

The Characterization and Evaluation of Some Edible Oils for Their Frying Stability

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Abstract –The oils and fats are used for frying foods which are a staple of the fast food industry in India. Such foods are very popular because of their desirable flavour, attractive colour and crispy texture. But eating too much of these foods can lead to serious health problems. The frying also causes substantial changes to physio-chemical-sensory-nutritional qualities of cooking oils. In this study, the most commonly and frequently used edible oils in India viz., sunflower oil, palmolein oil and coconut oil, are analysed before and after frying to evaluate their quality during frying purposes.

Abbreviations: AV-Acid Value, BRR – Butyro Refractometer Reading, FAME-Fatty Acid Methyl Ester, FBO – Food Business Operator, FID-Flame Ionisation Detector, FSSAI-Food safety and Standards Authority of India, FSSR-Food Safety and Standard Regulation, GC-Gas Chromatography, IV – Iodine Value, RI-Refractive Index, TLC-Thin Layer Chromatography, TPC – Total Polar Compounds, SV – Saponification Value, UV-Ultra Violet.

Keywords– Acid value, Baudouin test, colour, deep-frying, deterioration, edible oils, fatty acids, Halphen test, iodine value, oxidation, peroxide value, polar compounds, polymerization, pyrolysis, rancidity, refractive index, smoke point.

I. INTRODUCTION

The edible fats and oils are used for frying different foods. Such foods have desirable flavor, attractive colour and crispy texture which make them very popular to consumers; but have serious public health concern such as high cholesterol levels, intake of excessive calories, ingestion of trans fatty acids etc.

Deep frying is a method of cooking food by submerging it in hot oil. The moisture inside the food turns into steam by the heat of oil, which cooks the food from inside. The steam also helps to keep the oil out of the food. The surface of food, which is in direct contact with oil, gets cooked instantly at this temperature. It creates a crispy and browned crust and a thoroughly cooked but still moist interior.

During the process, the food absorbs oil. The majority of absorbed oil accumulates near the surface, which amounts to about 9 – 15 % of the finished weight in the fried food product. The amount absorbed depends on the temperature, time of frying, surface area of the food, the moisture content of food and the nature of food. The ideal temperature for the frying is around 150-200 °C. If the temperature is too low, the oil will seep into the food, making it greasy. If the temperature is too high, food gets dried out and oil gets oxidized instantly. Thus maintaining the ideal temperature is very essential for deep-frying foods. This type of cooking causes substantial changes to general appearance and quality of oils. The oil

gets darkened and becomes more viscous during frying. The chemical changes include thermal oxidation, hydrolysis, polymerization and decomposition. Configurational changes to fatty acids also occur. All these have significant impacts on the quality of frying oils. In India, fried foods are a staple of the fast food industry. They frequently use the same oil in a number of times for the preparation of different products. Eating too much of such fried foods can lead to serious health problems.

The present study is conducted to identify the best choice of oil among sunflower, palmolein and coconut oils for deep frying purposes. Hopefully, it also helps the regulator, FSSAI, to conduct further scientific studies to devise the existing specification limit for used edible oils.

II. MATERIALS

1. Sampling

The oils (sunflower oil, refined palmolein and coconut oil) as well as potatoes used in this study were purchased from local markets in Trivandrum, Kerala. The potatoes were peeled, washed and then sliced into thin pieces.

2. Frying Process

About 500 ml oil was taken in a frying pan and heated to 170-190 °C. Then freshly prepared potato chips (exactly 25 pieces in numbers) were submerged in the hot oil and fried until proper light brown colour was developed. This

will takes approximately eight minutes. The constancy of frying temperature is monitored using a thermometer of 250 °C capacity. The frying process was repeated six times with each oil. After each frying, the oil is cooled, approximately 50 ml fried oil was drawn for oil characterization and kept in a polythene bottle at room temperature and the frying process continued with remaining portion of used fried oil.

3. Apparatus and glass wares

The apparatus such as electronic balance, Abbe Refractometer, gas chromatography (GC-FID), UV cabinet, frying oil monitor, thermometer and water bath and glass wares such as beakers, specific gravity bottles, conical flasks, iodine value flasks, pipettes (25 ml), burettes (10 ml and 50 ml capacities), measuring cylinders, test tubes, capillary tubes etc are used. Chromatographic set up such as TLC plate and glass chamber with lid are also used for this study.

