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Bangladesh J. Sci. Ind. Res. **57(1)**, 49-60, 2022

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Qualitative changes of different vegetable oils during repeated deep frying

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Abstract

Repeated use of frying oils can produce elements that degrade food quality and promote the creation of chemicals with negative nutritional consequences and potential health risks. During multiple frying cycles in French fries, the quality of edible oils (soybean oil, rice bran oil, sunflower oil, and palm olein) was assessed. Except for RBO (F: 0.37-0.56 %), FFA percent was discovered in the usual range in SBO, SnFO, and PO. PV was raised by repeated frying, but SnFO showed the most instability (2.38-30.96) meq O_2/kg. RBO produced the most trans-fat (0.85-1.21 percent), but SnFO did not produce any. While vitamin A content decreased after three frying cycles, the PO used before retained higher vitamin A (16.29-14.61 mg/kg). However, no oil, even extracted oils, holds up to the quality requirement after three frying cycles.

Received: 13 December 2021
Revised: 06 February 2022
Accepted: 13 February 2022

DOI: https://doi.org/10.3329/bjsir.v57i1.58900

Keywords: Deep fat frying; Oil quality; French fries; Peroxide Value; Trans-fat; Repeated frying

Introduction

Deep frying is a well-known cooking method and worldwide this method is used for cooking foods such as french fries, chicken fries, potato chips etc. Deep frying is done by submerging a portion of food in extremely hot oil (150-190°C) until it reaches a safe minimum internal temperature. The simultaneous heat and mass transfer of oil, food and air produce fried foods desirable and unique quality during frying. Properly fried food will be hot and crispy outside and cooked safely in the centre.

The presence of polyunsaturated fatty acids in vegetable oils such as soybean, sunflower, corn or rapeseed makes them unsuitable for continuous frying (Gertz *et al.,* 2000). Olive oil, palm oil, coconut oil, avocado oil and peanut oil, on the other hand, can sustain far greater temperatures than others. Because, fats rich in monounsaturated fatty acids are more stable and resistant to peroxidation and oxidative stress than oils with a higher amount of polyunsaturated acids (Calder, 2017), it is critical to choose oils that are primarily made up of them.

When oil is used for deep frying regularly, its quality deteriorates from fresh to deteriorate. The TAG molecule undergoes various chemical processes, which can be classified as hydrolysis, oxidation, or polymerization (Sanibal and Mancini, 2004). The production of free fatty acids may result from the hydrolysis of oils. The nonvolatile breakdown products of utilized frying fats and oils are the most nutritionally important because they remain in the oil, are kept in the food and are then swallowed. The oxidation condition of vegetable oil interacts strongly with the stability of vitamin A in the oil, as measured by peroxide levels. In the presence of oxidized oils, vitamin A oxidizes faster and loses its action (GAIN and ICDDR,B, 2017). Some physical properties have also changed, like colour, density, viscosity etc., during repeated deep fry, the changes are visible as the oil colour darkens.

Cooked food absorbs frying oils, which form part of our nutrition. The amount of absorbed oil in diet varies between 4 and 14% of the overall weight (Ghidurus *et al.,* 2010).

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Repeated frying over a long period can produce anti-nutritional qualities that can inhibit enzymes and reduce food absorption, degrade vitamins, oxidize lipids, and cause gastrointestinal distress or mutation. Trans-fat, which has been identified as a risk factor for coronary heart disease, atherosclerosis and thrombosis, can be produced by repeatedly heating at a high temperature for a long time (Ghidurus *et al.,* 2010).

To save money, many restaurants and street vendors in Bangladesh have reused the oil for a long time. Furthermore, throughout Ramadan, it is common practice among the general public to save frying oils from iftar products to reuse on subsequent days. The general public is unaware of the detrimental effects of frequent frying oil use and the frying performance of various vegetable oils available on the market. As a result, it is critical to evaluate frying oil quality and improve public awareness. The goal of this study is to look into the changes in oxidative stability, trans-fat formation and nutritional changes such as fatty acid composition and vitamin A content in oils commonly used for frying in Bangladesh: Soybean oil, Palm olein, Rice bran oil, Sunflower oil and the quality of the oil extracted from french fries during repeated frying.

Materials and methods

Frying procedure

The potatoes were peeled, rinsed and cut into Julienne strips. One kg of potatoes was used in each frying. Each oil sample was poured into a typical cooking pan with a capacity of two liters. One kilogram of potatoes was fried at 165°C till golden brown. The oil sample was chilled in the frying pan overnight after being fried once. Fresh potatoes were peeled, rinsed and then fried the next day (after 24 hours). The operation was repeated three times because, according to the peroxide value, the oil was no longer edible after that period. Each time, a small sample of oil was obtained for analysis. Between frying sessions, no more oil was applied.

Sample collection

Four types of oil (1liter) (soybean, rice bran, sunflower, palm olein) and potatoes were purchased from local market. The initial oil samples, frying oils after each frying cycle and extracted oils from French fries were collected for analysis. The samples were coded for frying oil as SBO-I, SBO-F1, SBO-F2, SBO-F3, RBO-I, RBO-F1, RBO-F2, RBO-F3, SnFO-I, SnFO-F1, SnFO-F2, SnFO-F3, PO-I, PO-F1, PO-F2, PO-F3 and for extracted oil as SBO-E1, SBO-E2, SBO-E3, RBO-E1, RBO-E2, RBO-E3, SnFO-E1, SnFO-E2, SnFO-E3, PO-E1, PO-E2, PO-E3. Total 28 samples were analyzed.

Standard and chemicals

Fatty Acid Methyl Ester (FAME) and Vitamin A (Retinyl Palmitate) standards were collected from Sigma-Aldrich, St. Louis, Missouri, USA. All the chemicals used in this study were of analytical grade, Merck, Germany. HPLC grade Methanol and Dichloromethane were used for HPLC analysis and GC grade petroleum ether (b. p. 40-60ºC) was used for GC.

Analysis of physical characteristics

The color of frying oils and extracted oils were determined by comparison with standard colored glass in a Lovibond Tintometer (Model F; Salisbury, Wilts, England) using a 1-inch (2.54 cm) cell. Both frying and extracted oils colors were expressed as the combination of yellowness and redness measured using the equation Y + 5R; Where Y= yellowness and R= redness. Density meter DMA 35_N was used to determine the density of frying and extracted oil. Oil content was estimated as crude ether extract of the dry material (AOAC, 1984).

