Oil characteristics of deep frying and pan frying of palm oil and sunflower oil

Nurul Ashikin Binti Subandi, Dr. Sherif Abdulbari Ali

Faculty of Chemical Engineering, Universiti Teknologi Mara Shah Alam

Abstract— The objective of this study is to determine the physical and chemical properties of palm oil and sunflower oil in repeated deep frying and pan frying. Second, to compare between deep frying and pan frying which oil shows a better performance. 5 kg of palm oil and sunflower oil is used to fry 2.5 kg of fries in electric deep fryer for 10 minutes while 1 kg of palm oil and sunflower oil were used to fry 0.5 kg fries in pan fryer for 10 minutes. First and final frying oil is collected to perform an analysis of peroxide value(PV), Free fatty acid(FFA), colorimetric, absorbance and FTIR analysis. An analysis such as anisidine value, total oxidation, total polar compound, rancidity, density and viscosity are not perform in this experiment. The result of the analysis shows that the quality of palm oil is better compare to sunflower oil after forth frying cycle while the quality of oil which used in electric deep fryer shows a good performance compare to pan frying.

Keywords— deep frying, palm oil, pan frying, sunflower oil

I. INTRODUCTION

Frying is the process where food or sample was immerse in the hot oil or fat at temperature in between 150 °c to 190 °c, [1]. Fried food have a unique aroma, taste and textural properties which does not have by other cooking technique. To produce the best product of deep frying, it must be carried out at high temperature. However, the oils will undergo physical and chemical deterioration which may affects the frying performance and the shelf life of the fried products. An overuse of the oil used in frying will change the colour and texture of the food products. It also may be harmful to the human health[2].

Under this research, we used two types of oil which is palm oil and sunflower oil. Palm oil are widely used in cooking industry. Nowadays, palm oil is an important energy sources for human as it is consisted various nutritious vegetable oil, trans fat free and rich content of vitamin and antioxidants. But, the quality of the oil may change when it is used for frying. Other than palm oil, there are another oil that can be used in the cooking and frying process which is sunflower seed oil is obtained from the extraction of sunflower seed. It is light, odourless and mild in flavour. Sunflower seed oil is commonly used for frying, fast food preparation and processed food.

During the frying process, there are many possible chemical reaction may be occurred in the presence of air. For example, hydrolysis, polymerization and thermal oxidation [3]. This reaction may cause production of harmful compounds such as polymer and ketones which can change the quality of the frying oil. The frying oil will be reused until the colour of the oil change to be dark. As more frequent the oil to be used, the darker the colour the worst the quality of the oil. It is not good for health because it may contain undesirable chemical compound.

By using a repeated frying oil, it may harm to the human health. However, different oil shows different performance and physical and chemical characteristics. By determining the physical and chemical properties of an oil, the quality of frying oil can be predicted. It is also can protect consumer's health [4].

II. METHODOLOGY

A. MATERIAL FOR FRYING

Refined, bleached and deodorized (RBD) palm oil and sunflower oil was purchased from a local market. French fries was selected as the frying food and was purchased from the local market.

B. FRYING PROTOCAL

The frying experiment were conducted with the same steps as actual household cooking process. Pan frying was performed by using uncovered stainless steel pan fryer. 0.5 ± 10 kg of French fries were fried in 1 kg of palm and sunflower oil for 10 min at constant temperature (165 ± 5° C). The oil temperature was monitored with a digital thermometer attached to a steel probe. After cooling, (approximate 1 hour) the frying process were repeated four times using the same oil without replenishment. For deep frying, a common electric fryer was used equipped with thermostat, and supplied with an inert cross-linked steel wire mesh which allowed the food to be dipped into the oil, without contact the fryer's inner surface. In every frying session 2.5 g ± 10 kg of french fries were deep fried for 10 min in 5.0 L palm oil and sunflower oil without replenishment. Excess oil in french fries will be drained on a cross-linked steel wire-mesh and was added to the oil remaining in the fryer. An oil sample will be collected once after the frying process. The collected oil samples were filtered to remove suspended food particles and stored in a glass bottles at -20 °C for further analysis.

C. PHYSICAL AND CHEMICAL ANALYSIS OF OIL

- **Measurement of colour of oil**

The colour of the oil was measured by using Lovibond Tintometer in 1 cm cell in the transmittance mode and express as red (R) and yellow (Y) value.