4. Reagents and Chemicals

The chemicals such as acetic acid, amyl alcohol, carbon disulphide, carbon tetra chloride, chloro form, methanol, ethanol (95%), hexane, phenolphthalein, starch, concentrated hydrochloric acid, potassium iodide, potassium hydroxide, Wij's iodine mono chloride solution (0.2 normal), petroleum ether 2,7-dichloro fluorescein, sodium chloride, sulphur and standardized solutions of sodium hydroxide (0.1 normal), hydrochloric acid (0.5 normal) and sodium thiosulphate (0.1 normal) are used in this study.

III. METHODS

The refined sunflower oil, refined palmolein oil and coconut oils were subjected to various physio-chemical characterization and adulteration tests before and after each frying process by the methods and procedures described below.

1. Physical Parameters

The physical properties analysed include refractive index and specific gravity.

1.1. Refractive Index (RI) and Butyro Refractometer Reading (BRR)

The RI was measured by using the instrument ATAGO RX-5000i Refractometer by IS 548 (Part-1) 1964:Reaffirmed 2015 method. The instrument was cleaned with rectified spirit, calibrated with distilled water, again cleaned with rectified spirit and then dried. A drop of oil was put into the sampling part of instrument and wait for the temperature to reach 40° C. Then the direct reading of RI was recorded for each oil sample. The corresponding BRR values are obtained from the

conversion table given in the IS 548 (Part-1) 1964:Reaffirmed 2015 method.

1.2. Specific gravity

It is measured by pycnometer method described in IS 548 (Part-1) 1964:Reaffirmed 2015 method.

2. Chemical Parameters

The chemical properties examined include acid value, saponification value, iodine value, peroxide value, total polar compounds and fatty acid profile.

2.1. Acid Value

It is measured by IS 548 (Part 1) 1964:Reaffirmed 2015 method. The method is based on the acid-base titration techniques in non-aqueous solvents. A known quantity of oil (approximately 10 grams) is boiled with hot neutral ethanol for 5-10 minutes and titrate with standard NaOH (0.1 N) using phenolphthalein as indicator until pink colour persisted. The AV is calculated by the formula

$$AV = \frac{56.1 \times V \times N}{W}$$

where W- weight of sample, N-Normality of Sodium hydroxide and V-volume in ml of sodium hydroxide for sample.

2.2. Saponification Value

It is measured by IS 548 (Part 1) 1964:Reaffirmed 2015 method. About 1.5 – 2 g of filtered oil is refluxed with a known excess of alcoholic KOH (say, 25 ml) until the oil gets completely saponified. The unreacted KOH is back titrated with standardized HCl (0.5 N), using phenolphthalein as indicator. A blank test is conducted in the same way.

The SV is calculated by the expression

$$SV = \frac{56.1 \times (B-S) \times N}{W}$$

where W- weight of sample, N-Normality of hydrochloric acid, B-volume in ml of hydrochloric acid for blank and S- volume in ml of hydrochloric acid for sample.

2.3. Iodine Value

The IV is measured by Wijs iodine monochloride method described in IS 548 (Part 1) 1964:Reaffirmed 2015 method. In this method, a known quantity of filtered oil, dissolved in carbon tetrachloride, is reacted with known excess of Wij's solution (25 ml) and kept in dark for half an hour. Halogen addition to double bond take place. Add 15 ml of potassium iodide solution (10 % w/w) and 100 ml distilled water. The KI reduces excess ICl to free iodine. The liberated iodine is then titrated with standardized sodium thiosulphate solution using starch indicator. A blank test is carried out in the same way.

The IV is calculated by the equation

$$IV = \frac{12.69 \times (B-S) \times N}{W}$$

where W- weight of sample, N-Normality of Sodium thiosulphate, B-volume in ml of sodium thiosulphate for

blank and S- volume in ml of sodium thiosulphate for sample

2.4. Peroxide value

The PV of oil was determined by IS 548 (Part-1) 1964 : Reaffirmed 2015 method. Accurately weigh about 5 grams of oil into glass stoppered conical flask, add 30 ml of glacial acetic acid-chloroform mixture (3:2 v/v) and swirl to dissolve. Then freshly prepared saturated solution of potassium iodide (0.5 ml) is added and let stand for one minute in dark with occasional shaking. Add 30 ml distilled water and titrate against standardized sodium thiosulphate solution (0.1 N) using starch indicator. Conduct a blank determination. The peroxide value is calculated by the equation

$$PV = \frac{(S-B) \times N \times 1000}{W} \text{milli-equivalents /1000 g}$$

where W- weight of sample, N- Normality of Sodium thiosulphate, S- volume in ml of sodium thiosulphate solution for sample and B- volume in ml of sodium thiosulphate solution for blank.