Analysis of qualitative characteristics

Chemical analysis

Free fatty acid and peroxide value of the samples were done following AOAC method 940.28 and AOAC 965.33 respectively (AOAC, 2005).

Analysis of fatty acid composition

Preparation of fatty acid methyl ester (FAME)

5-7 drops of oil were taken in a 15 ml test tube and 3 ml of 0.5 M sodium methoxide (prepared by mixing metallic sodium in methanol) was added and digested by stirring in a boiling water bath for about 15 minutes. It was allowed to cool to room temperature and 1.0 ml of petroleum ether (b. p. 40-60ºC) was added, followed by 10 ml deionized water, mixed gently and allowed to settle for 5-6 minutes. The distinct upper layer of methyl ester in petroleum ether was separated carefully in a capped vial and used for analysis. Aliquots of 1.0 µl FAME were injected, and the peaks of fatty acids were recorded for their respective retention time and areas by the data processor unit of GC.

Gas chromatography

The fatty acid composition was analyzed using gas chromatography (Shimadzu GC-14B, Japan) equipped with flame ionization detector and fused silica capillary column (FAMEWAX, Crossbond® polyethylene glycol, 15 m x 0.25 mm x 0.25 µm film thickness, Restek; Pennsylvania, USA). Spitless injection technique with nitrogen as carrier gas at a constant flow rate of 20 ml/min was used. Injector temperature was 250ºC, the initial oven temperature was 150ºC and held for 5 minutes. The temperature increment was 80ºC/min up to 190ºC and then expanded to 200ºC with 20ºC/min, and the holding time was 10 minutes. The fatty acids were identified using respective fatty acid methyl ester

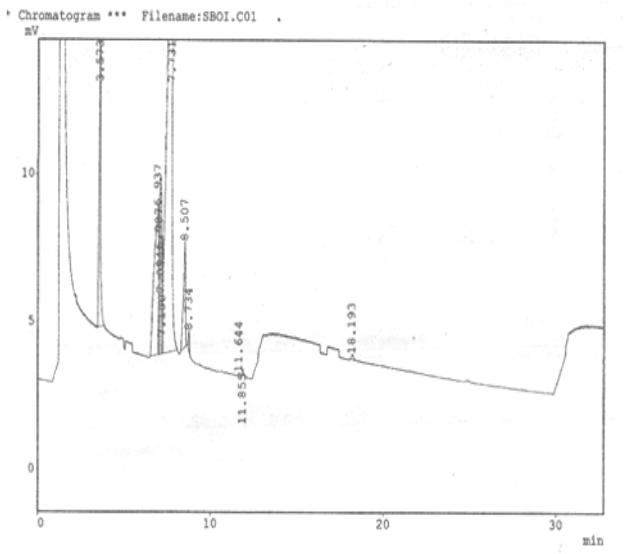

Fig. 1. Chromatogram of Fatty Acids Composition in Soybean oil (Initial)

standards and presented as relative percentages by the automated GC software (Class GC-10, version-2.00). Figure 1 shows the chromatogram of the fatty acid composition of initial soybean oil.

Vitamin A estimation

Vitamin A was quantified by High Performance Liquid Chromatography (Shimadzu Corporation, Japan) equipped with a central controlling unit (SCL-10AVP), two high pressure pumps (LC-10ATVP), a degasser (DGU-14A), a column oven (CTO-10ASVP) with 20 µl injector loop along with a Luna C18 column (250 mm ξ 4.6 mm I.D., 5µm particle size) and a UV detector (SPD-10AVP). A single Class VP software was used to control the vitamin estimation.

Extraction of vitamin A

Samples were prepared by dissolving 4 g of each oil sample with dichloromethane and methanol in a 50 ml amber colour volumetric flask. The standard stock solution was prepared by dissolving 0.005 g of retinyl palmitate in 50 ml dichloromethane and methanol to get a final concentration of 100 µg/ml. Both sample and standard were sonicated in an ultrasonic bath for 5 minutes and then filtered with 0.45 µm syringe filter in a 1.5 ml glass vial. An aliquot of the overly was injected into the HPLC column. All of the standards and samples were run in triplicate.

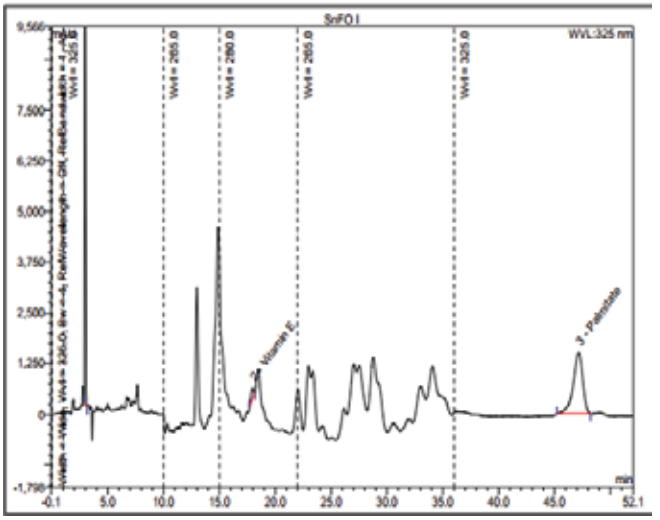

Fig. 2. Chromatogram of Vitamin A content in Sunflower Oil (Initial)

High performance liquid chromatography (HPLC) condition

Detection was performed at 325 nm using UV-Vis Detector for vitamin A as Retinyl palmitate and absolute methanol was used as the elution solvent. The analytical column was kept at 30ºC for vitamin A. The separation was done using the isocratic mode. The flow rate was 1.0 ml/min and the run time for each standard and sample was 60 minutes for vitamin A. Sample injection volume was 20 µl. Vitamin A (as retinyl palmitate) concentration was determined with external standards. Data was collected and processed by Class-VP

Automated Software (Shimadzu Corporation). Figure 2 shows the chromatogram of vitamin A content in initial sunflower oil.