- **Absorbance**

Oil absorbance was determined by using a UV-Visible spectrophotometer equipped with a temperature control system. Sample was maintained at constant temperature (60℃). The absorbance was determined over a spectrum in the visible range of 400-700 nm with air in an empty cell as reference.

- **Determination of free fatty acid (FFA)**

Free fatty acid is measured to determine the free fatty acid of an oil. The oil was weight in 3-10 g and neutralized alcohol

was added to a sample (IPA). The mixture was boiled up and titrated with sodium hydroxide by using phenolphthalein indicator until the color of the sample change to purple-pink.

$$Free\ Fatty\ Acid(FFA) = \frac{VNM}{10W}$$

Where
W=Weight (in mg) of sample
V=Volume (in ml) of sodium hydroxide solution
N=Normality of sodium hydroxide
M=Molecular weight of fatty acid (256)

- **Determination of peroxide value (PV)**

Peroxide value is measured to determine the peroxide contain in the oil. PV is determined by measuring iodine release from iodide potassium, KI. An oil sample was weight and dissolved in acetic acid and chloroform then saturated KI mixture is added to the weight sample. The amount of iodine liberated from KI by oxidative action of peroxide present in the oil is determine by titration with standard sodium thiosulphate using starch solution as indicator. The titration also determines for blanks

$$Peroxide\ Value\left(\frac{meq}{kg}\right) = \frac{1000(V1-V2)}{W}$$

Where
W=Weight of sample
V1=Volume of Sodium Thiosulphate used in test
V2=Volume of Sodium Thiosulphate used in blank
V3=Normality of Sodium Thiosulphate

- **FTIR analysis**
  FTIR spectra of oil sample initial and final frying were recorded by Fourier Transform Spectroscopy.

III. RESULTS AND DISCUSSION

A. Physical characteristics

- *Colorimetric analysis*

Type of oil		Result
Palm oil	Deep frying (initial)	3.3 R 33 Y
	Deep frying (final)	4.4 R 44 Y
	Pan frying (initial)	3.3 R 33 Y
	Pan frying (final)	4.3 R 43 Y
Sunflower oil	Deep frying (initial)	1.3 R 13 Y
	Deep frying (final)	1.6 R 16 Y
	Pan frying (initial)	2.0 R 20 Y
	pan frying (final)	2.2 R 22 Y

Table 1 Colour of palm oil and sunflower oil for deep frying and pan frying cycle (initial and final)

The change in colour of both palm oil and sunflower oil for deep and pan frying cycle is shown in table 1. The red colour of the palm oil of deep frying and pan frying increased from 3.3 unit to 4.4 unit and 4.3 unit respectively. While, the yellow colour change from 33 unit to 44 and 43 for deep frying and pan frying respectively. While, the red colour of sunflower oil of deep frying and pan frying increased from 1.3 unit to 1.6 unit and 2.0 unit to 2.2 unit respectively. The yellow colour change from 13 unit to 16 unit and 20 unit to 22 for deep frying and pan frying respectively. The colour of the oil is changes due to presence of unsaturated carbonyl compound., formation of degraded compound of oxygen, non-polar compound of fries leached in frying oil. The colour of both oil sample is increases for deep frying and pan frying process. The colour of the oil is increases due to the Millard reaction (carbohydrate/aldehydes react with amino compounds) occurred during frying process, [5]. The Millard reaction is occurred in fries and the carbon compound is leached out from the fries to the oil which cause the oil become darker.

- *Absorbance*

Type of oil		Position(nm)/Intensity(A)
Palm oil	Deep frying 1st frying 4th frying	 759.97: -0.198 644.17: 0.0026 643.89: - 0.06165
	Pan frying 1st frying 4th frying	 759.67 : -0.03234 647.14: -0.02094 759.90: -0.01003 644.18: 0.005852
Sunflower oil	Deep frying 1st frying 4th frying	 759.96:0.01578 656.52: 0.03461 760.00: 0.02888 647.04: 0.04688
	Pan frying 1st frying 4th frying	 759.72: -0.0209 656.31: -0.01578 759.96: 0.03876 656.31: 0.04375

Table 2 Absorbance of palm oil and sunflower oil for deep frying and pan frying cycle (initial and final)