2.5. Total Polar Compounds

The TPC is measured by ATAGO Frying Oil Monitor DOM-24 instrument. The value can be read directly from the instrument at specified temperature.

2.6. Fatty Acid Profile

The fatty acid profile of oils were determined by Gas Chromatography after derivatizing the fatty acids to their methyl esters (FAME). The instrument is GC-FID by Thermo Scientific.

3. Adulteration Tests

The presence of adulterants such as mineral oil, sesame oil, cotton seed oil and oil soluble colour are checked.

3.1. Mineral Oil

It is tested by the thin layer chromatography (TLC) technique as described in IS 548 (Part-2) 1976: Reaffirmed 2010 method.

The oil sample is dissolved in chloroform to make a 10% solution and applied to a TLC plate using a capillary tube. Dry and place the plate in TLC chamber containing petroleum ether. The solvent is allowed to travel for 6 cm from the origin. Remove the plate, dry and spray 0.2% ethanolic solution of 2,7-dichlorofluorescein and view under UV light. Occurrence of a yellow fluorescent spot on the solvent front indicates the presence of mineral oil.

3.2. Test for Sesame Oil (Baudouin Test)

The presence of sesame oil is checked by modified Baudouin test as described in IS 548 (Part-2) 1976: Reaffirmed 2010 method. Take 5 ml of oil sample in a glass stoppered test tube and add 5 ml concentrated hydrochloric acid and 0.4 ml furfural solution. Stopper and shake vigorously for 2 minutes. Allow the mixture to separate. The development of pink/red colour in the lower acid layer indicates the presence of sesame oil. Then add 5 ml water to the mixture and shake again. If the colour in acid layer persists, the presence of sesame oil is confirmed.

3.3. Test for Cottonseed Oil (Halphen Test)

The presence of cotton seed oil is checked by Halphen test as described in IS 548 (Part-2) 1976: Reaffirmed 2010 method. Mix 5 ml oil sample with equal volume of sulphur solution (1% solution in carbon disulphide) in a test tube. Heat gently on a water bath (at 70-80 °C) with occasional shaking till carbon disulphide is boiled off. Place the tube in a saturated brine bath maintained at 110-115 °C and hold for 1-2 hours. The development of a red colour indicates the presence of cotton seed oil.

3.4 Oil Soluble Colour

The presence of oil soluble colour is checked by the test described in IS 548 (Part-2) 1976: Reaffirmed 2010 method. About 2-3 g of oil is mixed with 50 ml hexane in a conical flask. Shake, filter and concentrate to about 10 ml. The concentrate is divided into three parts and treat with concentrated hydrochloric acid and water mixtures 4:1, 2:1 or 1:1 respectively. If the acid layer or the whole extract develops pink to reddish violet colour, the presence of synthetic food colour is indicated.

IV. RESULTS & DISCUSSION

1. Analysis of Original Samples

The analytical values of different physio-chemical characteristics of refined sunflower, refined refined palmolein and coconut oils before deep-frying are given in Table-1. The values are in agreement with the range prescribed in the Food Safety and Standards (Food Products Standards and Food Additives) Regulations 2011, the mandatory regulation for domestic and imported foods, issued by FSSAI, given in Table-2 as a reference. The RI and BRR is characteristic of the nature of oil. It depends on molecular weight, fatty acid chain length, degree of unsaturation in oil. The high value of RI for sunflower oil is probably because of higher level of unsaturation and greater proportion of long chain fatty acids in it. The higher unsaturation also explains the high iodine value for sunflower oil.

Table 1 Analytical values of Original Samples

Sl No	Parameters	Refined Sunflower Oil	Refined Palmolein Oil	Coconut Oil
1	Refractive Index	1.46609	1.45863	1.44961
2	BRR	60.3	48.9	36.1
3	Specific Gravity	0.9118	0.9096	0.9080
4	Acid Value	0.18	0.12	0.74
5	Saponification Value	188.73	197.04	258.39
6	Iodine Value	132.73	56.82	8.36
7	Peroxide Value	0.31	0.14	0.10
8	Total Polar Compounds	9.0	8.5	---
9	Test for Mineral Oil	Shall be Negative	Shall be Negative	Shall be Negative
10	Baudouin Test	Shall be Negative	Shall be Negative	Shall be Negative
11	Halphen Test	Shall be Negative	Shall be Negative	Shall be Negative
12	Test for Oil Soluble Colour	Shall be Negative	Shall be Negative	Shall be Negative