Statistical analysis

All of the analyses were done three times, and the results were then expressed as mean values and standard deviations (SD). MS Excel was used to analyze the data in a methodical manner.

Table I. Color, Density and Oil content of Repeatedly Used Frying and Extracted oils

Name of Oils	Sample code	Color			Relative Density at 20°C (g/cm^3) *(MEAN±SD)*	Oil Content (%)
		Y	R	Y+5R		
Soybean Oil	SBO -I	1	0.4	3	0.9192±0.0008	N/A
	SBO -F1	2	0.8	6	0.9187±0.0003	N/A
	SBO -F2	3	0.8	7	0.9192±0.0003	N/A
	SBO -F3	4.3	0.6	7.3	0.9192±0.0007	N/A
	SBO -E1	9	2	19	0.9171±0.0008	9.92
	SBO -E2	10	2	20	0.9189±0.0003	10.20
	SBO -E3	10	3	25	0.9197±0.0009	11.02
Rice Bran Oil	RBO -I	6	4	26	0.9187±0.0005	N/A
	RBO -F1	7	4	27	0.9186±0.0006	N/A
	RBO -F2	7.2	4	27.2	0.9193±0.0003	N/A
	RBO -F3	7.6	4	27.6	0.9198± 0.0002	N/A
	RBO -E1	9	5	34	0.9185±0.0008	9.99
	RBO -E2	10	5	35	0.9178±0.0008	9.54
	RBO -E3	10	6	40	0.9187±0.0003	11.18
Sunflower Oil	SnFO -I	1	0.3	2.5	0.9175±0.0004	N/A
	SnFO -F1	2	0.3	3.5	0.9184±0.0009	N/A
	SnFO -F2	2.9	0.3	4.4	0.9188±0.0009	N/A
	SnFO -F3	3.1	0.3	4.6	0.9189±0.0006	N/A
	SnFO -E1	0.8	0.3	2.3	0.9169±0.0009	8.76
	SnFO -E2	1.5	0.3	2.5	0.9179±0.0005	10.67
	SnFO -E3	2	0.3	3.5	0.9173±0.0011	9.69
Palm Olein	PO -I	3	1	8	0.9110±0.0006	N/A
	PO -F1	5	2	15	0.9109±0.0004	N/A
	PO -F2	7	2	17	0.9106± 0.0001	N/A
	PO -F3	9	2	19	0.9111±0.0007	N/A
	PO -E1	7	3	22	0.9097±0.0010	9.71
	PO -E2	9	4	29	0.9104±0.0005	10.42
	PO -E3	10	4	30	0.9101±0.0005	10.15

Results and discussion

Physical characteristics of frying and extracted oils

Color

When fat/oil is fresh, it has a bright yellow tint that quickly turns orange-brown when heated. Polymerization and oxidation occur during high-temperature heating, changing the hue of the oil/fat. The color of several oil samples has been presented in Table I for each frying cycle. Fresh soybean, rice bran, sunflower oil and palm olein had color intensities of 3, 26, 2.5, and 8, respectively, which met the BSTI criteria except for rice bran oil (BDS 1769:2014, 1886:2014, 1773:2016, 1770:2014). After each frying, the color intensity grew progressively, with the greatest color being 27.6 in rice bran oil and the lowest being 4.6 in sunflower oil after the third frying. After three frying cycles, the red hue of palm olein remained stable, whereas the yellowness of palm olein gradually increased.

On the other hand, sunflower oil (0.3) and rice bran oil (4) did not show any changes in redness, while yellowness increased, as did soybean oil. After each frying cycle, the color intensity of all samples rose. The higher the color value, the more likely it is that cooking oils are exposed to high temperatures for an extended period.

Table I also shows the color of extracted oils from French fries. After three frying cycles, rice bran oil had the greatest color score of 40, while sunflower oil had the lowest color score of 2.3. It can be noticed that the hue of extracted oils from french fries fried in several sample oils changed with each frying. Oil samples turned dark due to the oxidation of phenolic compounds present in the oil after heating, according to Nor *et al.* (2008).

Relative density

In Tables I, the density results for all samples are also shown. Fresh oil samples had densities of 0.9192 in SBO, 0.9187 in RBO, 0.9175 in SnFO, and 0.9110 in PO, all of which met the BSTI standard (BDS 1769:2014, 1886:2014, 1773:2016, 1770:2014). No significant changes were seen in both the frying and extracted oils during the subsequent frying.

Chemical analysis of frying and extractedoils

Oil Content

Table I also shows the oil uptake (percentage) in french fries after repeated frying with various vegetable oils. All vegetable oils had a similar oil uptake on the first frying day. After that, compared to the first day of frying, an increase in oil uptake was noted on the second and third days. After three days of frying, the results showed that potatoes fried with various vegetable oils uptake around 9-11 percent of the oil. Many factors influence oil uptake, including oil quality, food content and form, and the frying method (Dana and Saguy, 2001). Oil absorption is more dependent on the quality of the frying oil/fat than on the type of frying oil/fat (Dobarganes *et al.,* 2000). The thickness of potato strips and the oil temperature had a significant impact on oil uptake and moisture loss in french fries. The oil content of potato strips increased with higher frying temperatures. (Krokida *et al.,* 2000). Mirzaei *et al.* (2015) concluded that 160ºC was better for deep-fat frying as the oil uptake was low and had suitable texture than 180ºC.

Free fatty acid (FFA)

Hydrolytic and oxidative processes yield free fatty acids from TGs. Acidity is mainly produced through triglyceride hydrolysis, aided by food moisture and oxidation or the reaction of the oil with moisture formed during other degradation reactions (Al-Harbi and Al-Kabtani, 1993). FFA content in frying oils (Figure 3A) increased from 0.090 to 0.219 in SBO, 0.372 to 0.562 in RBO, 0.143 to 0.184 in SnFO and 0.108 to 0.140 in PO in an experiment. Except for RBO, all initially meet the BSTI criteria. As a result, the percentage of FFA in rice bran oil increased rapidly. The amount of FFA discovered in frying oil reflects not just those generated during the frying process but also the level of acidity in the oil before it was heated (Fritch, 1981). As a result, it is vital to be FFA inside a specific range at first.

