leads to degradation of the oil which in turn affects the oxidative stability. However, the blends of SFO and SBO with POo showed better oxidative stability index values compared to the initial SFO and SBO alone. Similar observations were reported on the study on POo blends with vegetable oils in different rations during frying process for improving the quality properties and oxidative stability (**Hashem *et al.*, 2017**). Among these blends, the POo:SBO blend showed better oxidative stability compared to POo:SFO blend. This could be due to the difference in the unsaturated fatty acid levels in SFO blend compared to SBO blend, which can be the factor for its reduced stability (**Mariola and Gruczyska, 2018**).

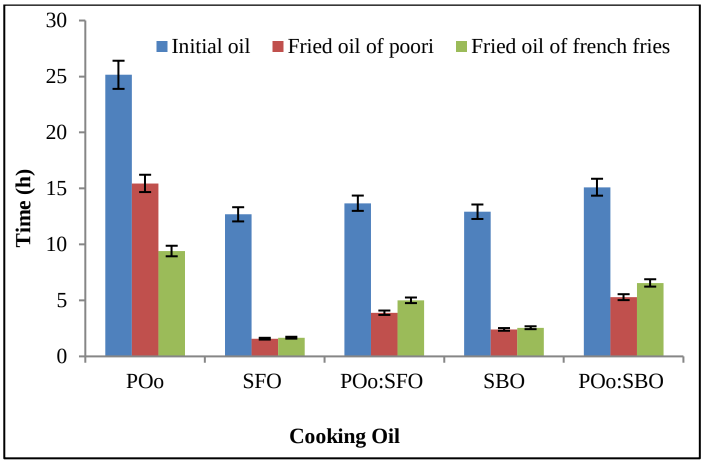

Figure 3 Changes in oxidative stability index (OSI) of the POo, SFO, SBO & 6:4 POo:SFO/SBO blends during frying. Results are expressed as means of two replicates ± standard deviation.

Frying leads to physico-chemical changes in the frying oil, which influences the nutritional and sensory properties of the oil. It is well known that frying results in the formation polar compounds such as polymerised triglycerides, diglycerides, monoglycerides, FFA, oxidised dimers and polymers, etc. Hence, TPM is considered as an important analytical parameter for assessing the quality of frying oil. Most of the countries have regulated the content of total polar compounds at not more than 25% so that the food industries can change the frying oil if the TPM exceeds the limit of around 25% (**Dana and Saguy, 2001**). In the present study, it was observed that all the oils and blends when subjected for frying for five cycles did not cross the limit of 25% TPM (Figure 4). Among the individual oils, lowest TPM was observed in SFO followed by POo and SBO. However, SFO showed high TPM compared to POo and SBO in both poori and French fries fried oils. For the blends the TPM was higher for SBO blend compared to SFO blend. But the TPM for poori fried oil with SFO was higher compared to SBO blend whereas, for French fries the TPM of SBO blend was higher compared to SFO blend. This slight difference could be due to the change in food materials being fried. In one of the study with ternary blend of POo, SMO and canola oil, the TPM changes were less compared to other blends studied indicating that ternary blends might have better stability in terms of TPM (**Alireza et al., 2010**).

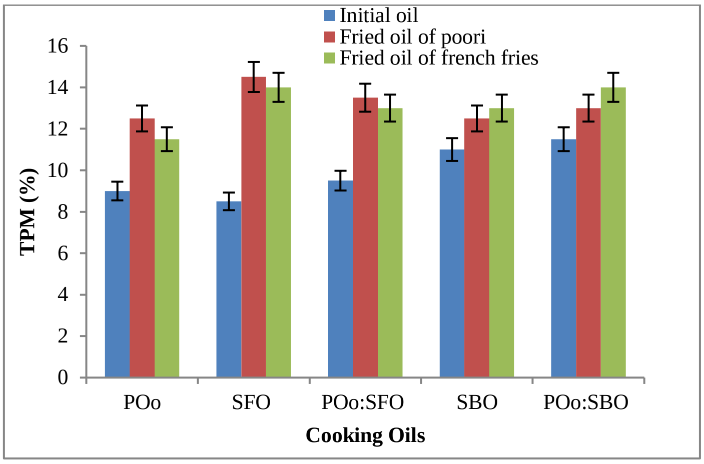

Figure 4 Changes in TPM values of the POo, SFO, SBO & 6:4 POo:SFO/SBO blends during frying. Results are expressed as means of two replicates ± standard deviation.