Table 2 Reference values under FSSR

Sl No	Parameters	Refined Sunflower Oil	Refined Palmolein Oil	Coconut Oil
1	Refractive Index	1.4640-1.4691	1.4550-1.4610	1.4480-1.4500
2	BRR	57.1 – 65.0	43.7 – 52.5	33.9-36.7
3	Specific Gravity	-----	-----	-----
4	Acid Value	Not more than 6.0 Not more than 0.5,if refined	Not more than 6.0 Not more than 0.5,if refined	Not more than 6.0 Not more than 0.5,if refined
5	Saponification Value	188 - 194	195 - 205	Not less than 250
6	Iodine Value	100 - 145	54 - 62	7.5 to 10.0
7	Peroxide Value	-----	-----	-----
8	Total Polar Compounds	-----	-----	-----
9	Test for Mineral Oil	Shall be negative	Shall be negative	Shall be negative
10	Baudouin Test	Shall be negative	Shall be negative	Shall be negative
11	Halphen Test	Shall be negative	Shall be negative	Shall be negative
12	Test for Oil Soluble Colour	Shall be negative	Shall be negative	Shall be negative

The sunflower and palmolein oils used are refined; refining reduce acidity; hence accounted for less acid value for these oils. The coconut oil contains more amount of short chain fatty acids than other oils under study. This accounts for high saponification value for coconut oil.

The increase in saponification values from sunflower to palmolein to coconut oils may be due to increase in the proportion of short chain fatty acids. The findings is supported by fatty acids analytical data of these oils (tables 10 to 12).

2. Effect of Deep-Frying on Refractive Index

The statistical data regarding the RI of oils and the corresponding BRR values has been presented in Table-3.

Table 3 Refractive Index and BRR values

Sl No	Nature of Oil	Sunflower Oil		Palmolein Oil		Coconut Oil	
		RI	BRR	RI	BRR	RI	BRR
1	Pure Oil	1.46609	60.3	1.45863	48.9	1.44961	36.1
2	Fried Oil-1	1.46697	61.7	1.45901	49.5	1.44981	36.4
3	Fried Oil-2	1.46726	62.2	1.45911	49.7	1.45003	36.7
4	Fried Oil-3	1.46743	62.4	1.45929	50.0	1.45018	37.0
5	Fried Oil-4	1.46771	62.8	1.45957	50.4	1.45039	37.2
6	Fried Oil-5	1.46793	63.1	1.45982	50.7	1.45068	37.7
7	Fried Oil-6	1.46812	63.4	1.46030	51.4	1.45102	38.1

The results show that there was a significant increase in RI and BRR with increments in the number of frying. The contributing factors include

- Thermal oxidation of fatty acids which increases the molecular weight and decreases the degree of unsaturation.
- The moisture in food
- Polymerisation reaction which increases the viscosity of oil
- Thermal decomposition of fatty acids forming non-volatile compounds which get accumulated in oil, thereby increase the density of oil
- Darkening of oil This indicates that deep frying increases rancidity of oil. Hence repeated use of same oil for frying should be discouraged.

The results indicate that more increase in RI was observed for sunflower oil because the sunflower oil is highly unsaturated and more prone to thermal oxidation than palmolein and coconut oils. A similar trend exists for BRR values. The RI and BRR of sunflower and palmolein oils not exceed the regulatory limit even after the sixth number of frying. However, these values exceeds the regulatory limit from third number of frying for coconut oil, inviting more concern of its use.

3. Effect of Deep-Frying on Specific Gravity

The statistical data regarding the specific gravity of oils is presented in Table-4

Table 4 Specific Gravity values

Sl No	Nature of Oil	Sunflower Oil	Palmolein Oil	Coconut Oil
1	Pure Oil	0.9118	0.9096	0.9080
2	Fried Oil-1	0.9156	0.9132	0.9104
3	Fried Oil-2	0.9165	0.9144	0.9115
4	Fried Oil-3	0.9176	0.9153	0.9124
5	Fried Oil-4	0.9188	0.9158	0.9125
6	Fried Oil-5	0.9197	0.9170	0.9138
7	Fried Oil-6	0.9204	0.9179	0.9147

The data reveals that the specific gravity increases progressively with number of frying irrespective of the nature of oil. The thermal oxidation and polymerization of oil during frying increases the molecular weight and make the oil more denser resulting in increase of specific gravity. The coconut oil remains more stable with respect to specific gravity than sunflower and palmolein oils in frying. This may be due to higher level of saturation and monounsaturations in coconut oil as compared to other oils. Moreover, the variation further reveals that the more the poly unsaturation in oil, the more will be increase in specific gravity. Evidently, sunflower oil shows maximum variation.