An absorbance spectra for each frying cycle of palm oil and sunflower oil were collected. The absorbance increase from initial frying to 4th frying cycle for deep and pan frying. This increase was more evident in the region of 640-760 nm which related to colour change in the frying oil as reported by (Sebastian et al, 2014) . The change in colour is due to an accumulation of highly conjugated of oxidation products. There are a few different theories were suggested in the past experiment that explain the colour change of the oil samples. Bansatl et. al, state that browning pigment from the food may dissolve in the frying oil and change the colour of frying oil to be darker [4]. There are another statement that related is certain food products may absorb a few of these colour pigments, thus decrease the colour of the frying oils, [4]. Zhang et.al state that all the change in the spectra during the frying process is cause by the chemical reaction or any reaction that occurred and the substance that may formed or disappeared during the frying process[6].

Chemical characteristics
Free fatty acid

Type of oil		Free fatty acid(FFA)
Palm oil	Deep frying (initial)	0.0974
	Deep frying (final)	0.1486
	Pan frying (initial)	0.1607
	Pan frying (final)	0.1803
Sunflower oil	Deep frying (initial)	0.1529
	Deep frying (final)	0.1687
	Pan frying (initial)	0.3907
	Pan frying (final)	0.4015

Table 3 Free fatty acid (FFA) of palm oil and sunflower oil for deep frying and pan frying (initial and final)

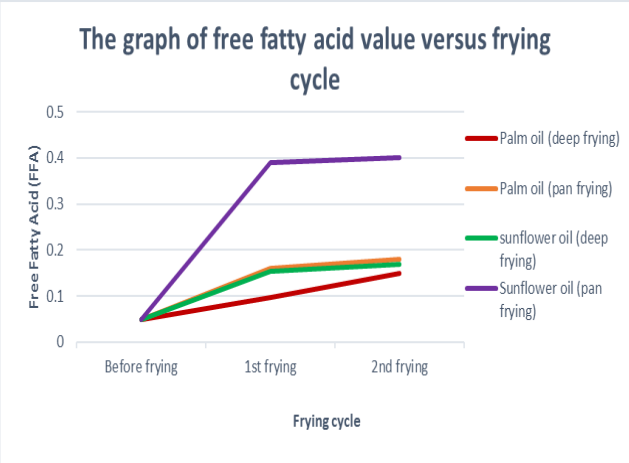

Figure 1 Free fatty acid (FFA) versus frying cycle

Free fatty acid (FFA) content is an indicator of oil quality in food industry as it leads to development of off-flavour in oils and fried products [5]. The FFA value of fats and oil can be used to identify the extent of its deterioration due to hydrolysis of TAG or cleavage and oxidation of fatty acid double bond. FFA value is directly proportional to the frying cycle. If the frying cycle increase the FFA value also increases. Table 4.4 shows the value of FFA of palm oil and sunflower oil of deep frying and pan frying. The result shows that the FFA value of palm oil and sunflower oil of deep frying and pan frying increases as the frying cycle increase. The initial FFA value of palm oil of deep frying and pan frying are 0.0974 and 0.3907 respectively. After the 4th frying cycle (final frying), the FFA value of palm oil of deep frying and pan frying increases to 0.1486 and 0.4015 respectively. From the result, it shows that, the quality of palm oil for deep frying is better compared to pan frying. While, the initial FFA value of sunflower oil of deep frying and pan drying are 0.1529 and 0.1607 respectively. Then, the FFA values of sunflower oil are increase to 0.1687 and 0.1803 for deep frying and pan frying respectively. The FFA value for both oil increase due to the cleavage and oxidation of double bond to form carbonyl compound which oxidized to low molecular weight fatty acid during frying. By comparing FFA value between palm oil and sunflower oil, the worst quality of oil is sunflower oil as the FFA value of sunflower oil after 4th frying is higher compare to palm oil.

