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 O₂/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.

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. 40-60°C) 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 35O 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. 40-60°C) 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). Splitless injection technique with nitrogen as carrier gas at a constant flow rate of 20 ml/min was used. Injector temperature was 250°C, the initial oven temperature was 150°C and held for 5 minutes. The temperature increment was 80°C/min up to 190°C and then expanded to 200°C with 20°C/min, and the holding time was 10 minutes. The fatty acids were identified using respective fatty acid methyl ester 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, 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 vial. All of the standards and samples were run in triplicate.

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 30°C 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 20ºC (g/cm³) | Oil Content (%) |
|--------------|-------------|-------|---------------------------------|-----------------|
|              | Y R Y+5R    |       | (MEAN±SD)                       |                 |
| 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 extracted oils

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 160°C was better for deep-fat frying as the oil uptake was low and had suitable texture than 180°C.

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 Deb Nath 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).
Between frying sessions, no more oil was applied.

The oil sample was chilled in the frying pan overnight on subsequent days. The general public is unaware of the anti-nutritional qualities that can inhibit enzymes and reduce the nutritional values of food. Repeated frying over a long period can produce significant changes in the oil used for frying.

For example, soybean, rice bran, and palm olein showed increased trans-fat (C18:2), while extracted rice bran oil (45.439 percent to 45.439 percent) had a higher content of unsaturated fatty acid profile displayed frying oil-like characteristics.

The total FFA (free fatty acid) content of the oils was measured using acid value. The extraction of vitamin A was done using a modified version of the AOAC (1990) method. A single Class VP software was used for data analysis.

Conclusion

The peroxidation is linked to vitamin A degradation in oil during frying. Cooking in the extracted oils revealed vitamin A loss. After three cycles of frying, the vitamin A content of the oils was significantly lower than that of the fresh oils. The vitamin A content of rice bran oil, soybean oil, and palm olein were 5.26 mg/kg, 9.13 mg/kg, and 14.61 mg/kg, respectively. The vitamin A content of the extracted oils was significantly lower than that of the fresh oils.

Extracted rice bran oil showed a reduced rate of vitamin A loss. The vitamin A content of the extracted rice bran oil was 4.81 mg/kg, 4.81 mg/kg, and 4.81 mg/kg, respectively. The vitamin A content of the extracted oils was significantly lower than that of the fresh oils.