4. Effect of Deep-Frying on Acid Value

The statistical data regarding the acid value of oils is presented in Table-5

Table 5 Acid Values

Sl No	Nature of Oil	Sunflower Oil	Palmolein Oil	Coconut Oil
1	Pure Oil	0.18	0.12	0.74
2	Fried Oil-1	0.20	0.16	0.81
3	Fried Oil-2	0.31	0.22	0.88
4	Fried Oil-3	0.40	0.34	0.93
5	Fried Oil-4	0.48	0.42	1.02
6	Fried Oil-5	0.57	0.51	1.14
7	Fried Oil-6	0.73	0.58	1.23

The data reveals that there was a significant increase in acid value with number of frying irrespective of the nature of oil. Oil is a triglyceride, an ester composed of three molecules of fatty acids joined to one molecule of glycerol. When oil is heated with moist food, it gets hydrolyzed to free fatty acids and glycerol. Thus hydrolysis (lipolysis) increases the amount of free fatty acids. The re-heating of oil produces toxic by-products such as trans fatty acids, aldehydes, polymerized and oxidized lipids which have health impacts, also enhance acidity.

The hydrolysis is more preferable in oil with short and unsaturated fatty acids than oil with long and saturated fatty acids because short and unsaturated fatty acids are more soluble in water than long and saturated fatty acids. Water from foods is easily accessible to short-chain fats and oils for hydrolysis (Nawar 1969). The development of high levels of free fatty acids during frying is usually associated with decrease in smoke point of the oil and a reduction in quality of fried foods. Furthermore, free fatty acids are more susceptible to oxidation than are the fatty acids esterified to glycerol. The results further indicate that AV of refined sunflower oil and refined palmolein oil exceed the limit at the fifth stage of frying. However, coconut oil is safe in acid value.

5. Effect of Deep-Frying on Saponification Value

The statistical data regarding the saponification value is given in Table-6

Table 6 Saponification Values

Sl No	Nature of Oil	Sunflower Oil	Palmolein Oil	Coconut Oil
1	Pure Oil	188.73	197.04	258.39
2	Fried Oil-1	192.38	201.02	263.15
3	Fried Oil-2	196.14	206.37	272.02
4	Fried Oil-3	215.33	229.94	297.84
5	Fried Oil-4	235.18	254.03	326.11
6	Fried Oil-5	256.91	277.56	352.82
7	Fried Oil-6	279.78	294.07	382.27

The saponification value increases with increase in number of frying. The SV is inversely proportional to average chain length of fatty acids. Repeated heating of oil may cause breakdown of long chain fatty acids into short chain fatty acids, thereby increasing the saponification value. The FAME result clearly shows that coconut oil contains more proportions of short chain fatty acids

,which tend to increase during frying.Thus,coconut oil shows high level increase in saponification value during the process..Since sunflower oil is deprived of short chain fatty acids,its howed the least increase in saponification value during frying process. The SV of sunflower and palmolein oils exceed the maximum limit at the second number of frying.The high increase in SV for coconut oil demands the fixing of upper limit for it.

6. Effect of Deep-Frying on Iodine Value

The statistical data regarding the iodine value is given in Table-7

Table 7 Iodine Values

S. No	Nature of Oil	Sunflower Oil	Palmolein Oil	Coconut Oil
1	Pure Oil	132.73	56.82	8.36
2	Fried Oil-1	127.36	54.05	7.85
3	Fried Oil-2	115.93	49.03	7.43
4	Fried Oil-3	106.48	43.98	6.72
5	Fried Oil-4	88.02	40.36	6.48
6	Fried Oil-5	71.68	36.55	5.83
7	Fried Oil-6	65.14	33.11	5.26

The IV decreases significantly with increase in the number of frying. The double bonds in unsaturated fatty acids get partially or completely destroyed by oxidation, hydrogenation and polymerization.This decreases the degree of unsaturation causing decreased iodine values.Thus decrease in iodine value is proportional to degree of unsaturation in the oil.

Sunflower oil showed more decrease in IV because of more unsaturation. Coconut oil contained the least unsaturation and experienced less decrease in iodine value during frying.The IV of sunflower oil moves down the minimum specification limit at the fourth number of frying.Inpalmolein and coconut oils the iodine value become less than the lower limit at the second stage of frying.