Figure 3B shows that the FFA content of SBO fried french fries grew from 0.115 to 0.192, RBO fried french fries climbed from 0.376 to 0.468, SnFO fried french fries increased from 0.141 to 0.207 and PO fried french fries increased from 0.127 to 0.153. During frying, the constant rise in the synthesis of FFA can be attributed partially to the hydrolysis and partly to the component carboxylic groups contained in polymeric products of frying (Tyagi and Vasishtha, 1996). The extracted RBO has a greater FFA content than the others. Sebastian *et al.* (2014) and Debnath *et al.* (2012) found that increasing the number of frying cycles increases oil FFA values. FFA formation is influenced by several factors, such as the type of vegetable oil used, initial FFA levels and frying time within the same operation (Lalas, 2008).

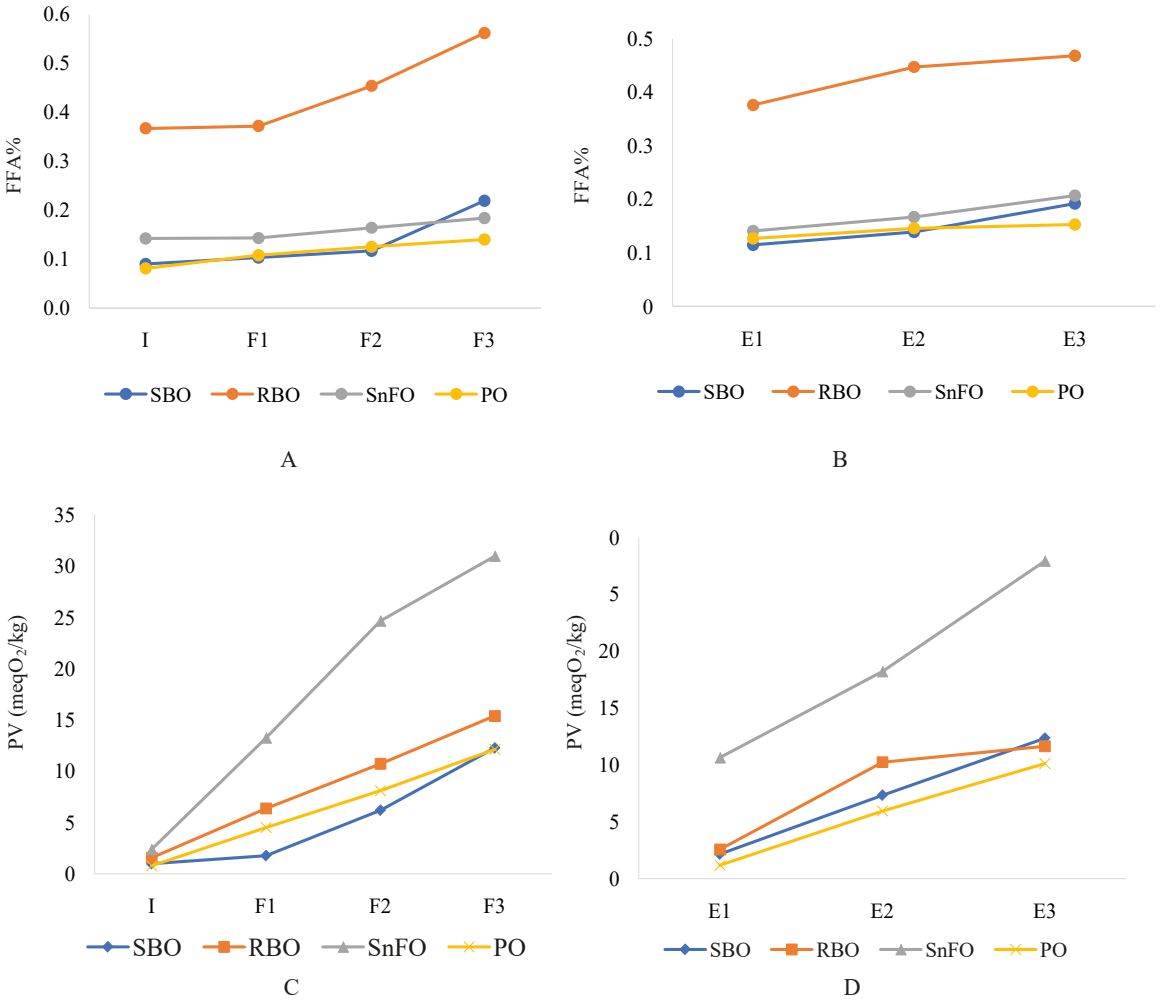

Fig. 3. A. Changes in FFA of repeatedly used frying oils, B.Changes in FFA of Extracted oils from French fries, C. Changes in PV of repeatedly used frying oils, D. Changes in PV of Extracted oils from French fries

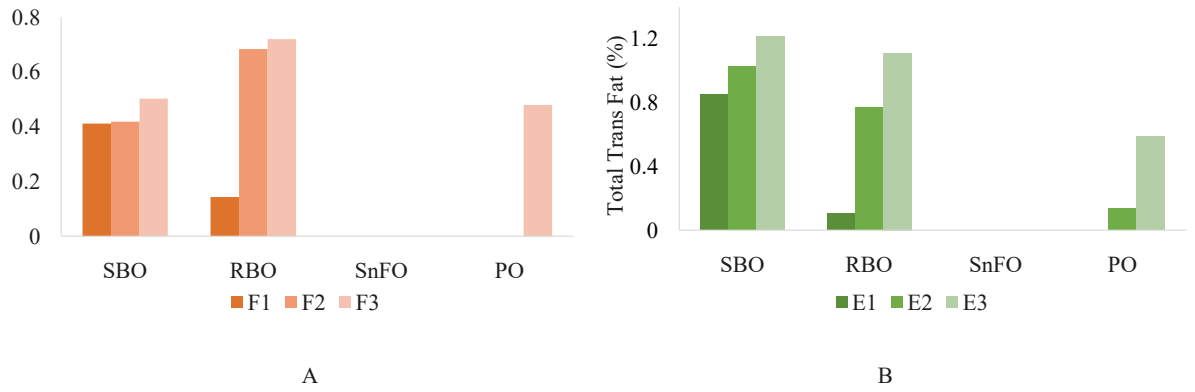

Fig. 4. Total trans-fat formation in A. repeated frying oils, B. extracted oils

Peroxide value (PV)