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 | Myristic Acid (C14:0) | Palmitic Acid (C16:0) | Stearic Acid (C18:0) | Arachidic Acid (C20:0) | Behenic Acid (C22:0) | Total SFA |
|--------------------|-------------|------------------------|------------------------|----------------------|------------------------|----------------------|-----------|
| Soybean Oil        | SBO-I       | ND                     | 10.55±0.273            | 2.85±0.094           | 0.09±0.057             | 0.23±0.015           | 13.74±0.439 |
|                    | SBO-F1      | 10.45±0.118            | 3.56±0.051             | ND                   | ND                     | ND                   | 14.02±0.168 |
|                    | SBO-F2      | 10.48±0.142            | 3.03±0.056             | ND                   | ND                     | ND                   | 13.51±0.198 |
|                    | SBO-F3      | 11.91±0.049            | 2.87±0.093             | ND                   | ND                     | ND                   | 14.79±0.142 |
|                    | SBO-E1      | 12.58±0.084            | 2.95±0.213             | ND                   | ND                     | ND                   | 15.54±0.297 |
|                    | SBO-E2      | 12.14±0.143            | 2.52±0.174             | ND                   | ND                     | ND                   | 14.67±0.317 |
|                    | SBO-E3      | 10.37±0.242            | 3.38±0.120             | ND                   | ND                     | ND                   | 13.76±0.362 |
| Rice Bran Oil      | RBO-I       | 0.25±0.039             | 20.51±0.400            | 1.49±0.256           | 0.10±0.054             | ND                   | 22.36±0.749 |
|                    | RBO-F1      | 0.34±0.073             | 24.31±0.067            | 1.14±0.124           | ND                     | ND                   | 25.81±0.264 |
|                    | RBO-F2      | 0.23±0.035             | 17.88±0.064            | 1.94±0.082           | 0.60±0.133             | ND                   | 20.66±0.314 |
|                    | RBO-F3      | 0.36±0.086             | 23.87±0.082            | 2.27±0.106           | 0.68±0.074             | ND                   | 27.19±0.342 |
|                    | RBO-E1      | 0.29±0.032             | 22.35±0.052            | 2.11±0.090           | 0.19±0.069             | ND                   | 24.95±0.211 |
|                    | RBO-E2      | 0.28±0.013             | 22.37±0.043            | 1.64±0.046           | 1.75±0.059             | ND                   | 26.06±0.161 |
|                    | RBO-E3      | 0.31±0.013             | 22.19±0.007            | 1.93±0.063           | 0.61±0.004             | ND                   | 25.05±0.087 |
| Sunflower Oil      | SnFO-I      | 0.33±0.459             | 5.68±0.192             | 2.80±0.062           | 0.15±0.031             | 0.41±0.011           | 9.40±0.755  |
|                    | SnFO-F1     | ND                     | 5.56±0.059             | 2.92±0.102           | ND                     | 0.18±0.017           | 8.67±0.178  |
|                    | SnFO-F2     | 0.04±0.002             | 5.52±0.033             | 3.08±0.071           | 0.09±0.019             | 0.32±0.011           | 9.07±0.136  |
|                    | SnFO-F3     | ND                     | 4.74±0.044             | 2.93±0.056           | ND                     | ND                   | 7.67±0.1   |
|                    | SnFO-E1     | 0.08±0.006             | 7.17±0.049             | 2.99±0.006           | ND                     | ND                   | 10.24±0.061 |
|                    | SnFO-E2     | ND                     | 13.38±0.038            | 3.03±0.145           | ND                     | ND                   | 16.41±0.183 |
|                    | SnFO-E3     | ND                     | 7.12±0.029             | 3.24±0.046           | ND                     | ND                   | 10.37±0.075 |
| Palm Olein         | PO-I        | 0.54±0.039             | 40.42±0.024            | 4.07±0.061           | ND                     | ND                   | 45.04±0.124 |
|                    | PO-F1       | 0.69±0.003             | 40.89±0.014            | 4.96±0.056           | ND                     | ND                   | 46.55±0.073 |
|                    | PO-F2       | 0.23±0.021             | 43.44±0.480            | 4.82±0.063           | ND                     | ND                   | 48.51±0.564 |
|                    | PO-F3       | 0.65±0.009             | 39.66±0.192            | 4.49±0.075           | ND                     | ND                   | 44.82±0.276 |
|                    | PO-E1       | 0.50±0.012             | 41.10±0.052            | 4.96±0.006           | ND                     | ND                   | 46.60±0.07 |
|                    | PO-E2       | 0.47±0.003             | 38.44±0.116            | 4.82±0.055           | ND                     | ND                   | 43.75±0.174 |
|                    | PO-E3       | 0.55±0.036             | 44.44±0.044            | 4.13±0.053           | ND                     | ND                   | 49.13±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 O2/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 185° and 215° 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 180°C, 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.
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The samples were coded for frying oil as SBO-I, SBO-F1, extracted oils from French fries were collected for analysis. Sample collection

liters. One kilogram of potatoes was fried at 165°C till golden on subsequent days. The general public is unaware of the food absorption, degrade vitamins, oxidize lipids, and cause

Repeated frying over a long period can produce 0.502% and 0.143 to 0.719 %, respectively (Figure 4A). soybean and rice bran oil, trans-fat increased from 0.411 to (MUFA: 22.9 0.1 23.0 0.2, PUFA: 61.0 0.2 60.3 0.2) were soybean, rice bran, and palm olein showed increased trans-fat oils. While the trans-fat formation in sunflower oil was null, rice bran oil, the percent trans-fat was 2.19. It was 44.401 percent) and palm olein had the highest Oleic acid (C18:2), while extracted rice bran oil (45.439 percent to percent to 52.941 percent) had the highest Linoleic acid unsaturation (Table III). Extracted soybean (60.254 had more oleic acid (C18:1). Several extracted oils’ total

were expressed as the combination of yellowness and redness Analysis of fatty acid composition was estimated as crude ether extract of the dry material deterioration. A large intake of saturated and trans-fatty acids (TFAs) from frying fats is nutritionally unsound. Furthermore, all frying oils

peroxidation is linked to vitamin A degradation in oil period, vitamin A becomes unstable. Furthermore, lipid

indicates rapid loss of vitamin A. The lowest level, 4.09 9.13 and 14.61 mg/kg, respectively. The vitamin A BSTI standard, vitamin A was identified in other fresh

A content (Figure 5A). Because vegetable oils are Different frying oils showed a gradual decline in vitamin

Detection was performed at 325 nm using UV-Vis condition standards and samples were run in triplicate. Samples were prepared by dissolving 0.005 g of retinyl palmitate in 50 ml

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