7. Effect of Deep-Frying on Peroxide Value

The statistical data regarding the peroxide value is given in Table – 8.

Table-8 Peroxide Values

Sl No	Nature of Oil	Sunflower Oil	Palmolein Oil	Coconut Oil
1	Pure Oil	0.31	0.14	0.10
2	Fried Oil-1	2.74	0.59	0.34
3	Fried Oil-2	3.86	1.31	0.72
4	Fried Oil-3	4.32	2.10	1.09
5	Fried Oil-4	5.24	2.83	1.82
6	Fried Oil-5	6.06	3.78	2.61
7	Fried Oil-6	6.48	4.67	3.43

The peroxide value increase with increase in number of frying. The presence of moisture in food and reheating of oil increases the rate of peroxidation of fatty acids, thereby increasing the peroxide value. The presence of higher levels of saturated fatty acids and monounsaturated fatty acids make oils more resistant towards oxidation at elevated temperatures during deep frying and more polyunsaturated fatty acids get rapidly oxidised.The more increase in peroxide value for sunflower oil is due to the presence of considerable amounts of polyunsaturated fatty acids,which get readily oxidised to form peroxides. The rate of increase in peroxide value diminishes with number of frying.This is because,hydroperoxide is a primary oxidation product which rapidly break down to secondary oxidation products such as aldehydes as frying prolongs.

8. Effect of Deep-Frying on Total Polar Compounds

The statistical data regarding the total polar compounds of different oils are given in Table-9.

Table-9 Total Polar Compounds

Sl No	Nature of Oil	Sunflower Oil	Palmolein Oil
1	Pure Oil	9.0	8.5
2	Fried Oil-1	9.5	9.0
3	Fried Oil-2	10.5	9.5
4	Fried Oil-3	11.0	10.0
5	Fried Oil-4	12.5	10.5
6	Fried Oil-5	14.0	11.0
7	Fried Oil-6	15.5	12.5

The total polar compounds increases with increase in the number of frying. The heating of oils in presence of moist foods may cause hydrolysis of triglycerides into free fatty acids, glycerol, monoglycerides and diglycerides. The presence of diglycerides and other by-products increase the percentage of total polar compounds. Generally, oils with higher proportions of unsaturated fatty acids produced more polar compounds than more saturated ones. Evidently, the total polar compounds in sunflower oil shows higher degree increase than palmolein oil. The frying time also contributes to total polar compounds.

The instrument does not provide correct results for coconut oil; hence such values are not reporting in this study. In India, the FSS regulation stipulates a maximum limit of 25% of TPC as a basis for the assessment of end use of frying oils. However, the value remained under this limit during deep-frying of food even after 6th frying in the present study.

9. Effect of Deep-Frying on Fatty Acid Profile

The statistical data regarding the fatty acid profile of different oils are given in tables 10 to 12.

Table-10 Sunflower Oil

Sl No	FAME component	Pure Oil	Fried Oil-1	Fried Oil-2	Fried Oil-3	Fried Oil-4	Fried Oil-5	Fried Oil-6
1	Butyric (C4:0)	-	-	-	-	-	-	-
2	Caproic (C6:0)	-	-	-	-	-	-	-
3	Caprylic (C8:0)	-	-	-	-	-	-	-
4	Capric (C10:0)	-	-	-	-	-	-	-
5	Lauric (C12:0)	-	-	-	-	-	-	-
6	Myristic (C14:0)	-	-	-	-	-	-	-
7	Palmitic (C16:0)	6.31	6.41	6.52	6.60	6.67	6.83	6.91
8	Palmitoleic (C16:1)	-	-	-	-	-	-	-
9	Stearic (C18:0)	3.18	3.25	3.32	3.38	3.45	3.52	3.59
10	Elaidic (C18:1 n9t)	-	-	-	-	-	-	-
11	Oleic (C18:1 n9c)	29.56	29.78	30.05	30.46	31.25	31.62	32.16
12	Linolelaidic (C18:2 n6t)	-	-	-	-	0.11	0.20	0.20
13	Linoleic (C18:2 n6c)	59.27	57.46	56.57	55.62	54.69	54.16	53.80
14	Arachidic (C20:0)	-	-	-	-	-	0.30	-
15	Behenic (C 22:0)	-	-	-	-	-	0.73	-
16	Lignoceric (C24:0)	-	-	-	-	-	0.25	-