Hydroperoxides, commonly referred to as peroxides, are the main lipid oxidation products. As a result of oxidative reactions that occur during frying, certain oxidative compounds accumulate and induce thermal deterioration of frying oil as rancidity indices (Lalas, 2008). During three times of frying, the PV of the employed frying oils for french fries grew from 1.762 to 12.269 in fried SBO, 6.364 to 15.386 in fried RBO, 13.249 to 30.962 in fried SnFO, and 4.502 to 12.132 in fried PO (see Figure 3C). Because of its extensive unsaturation ranges, sunflower oil demonstrated the fastest increase in peroxide value of the four oils. Because it has a higher spectrum of polyunsaturated fatty acids than the other three oils, sunflower oil showed a quick increase in peroxide value (Day, 2004). The general increase in peroxide value happens especially during the cooling period when the frying oil is exposed to hot air (Augustin and Berry, 1983).

Table II. Saturated Fatty Acid (MEAN±SD) Composition of Repeated Frying and Extracted Oils (% w/w)

Name of Oils	Sample Code	Saturated Fatty Acids (SFA)					Total SFA
		Myristic Acid (C14:0)	Palmitic Acid (C16:0)	Stearic Acid (C18:0)	Arachidic Acid (C20:0)	Behenic Acid (C22:0)	
Soybean Oil	SBO-I	ND	10.553±0.273	2.854±0.094	0.095±0.057	0.238±0.015	13.740±0.439
	SBO-F1	ND	10.459±0.118	3.565±0.051	ND	ND	14.024±0.168
	SBO-F2	ND	10.483±0.142	3.036±0.056	ND	ND	13.519±0.198
	SBO-F3	ND	11.913±0.049	2.879±0.093	ND	ND	14.792±0.142
	SBO-E1	ND	12.588±0.084	2.959±0.213	ND	ND	15.547±0.297
	SBO-E2	ND	12.149±0.143	2.521±0.174	ND	ND	14.670±.317
	SBO-E3	ND	10.379±0.242	3.385±0.120	ND	ND	13.764±0.362
Rice Bran Oil	RBO-I	0.253±0.039	20.515±0.400	1.489±0.256	0.107±0.054	ND	22.364±0.749
	RBO-F1	0.349±0.073	24.314±0.067	1.147±0.124	ND	ND	25.810±0.264
	RBO-F2	0.239±0.035	17.884±0.064	1.940±0.082	0.602±0.133	ND	20.665±0.314
	RBO-F3	0.361±0.086	23.871±0.082	2.274±0.106	0.685±0.074	ND	27.191±0.342
	RBO-E1	0.292±0.032	22.358±0.052	2.117±0.090	0.191±0.069	ND	24.958±0.211
	RBO-E2	0.282±0.013	22.375±0.043	1.649±0.046	1.759±0.059	ND	26.065±0.161
	RBO-E3	0.317±0.013	22.193±0.007	1.932±0.063	0.615±0.004	ND	25.057±0.087
Sunflower Oil	SnFO-I	0.337±0.459	5.689±0.192	2.808±0.062	0.154±0.031	0.414±0.011	9.402±0.755
	SnFO-F1	ND	5.568±0.059	2.927±0.102	ND	0.184±0.017	8.679±0.178
	SnFO-F2	0.048±0.002	5.525±0.033	3.082±0.071	0.099±0.019	0.323±0.011	9.077±0.136
	SnFO-F3	ND	4.742±0.044	2.931±0.056	ND	ND	7.673±0.1
	SnFO-E1	0.080±0.006	7.172±0.049	2.996±0.006	ND	ND	10.248±0.061
	SnFO-E2	ND	13.381±0.038	3.037±0.145	ND	ND	16.418±0.183
	SnFO-E3	ND	7.124±0.029	3.246±0.046	ND	ND	10.370±0.075
Palm Olein	PO-I	0.548 ±0.039	40.427 ±0.024	4.072 ±0.061	ND	ND	45.047±0.124
	PO-F1	0.699 ±0.003	40.897 ±0.014	4.961 ±0.056	ND	ND	46.557±0.073
	PO-F2	0.250 ±0.021	43.448 ±0.480	4.820 ±0.063	ND	ND	48.519±0.564
	PO-F3	0.653 ±0.009	39.606 ±0.192	4.499 ±0.075	ND	ND	44.82±0.276
	PO-E1	0.508±0.012	41.104±0.052	4.996±0.006	ND	ND	46.608±0.07
	PO-E2	0.473±0.003	38.449±0.116	4.828±0.055	ND	ND	43.750±0.174
	PO-E3	0.553±0.036	44.448±0.044	4.138±0.053	ND	ND	49.139±0.133

ND: Not Detected

The extracted oils from french fries shown in figure 3D demonstrated that after one to three frying cycles, the PV of extracted oils increased along with the frying oils. The PV content of extracted sunflower oil was higher than that of other oils. Because the PV was larger than 10 meq O_2/kg after the third time of frying, no oil was judged edible (CODEX STAN 210-1999). Many research studies (Park, 2016; Nasirullah, 2001; Fan, 2013) found that when oils were repeatedly fried at high temperatures, the rate of peroxides increased.

Fatty acid composition

The fatty acid composition is commonly utilized to determine the oil's oxidative stability and validity. The effect of repeated frying on fatty acid composition was measured after three days of consecutive frying and the French fries.

Saturated fatty acid

Table II shows the distribution of saturated fatty acids in various oils at various frying periods. Fresh SBO, RBO, SnFO and PO were found to contain 10.553 percent, 20.515 percent, 5.689 percent, 40.427 percent palmitic acid, 2.854 percent, 1.489 percent, 2.808 percent, 4.072 percent stearic acid, 0.095 percent, 0.107 percent, 0.154 percent arachidic acid, SBO and SnFO both contained 0.238 percent and 0.414 percent behenic acid, respectively. SFA composition in each type of frying oil was also analyzed, with palm olein having the greatest total SFA at 48.519 percent and sunflower oil having the lowest at 7.673 percent.