Abdulkarim et. al evaluated the frying quality and stability of high-oleic Moringa oleifera seed oil with other vegetable oil which is palm olein(PO), canola oil (CLO) and soybean oil (SBO). The result of an experiment shows the initial FFA value of CLO is lowest (0.10%) followed by MoO(0.17%), PO (0.19%) and SBO(0.22%), [7]. However, at the end of the frying cycle (5 days), the total change in FFA value from initial to final day of frying was found to be lowest in SBO(60%) followed by PO (65.0%) and MoO (66.6%) while the highest percentage of FFA was found in CLO (71.4%). In a similar study, Aladedunye et. Al evaluate the frying stability of high oleic sunflower oils. They said that the frying stability was affected by composition of tocopherol isomers and linoleic acid content [8]. However, the result of an experiment shows that there are no significant difference in FFA value among the three high oleic oils which means that the level of linoleic acid and the tocopherol isomeric composition have no significant influence on the hydrolytic reaction.

Peroxide value

Type of oil		**Result (meq/kg)**
Palm oil	Deep frying (initial)	4.06
	Deep frying (final)	15.30
	Pan frying (initial)	6.94
	Pan frying (final)	11.00
Sunflower oil	Deep frying (initial)	13.23
	Deep frying (final)	23.09
	Pan frying (initial)	13.79
	Pan frying (final)	10.72

Table 4 Peroxide value of palm oil and sunflower oil for deep frying and pan frying (initial and final)

Peroxide values (PV) is the initial reaction product of lipid oxidation or known as primary oxidation. It is measure the extent to which rancidity reaction have occurred. Other than that, it could be used as indication of the quality and stability of fats and oils. Peroxide value may increase with increasing of storage time, temperature and samples oil contact with air. Table 4 shows the initial and final peroxide value of palm oil and sunflower oil. The peroxide value of both oil increase as the frying cycle increase. From the table 4 the peroxide value after 4th frying cycle of palm oil is lower compare to sunflower oil which is 15.03 meq/kg (deep frying) and 11.00 meq/kg (pan frying). While, the final peroxide value of pan frying is lower compared to deep frying. It shows that, the way how fry a food will affect the quality of the oil and the food products. Then, the initial value of peroxide of sunflower oil for deep frying and pan frying shows the almost the same which is 13.23 meq/kg and 13.79 meq/kg respectively. Then, after the 4th frying cycle, the peroxide value of sunflower for deep frying increase to 23.09 meq/kg and for pan frying the peroxide value is decrease to 10.72 meq/kg. initially, an oil will form hydroperoxide compounds which acts as an indicator of lipid oxidation under normal condition. However, when the oil is heated in high temperature it will breaks and form secondary oxidation products. Since the peroxide value of sunflower oil for pan frying is decreases after 4th frying cycle, the oil may undergo a secondary oxidation.

Debnath et al,2012 has done an experiment on effect of frying cycles on physical, chemical and heat transfer quality of rice bran during deep-fat frying of poori. The result of the experiment shows that the peroxide value of rice bran oil (RBO) after heating and frying is increase from 2.2 meq/kg to 3.6 meq/kg and 3.0 meq/kg to 4.0 meq/kg respectively. The peroxide value shows the higher degree of degradation during frying compare to heating only [5]. From this result, it can conclude that the pan frying shows the higher degree of degradation compare to deep frying as the peroxide value of pan frying is higher compare to pan frying.

FTIR analysis

FTIR spectroscopy is an excellent tool for analysis as the intensities of the bands in the spectrum are proportional to concentration , [9]. The characteristics of an edible oil and fats have been identified by using Mid IR because it differ in the intensity and the exact frequency at which the max absorbance or transmittance of the band appears, which depends on to the nature and composition of the sample. From the result, the FTIR spectra of palm oil and sunflower oil shows the difference in the band for repeated pan frying and deep frying. The position of the band was affected by the composition of the oil and yield a shift when the proportion of fatty acids changed.

As the frying cycle is repeat with the same quantities of palm oil and sunflower oil (without any replenishment), the percentage transmittance of almost all the peaks are increases. It may cause by the hydrolysis of an oil during the frying cycle and formation of free fatty acid (FFA) and mono and diglycerides. All these compound is accumulated in the frying oil. Hydroperoxide will be decrease due to the decomposition of hydroperoxide (primary oxidation) and formation secondary oxidation.