Table-11 Palmolein Oil

Sl No	FAME component	Pure Oil	Fried Oil-1	Fried Oil-2	Fried Oil-3	Fried Oil-4	Fried Oil-5	Fried Oil-6
1	Butyric (C4:0)	-	-	-	-	-	-	-
2	Caproic (C6:0)	-	-	-	-	-	-	-
3	Caprylic (C8:0)	-	-	-	-	-	-	-
4	Capric (C10:0)	-	-	-	-	-	-	-
5	Lauric (C12:0)	0.15	0.18	0.25	0.36	0.44	0.52	0.59
6	Myristic (C14:0)	0.60	0.69	0.82	0.98	1.17	1.22	1.28
7	Palmitic (C16:0)	41.12	41.86	42.08	42.37	42.71	43.04	43.55
8	Palmitoleic (C16:1)	0.03	0.05	0.09	0.13	0.17	0.23	0.31
9	Stearic (C18:0)	3.52	3.72	3.94	4.25	4.54	4.76	4.98
10	Elaidic (C18:1 n9t)	-	-	-	0.07	0.13	0.26	0.38
11	Oleic (C18:1 n9c)	41.96	41.57	41.28	41.09	40.96	40.77	40.52
12	Linolelaidic (C18:2 n6t)	-	-	-	-	0.07	0.16	0.32
13	Linoleic (C18:2 n6c)	10.25	10.05	9.84	9.62	9.08	8.49	8.11
14	Arachidic (C20:0)	-	-	-	-	-	-	-
15	Gamma-Linolenic (C18:3 n)	-	-	-	-	0.56	0.59	0.64
16	Linolenic (C18:3 n3)	0.28	0.26	0.22	0.19	0.16	0.12	0.06
17	Behenic (C 22:0)	-	-	-	-	-	-	-
18	Lignoceric (C24:0)	-	-	-	-	-	-	-

Table-12 Coconut Oil

Sl No	FAME component	Pure Oil	Fried Oil-1	Fried Oil-2	Fried Oil-3	Fried Oil-4	Fried Oil-5	Fried Oil-6
1	Butyric (C4:0)	-	-	-	-	-	-	-
2	Caproic (C6:0)	-	-	-	-	-	-	-
3	Caprylic (C8:0)	4.85	5.29	5.62	5.91	6.17	6.28	6.37
4	Capric (C10:0)	5.00	4.84	4.67	4.70	4.74	4.84	4.95
5	Lauric (C12:0)	44.26	43.92	43.79	43.64	43.52	43.40	43.28
6	Myristic (C14:0)	18.83	19.34	19.55	19.65	19.77	19.89	20.04
7	Palmitic (C16:0)	10.85	11.43	11.84	11.92	12.03	12.20	12.35
8	Palmitoleic (C16:1)	-	-	-	-	-	-	-
9	Stearic (C18:0)	2.76	2.89	3.08	3.11	3.14	3.18	3.21
10	Elaidic (C18:1 n9t)	-	-	-	-	0.06	0.14	0.23
11	Oleic (C18:1 n9c)	9.91	9.63	9.46	9.24	9.03	8.87	8.65
12	Linolelaidic (C18:2 n6t)	-	-	-	-	-	-	-
13	Linoleic (C18:2 n6c)	2.37	2.21	1.99	1.73	1.54	1.40	1.28
14	Arachidic (C20:0)	-	-	-	-	-	-	-
15	Gamma-Linolenic (C18:3 n)	-	-	-	-	-	-	-
16	Linolenic (C18:3 n3)	-	-	-	-	-	-	-
17	Behenic (C 22:0)	-	-	-	-	-	-	-
18	Lignoceric (C24:0)	-	-	-	-	-	-	-

The result is described as follows

1. Short chain saturated fatty acids

The common saturated short chain fatty acids found in oils and fat are butyric, caproic, caprylic and capric acids. The sunflower and palmolein oils do not form these short chain fatty acids even after sixth frying; but the continuation of decomposition of long chain fatty acids indicates the formation of high levels of non-volatile compounds, which accumulate in oil, leading to its darkening. Since, sunflower oil is about 80% unsaturated, the rate of decomposition and formation of non-volatile compounds is more in sunflower oil than in palmolein oil. However, coconut oil contains the short chain fatty acids -caprylic and capric acids, almost 5% each. The percentage of both these acids increases with increase in the number of frying, indicating hydrogenation and thermal decomposition of long chain fatty acids. The non-formation of butyric and caproic acids, here also, indicates the formation of non-volatile compounds.