The SFA content of extracted oils derived from three frying cycles of four different oils is also shown in Table II. Total SFA levels were highest in extracted palm olein (43.750 to 49.139%) and lowest in (10.248 to 16.418%). Total SFA was highest in five different branded palm oleins, ranging from 39.85 to 46.97 percent in one study, and palm olein includes more palmitic acid (Kabir *et al.* 2018). During the repeated deep fat frying cycles in both the rice bran oil and blended oil samples, no significant changes ($P<0.05$) in the myristic, palmitic, and stearic acid composition were found (Mishra, 2011).

Unsaturated fatty acids

Compared to their fresh states, SBO, RBO, SnFO and PO had a similar amount of unsaturated fatty acid after being heated once to three times (Table III). After one to three frying cycles, increased unsaturation was observed in

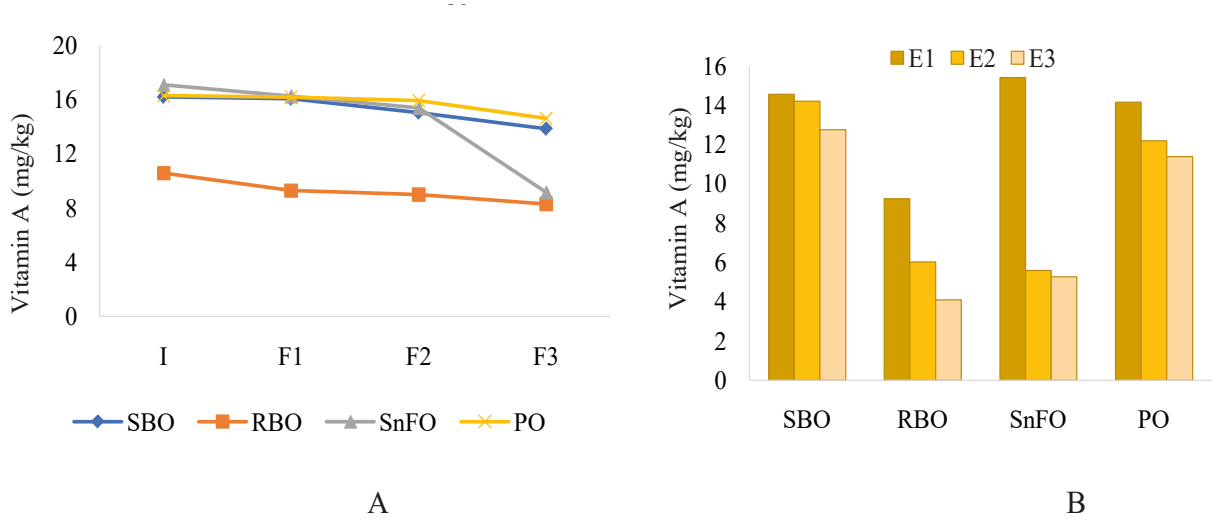

Fig. 5. Decrease in Vitamin A content in A. repeatedly used frying oils, B. extracted oils

Table III. Unsaturated Fatty Acid (MEAN±SD) Composition of Repeated Frying and Extracted Oils (% w/w)

Name of Oils	Sample Code	Unsaturated Fatty Acids (USFA)				Total USFA
		MUFA		PUFA		
		Oleic Acid (C18:1)	Eicosenoic Acid (C20:1)	Linoleic Acid (C18:2)	Linolenic Acid (C18:3)	
Soybean Oil	SBO-I	23.321±0.119	0.186±0.024	58.201±0.133	4.552±0.317	86.260±0.593
	SBO-F1	24.932±0.081	ND	56.158±0.132	4.385±0.139	85.475±0.352
	SBO-F2	22.845±0.117	ND	58.778±0.072	4.447±0.058	86.070±0.247
	SBO-F3	20.477±0.079	ND	60.496±0.052	3.817±0.062	84.790±0.193
	SBO-E1	20.635±0.258	ND	57.887±0.092	4.718±0.093	83.240±0.443
	SBO-E2	20.750±0.260	ND	60.254±0.034	3.299±0.119	84.303±0.413
	SBO-E3	21.425±0.369	ND	59.369±0.104	4.591±0.052	85.385±0.525
Rice Bran Oil	RBO-I	43.634±0.533	0.111±0.114	33.435±0.216	0.456±0.093	77.636±0.956
	RBO-F1	44.289±0.156	ND	28.917±0.018	0.888±0.058	74.094±0.232
	RBO-F2	44.672±0.092	ND	33.600±0.067	0.439±0.090	78.711±0.249
	RBO-F3	43.278±0.102	ND	28.316±0.022	0.533±0.043	72.127±0.167
	RBO-E1	44.401±0.053	ND	30.405±0.229	0.130±0.121	74.936±0.403
	RBO-E2	45.245±0.040	ND	27.266±0.075	0.411±0.023	72.922±0.138
	RBO-E3	45.439±0.073	ND	28.315±0.014	0.494±0.009	74.248±0.096
Sunflower Oil	SnFO-I	32.312±0.070	ND	58.185±0.018	0.101±0.095	90.598±0.183
	SnFO-F1	29.893±0.119	ND	61.436±0.013	ND	91.329±0.132
	SnFO-F2	30.334±0.080	ND	60.67±0.011	ND	91.004±0.091
	SnFO-F3	28.558±0.074	ND	63.793±0.017	ND	92.351±0.091
	SnFO-E1	30.332±0.009	ND	59.414±0.025	0.066±0.004	89.812±0.038
	SnFO-E2	30.641±0.145	ND	52.941±0.057	ND	83.582±0.202
	SnFO-E3	31.829±0.062	ND	57.845±0.044	ND	89.674±0.106
Palm Olein	PO-I	45.694±0.109	ND	9.153±0.026	0.131±0.014	54.978±0.149
	PO-F1	43.618±0.044	ND	9.773±0.012	0.075±0.002	53.466±0.058
	PO-F2	41.849±0.054	ND	9.632±0.032	ND	51.481±0.086
	PO-F3	43.941±0.437	ND	10.760±0.012	ND	54.701±0.449
	PO-E1	45.588±0.015	ND	7.804±0.147	ND	53.392±0.162
	PO-E2	44.678±0.103	ND	11.081±0.027	ND	55.759±0.13
	PO-E3	41.818±0.093	ND	8.935±0.045	ND	50.753±0.138