The snacks after frying were also subjected for oil content determination followed by its characterisation for AV, PV and TPM and the results are given in Table 3. It was observed that the oil absorption was dependant on the nature of the snack being fried as it could have some influence on the frying time and oil absorption. In general, it is reported that oil uptake is observed to be higher in the raw food material which has more water compared to the dried material or material with less water like poori (**Mishra and Sharma, 2014**). In the present study, it was observed that absorption of oil by poori was less compared to French fries, this may be due to the presence of higher amounts of moisture in French fries and also the frying time of French fries is longer compared to poori. It is reported that the amount of oil absorbed by the fried foods depends on the frying time, food surface area, moisture content of the food being fried and the frying oil. The oil absorbed by the food tends to accumulate on the surface of the food during frying and later moves into the interior of the food during cooling (**Rosana *et al*., 1997**). The absorption of SFO by the fried food material was found to be higher compared to POo and SBO. The increase in AV was lower in pure fried SFO compared to POo and SBO. The increase in PV was found to be higher for 6:4 POo:SBO blend compared to 6:4 POo:SFO blend during frying of both the snacks. Addition of antioxidants to the blend along with separation of the FFA and peroxides can extend the life of the blended oils as the oxidation was observed more in blends of both SBO and SFO. The present study showed that the frying stability of SFO and SFO was increased by blending with POo. Reported studies also show that the frying performance was better for binary and ternary blends of canola oil with POo and other vegetable oils (**Reza *et al*., 2009**).

Table 3 Physico-chemical properties of the oils extracted from the fried food samples after 5th cycle of frying

Test parameter	POo		SFO		SBO		6:4 POo:SFO		6:4 POo:SBO	
	Poori	FF	Poori	FF	Poori	FF	Poori	FF	Poori	FF
Oil (%)	16.7	31.0	23.0	28.5	20.1	25.5	28.2	30.3	24.1	31.7
AV (mg KOH/g)	0.54	0.64	0.53	0.29	1.24	1.46	2.26	1.61	1.36	1.40
PV (meq/kg)	2.45	3.23	4.44	5.46	22.6	23.1	3.96	3.83	12.3	12.8
TPM (%)	12.5	13.5	14.0	13.5	13.0	15.0	14.5	14.0	11.0	14.5

Data are shown as average of two measurements. FF = French fries

The ANOVA test results of the frying studies data also indicated the impact of AV, PV and TPM as significant. AV, PV and colour of the POo blend was found to increase after each frying of both poori and French fries for five consecutive frying cycles which showed significance ($p<0.05$). The results of study indicated that present approach could be used to assess and improve the frying stability of blends with respect to AV, PV, absorbed oil content, oxidative stability, colour and TPM. The AV and PV of extracted oil from snacks contributed significantly in French fries compared to poori which was proven with a confidence level of more than 95% by ANOVA analysis. Therefore, the study focusing on the stability of extracted oil from snacks on various physico-chemical properties during the frying process was successfully established by the statistical analysis with a p-value less than 0.05.

CONCLUSIONS

Palm olein (POo) was blended with SFO and SBO in 1:1 and 6:4 mass ratios and their fatty acid composition was determined. The 6:4 (wt/wt) blends exhibited the desired balanced fatty acid profiles closer to AHA and WHO recommended SFA:MUFA:PUFAS ratios of 1:1.5:1 and 1:1:1 respectively. Deep fat frying of poori and French fries was carried out using these 6:4 POo:SFO/SBO blends to study their frying performance. In the present study, it was observed that oxidation occurred more rapidly during deep-fat frying with individual SFO and SBO compared to their 6:4 POo blends. Overall, it was found that during frying, the oils with higher acid value (AV) and higher amounts of unsaturated fatty acids showed a higher rise in the degradation products indicating that the individual oils may not be the ideal choice for frying compared to the blended oils. The TPM values indicate that the number of frying cycles can be increased as the TPM was well within the limits even after 10 cycles of frying. It can be concluded that the blending of POo with unsaturated rich oils has beneficial effects in terms of oxidative stability index as POo attributes higher stability to oils rich in unsaturated fatty acids.

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