2. Long chain saturated fatty acids

The common saturated long chain fatty acids found in oils and fats are lauric, myristic, palmitic and stearic acids. The results show that palmitic and stearic acids with palmitic acid constitute the major component, are present in all the oils taken for analysis. The amounts of these acids increases with increase in the number of frying. It is well known that unsaturated fatty acids are more susceptible to oxygen attack (during thermal oxidation) than the saturated ones.

This results in higher levels of saturated fatty acids. The other contributing factors for higher levels of saturated fatty acids are hydrolysis, hydrogenation and polymerization of long chain unsaturated fatty acids. In addition, coconut oil contains significant amounts of lauric and myristic acids; these acids are also present in palmolein oil but in very less quantities.

In coconut oil, the percentage of lauric acid decreases with increase in the number of frying, indicating its thermal decomposition resulting the formation of short chain fatty acids. Since no short chain fatty acids are present in or formed during frying of palmolein oil, an increase in proportion of lauric acid has been explained. However, both oils show an increase in the percentage of myristic acid with increase in the number of frying, indicating hydrogenation and thermal decomposition of unsaturated fatty acids.

3. Unsaturated fatty acids

The common unsaturated fatty acids present in these oils are oleic (monounsaturated) and linoleic (polyunsaturated) acids. About 80% of sunflower oil is composed of these acids with linoleic acid contained as almost double the amount of oleic acid; the palmolein oil is about 50% unsaturated with oleic acid contained as almost four times the amount of linoleic acid and the coconut oil is the least unsaturated containing about 12% of such acids. The unsaturated fatty acids are more susceptible to thermal oxidation, hydrolysis and polymerization than saturated acids. This decreases the content of both oleic and linoleic acids. However, in sunflower oil the percentage of oleic acid increases, probably because some linoleic acid get partially saturated to form oleic acid during the frying process. In palmolein and coconut oils decomposition predominates over hydrogenation.

4. Trans fatty acids

The Food Safety and Standards Regulations, 2011 does not permit the presence of trans fatty acids in any edible oils. The pure oils analysed in this experiment do not contain any trans fat. However, continuous frying causes configurational changes to unsaturated fatty acids. Consequently, oleic acid configures to its trans isomer elaidic acid and linoleic acid configures to its trans form linoelaidic acid during frying. The average frying temperature is around 180 °C.

The fatty acid profile analysis of sunflower oil reveals that the formation of the trans fatty acid, linoelaidic acid begins from fifth number of frying. Since this is deterioration, we can assume that at this stage smoke point become lesser than the frying temperature and oil become unfit for frying purpose. Similarly, in palmolein oil, the formation of the trans fatty acid, elaidic acid begins from third number of frying and linoelaidic acid begins

from fourth number of frying and in coconut oil, the formation of trans fatty acid, elaidic acid occurs at fourth number of frying; linoelaidic acid is not formed even at sixth number of frying. The trans fat raises LDL (bad cholesterol) which build up in the walls of arteries, making them hard and narrow and lowers HDL (good cholesterol). Thus eating food with too much trans fat increase the risk for heart attacks, stroke and type-2 diabetes.

V. CONCLUSION

The present study reveals that the common physico-chemical properties of oil show significant changes during deep frying. In India, the quality of used oil is assessed by its TPC value. The regulator, FSSAI, stipulates a maximum TPC limit of 25 as the end use of oil. However, the value remained within this limit even after the sixth stage of frying done in this study. The peroxide value is an indication of spoilage and edible oils which have not undergone rancidity must have PV below 10 meq/kg (Pearson, 1976). The PV of analysed samples are well within this limit. These two regulatory requirements create a false impression on the consumers and FBOs that these oils can be safely used for six times frying, extending 48 minutes or even more time.

However, the interpretation of refractive index values, acid values, saponification values and iodine values which are the primary quality parameters of edible oils indicate that we can safely use the oils for one time frying only. Moreover, the discussion on FAME results indicates the formation of trans fatty acids which adversely affect the health of consumers. The sunflower oil offers more resistance than coconut and palmolein oils towards trans fat formation. Hence it is healthier to use sunflower oil for frying purposes; trans fat free frying for maximum 32 minutes. In this context, I advise consumers to avoid using too much of fried foods. I strongly recommend the regulators to rewrite the current specification, which contains TPC and PV, for used oil and suggesting to include at least fatty acid profile for determining the quality of used oil.

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