ND: Not Detected

sunflower oil (91.002 percent to 92.351 percent), soybean oil (84.790 percent to 86.070 percent), rice bran oil (72.127 percent to 78.711 percent), and palm olein (51.481 percent to 54.701 percent). Sunflower oil had more linoleic acid (C18:2), while rice bran oil and palm olein had more oleic acid (C18:1). Several extracted oils' total unsaturated fatty acid profile displayed frying oil-like unsaturation (Table III). Extracted soybean (60.254 percent to 57.887 percent) and sunflower oil (59.414 percent to 52.941 percent) had the highest Linoleic acid (C18:2), while extracted rice bran oil (45.439 percent to 44.401 percent) and palm olein had the highest Oleic acid (C18:1) (41.818 percent to 45.588 percent).

During 7 days of frying at 185º and 215º C, Aladedunye (2008) found a steady decline in linoleic and linolenic acid contributions. During repeated deep fat frying cycles in rice bran oil, the level of USFA dropped steadily, according to Mishra (2011).When refined soybean oil was heated 80 times at 180ºC, significant changes in USFA (MUFA: 22.9 0.1 23.0 0.2, PUFA: 61.0 0.2 60.3 0.2) were detected. The increase in SFA and decrease in USFA in fried oils may be due to USFA oxidation being greater than SFA oxidation in oils during frying (K. T. Hwang, 2017). Polyunsaturated fatty acids were lost during deep-frying, according to Tyagi and Vasishtha (1996).

Trans fat formation

Trans-fat was not found in fresh sample oils as expected. However, frying has been suggested as a source of trans-fat (Sanibal and Mancini, 2004). After three times of frying soybean and rice bran oil showed a significant amount of trans-fat formation while sunflower oil did not form any trans-fat and on third frying palm olein produced trans-fat. In soybean and rice bran oil, trans-fat increased from 0.411 to 0.502% and 0.143 to 0.719 %, respectively (Figure 4A).

The amount of trans fatty acids formed during frying increased when temperature and time increased (Aladedunye, 2008). According to Mishra (2011), the total trans-fat was 0.50 percent in sunflower oil compared to 1.27 percent in rice brand oil. After the 6th frying cycle for rice bran oil, the percent trans-fat was 2.19. It was suggested that the trans-fat increased with repeated deep fat frying cycles.

Figure 4B shows the gradual increase of trans-fat in extracted oils. While the trans-fat formation in sunflower oil was null, soybean, rice bran, and palm olein showed increased trans-fat formation range from 0.851 to 1.212%, 0.106 to 1.112% and not detected (ND) to 0.586%, respectively.

Vitamin A content

Different frying oils showed a gradual decline in vitamin A content (Figure 5A). Because vegetable oils are fortified with vitamin A, the lowest level was observed in fresh RBO, which had 10.57 mg/kg. According to the BSTI standard, vitamin A was identified in other fresh oils (15-30 ppm). After three cycles of frying with different vegetable oils, the vitamin A content of SBO, RBO, SnFO and PO was determined to be 13.83, 8.27, 9.13 and 14.61 mg/kg, respectively. The vitamin A concentration of palm olein decreased less. There was also a drop in vitamin A in the extracted oils from french fries (Figure 5B). Vitamin A content was 5.26 mg/kg after the third time of frying in sunflower oil fried french fries, indicating rapid loss of vitamin A. The lowest level, 4.09 mg/kg, was discovered in rice bran oil.

On the other hand, extracted soybean and palm olein oils exhibited a reduced rate of vitamin A loss. Cooking in the open air at high temperatures for extended periods appears more harmful. According to studies, heating at 160°C, 180°C and 200°C for half an hour resulted in a 20%, 3% and 50% loss of vitamin A, respectively (Haffman *et al.,* 1994). When exposed to light, air, or heat for an extended period, vitamin A becomes unstable. Furthermore, lipid peroxidation is linked to vitamin A degradation in oil (GAIN and ICDDR, B, 2017).

Conclusion

Although fried foods have a high market acceptance due to their unique sensory features, a considerable volume of oil is used frequently, causing oil to deteriorate and making the dish an undesirable product in terms of nutritional facts. This study found that sunflower oil has minor peroxide stability due to its high PUFA content, making it inappropriate for deep fat frying, whereas palm olein has a lower peroxide generation rate but is not regarded as edible after three frying cycles, followed by soybean and rice bran oil. Furthermore, all frying oils and extracted oils used frequently revealed vitamin A deterioration. A large intake of saturated and trans-fatty acids (TFAs) from frying fats is nutritionally unsound. The general conclusion is that palm olein outperforms other vegetable oils when frying.

Acknowledgment

The Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh, produced this paper as part of a research and development effort. The authors are grateful to BCSIR for providing the finances and instruments needed to complete the study. The equipment utilized in this study was made possible by an ADP project financed by Ministry of Science and Technology Bangladesh. All laboratory workers and technical experts of the Oilseed and Lipid Technology Section, IFST, BCSIR, are also thanked for their help.

References

Aladedunye FA and Przybylski R (2008), Degradation and Nutritional Quality Changes of Oil During Frying, *J Am Oil Chem Soc.* **86(2):** 149–156. DOI: 10.1007/s11746-008-1328-5

Al-Harbi M (1993), Chemical and biological evaluation of discarded frying palm oil from commercial restaurants. *Food Chem*. **48**(4): 395–401. DOI: 10.1016/0308-8146(93)90324-9

AOAC (2005), Official Method of Analysis of the Association of Official, Analytical Chemist. (Gaithersburg, USA) 2005, **41:**（6-7): 11-13.

Assessment of presence of edible oil brands in Bangladesh and their content of fortification. Global Alliance for Improved Nutrition (GAIN), International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka (ICDDR,B). 2017.

Augustin MA and Berry SK (1983), Efficacy of the antioxidants BHA and BHT in palm olein during heating and frying, *J Am Oil Chem Soc.* **60**(8): 1520-1523. DOI: 10.1007/ bf02666575

BSTI, Bangladesh standards Specification for vegetable oils- a. BDS 1769: 2014 (Fortified soybean oil), b. BDS 1773: 2016 (Fortified sunflower oil), c. BDS 1770: 2014 (Fortified edible palm oil), d. BDS 1886: 2014 (Fortified edible rice bran oil).

Calder PC (2017). Omega-3 fatty acids and inflammatory processes: from molecules to man, *Biochem. Soc. Trans.* **45:** 1105-1115. DOI: 10.1042/BST20160474

CODEX-STAN, Codex Standards for Fats and Oils from Vegetable Sources. Codex Standard for Named Vegetable Oils (CODEX-STAN 210-1999).

Dana D and Saguy IS (2001), Frying of Nutritious Foods: Obstacles and Feasibility, *Food Sci Technol Res.* **7**(4): 265-279. DOI: 10.3136/fstr.7.265

Day L (2004), Lipid Chemistry. Encyclopedia of Grain Science. 2004, pp 157-165. DOI: 10.1016/b0-12-765490-9/00082-

Debnath S, Rastogi NK, Gopala Krishna AG and Lokesh BR (2012), Effect of frying cycles on physical, chemical and heat transfer quality of rice bran oil during deep-fat frying of poori: An Indian traditional fried food, *Food Bioprod. Process.* **90**(2): 249–256. DOI: 10.1016/j.fbp.2011.05.001

Dobarganes C, Márquez-Ruiz G and Velasco J (2000), Interactions between fat and food during deep-frying, *Eur J Lipid Sci Technol,* **102**(8-9): 521-528. DOI: 10.1002/ 1438-9312 (200009) 102:8/ 9<521::aid-ejlt521>3.0.co;2-a

Fan HY, Sharifudin MS, Hasmadi M and Chew HM (2013), Frying stability of rice bran oil and palm olein, *Int. Food Res. J.* **20**(1): 403-407.

Fritsch CW (1981), Measurements of frying fat deterioration: A brief review, *JA m Oil Chem Soc* **58**(3Part2): 272–274. DOI: 10.1007/bf02582355

Gertz C, Klostermann S and Kochhar SP (2000), Testing and comparing oxidative stability of vegetable oils and fats at frying temperature, *Eur J Lipid Sci Technol* **102**(8-9): 543–551. DOI: 10.1002/1438-9312 (200009)102

Ghidurus M, Turtoi M, Boskou G, Niculita P, Stan S (2010), Nutritional and health aspects related to frying (I), *Rom. Biotechnol. Lett.* **15**(6): 5675-5682.

Haffman F and Roache La (1994), The Fortification and Coloring of Edible Fats and Oils. Technical Bulletin. A.G. Switzerland.

Kabir MA, Khan S, Lisa SA and Islam F (2018), Quality of oil used to prepare French fries in Dhaka city, *Bangladesh J. Sci. Ind. Res.* **53**(2): 117-124. DOI: 10.3329/ bjsir.v53i2.36672

Krokida MK, Oreopoulou V and Maroulis ZB (2000), Water loss and oil uptake as a function of frying time, *J. Food Eng.* **44:** 39-46.

LALAS S (2008), Quality of frying oil. In Advances in Deep-Fat Frying of Foods. (CRC Press, Boca Raton, Florida), pp 57-80

Mirzaei HO, Karapanthios T, Garoumi H (2015), Effect of frying temperature on amount of oil uptake of potato French fries, *MOJ Food process Technol.* **1**(1): 17-19. DOI: 10.15406/ mojfpt.2015.01.00006

Mishra R and Sharma HK (2011), Effect of frying conditions on the physico-chemical properties of rice bran oil and its blended oil, *J. Food Sci. Technol* **51**(6): 1076-1084 DOI: 10.1007/s13197-011-0602-y

Nasirullah (2001), Development of deep-frying edible vegetable oils, *J. Food Lipids.* **8**(4): 295-304. DOI: 10.1111/j. 1745-4522.2001.tb00204.x

Nor FM, Mohamed S, Idris NA and Ismail R (2008), Antioxidative properties of *Pandanus amaryllifolius* leaf extracts in accelerated oxidation and deep-frying studies, *Food Chem.* **110**(2): 319-327. DOI: 10.1016/j.foodchem.2008.02.004

Park JM and Kim JM (2016), Monitoring of Used Frying Oils and Frying Times for Frying Chicken Nuggets Using Peroxide Value and Acid Value, *Korean J Food Sci Anim Resour* **36**(5): 612–616. DOI: 10.5851/ kosfa.2016.36.5.612

Parveen R, Butt MS,Yasin M, Imran A and Imran M (2011), Storage and frying behavior of sunflower oil blended with peanut oil, *Internet Journal of Food Safety*. **13:** 214-220.

Proceedings of the 1999 PORIM International Palm Oil Congress (1999), quality of potato chips fried in palm olein and high oleic sunflower oil during batch frying, Razali I, Fauziah A and Nor AINIS, pp 99-103.

Sanibal E AA and Mancini-Filho J (2004), Frying oil and fat quality measured by chemical, physical and test kit analyses, *J Am Oil Chem Soc* **81**(9): 847-852. DOI: 10.1007/s11746-004-0990-8

Sebastian A, Ghazani SM and Marangoni AG (2014), quality and safety of frying oils used in restaurants. *Int. Food Res. J.* **64:** 420–423. DOI: 10.1016/j. foodres.2014.07.033

Tan YA, Ong SH, Berger KG, Oon HH and Poh BL (1985), A study of the cause of rapid color development of heated refined palm oil, *J Am Oil Chem Soc* **62(6):** 999–1006. DOI: 10.1007/bf02935701

Tyagi VK and Vasishtha AK (1996), Changes in the characteristics and composition of oils during deep-fat frying, *JAm Oil Chem Soc* **73(4):** 499–506. DOI: 10.1007/bf02523926

Yu KS, Cho H and Hwang KT (2017), Physicochemical properties and oxidative stability of frying oils during repeated frying of potato chips, *Food Sci. Biotechnol.* **27**(3): 651–659. DOI: 10.1007/s10068-017-0292-y.