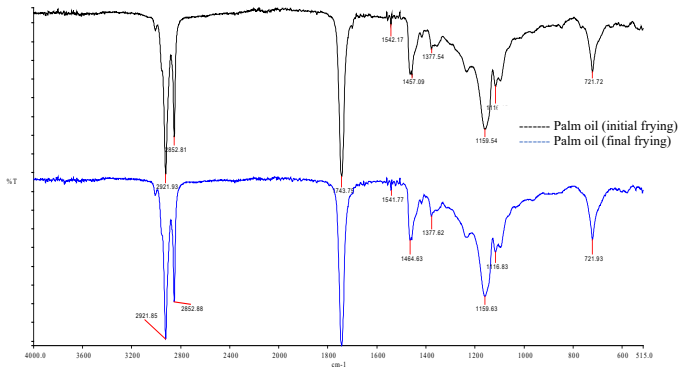

Figure 2 Palm oil in deep fryer (initial and final frying)

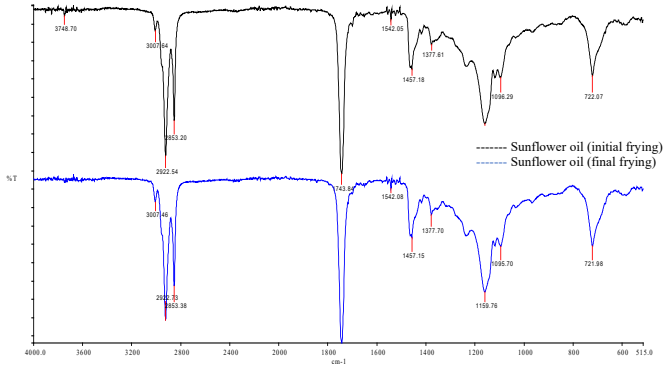

Figure 3 Sunflower oil in deep fryer (initial and final frying)

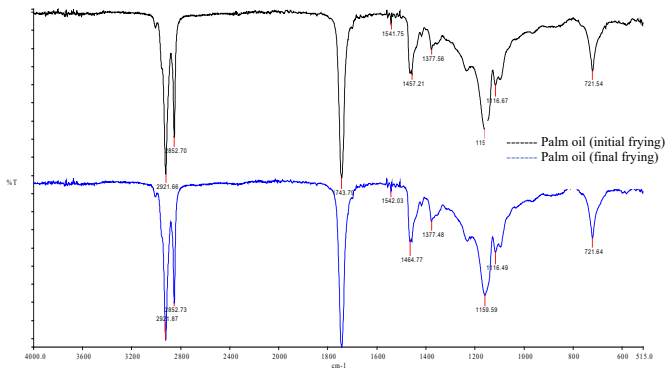

Figure 4 Palm oil in pan frying (initial and final frying)

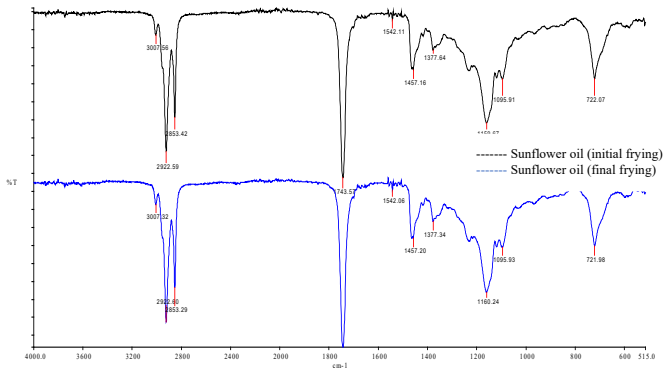

Figure 5 Sunflower oil in pan frying (initial and last)

Each peak of the spectrum shows different functional group. The peaks which located around 3100- 3000 cm^{-1} are C-H stretching vibration of the cis double bond (=C-H). The sunflower oil for both deep and pan frying had a peaks at 3007.64 cm^{-1} to 3007.32 cm^{-1}. But the peak of sunflower for deep fryer is higher compare to pan fryer and the peak is decrease as the frying cycle increase. Then, the peak around 2960 cm^{-1} to 2850 cm^{-1} shows C-H symmetric stretching vibration of the aliphatic CH_2. Both palm oil and sunflower oil shows the peaks in these range and the peaks for deep frying for both oil shows the higher value compare to pan frying. From the FTIR result analysis, the oils shows the peaks around 1743 cm^{-1} which show that there are presence of an ketone or other secondary oxidation products. As the oil undergoes several changes during the oxidation process, the spectra of the oil shows some deformation and bending at 1457 cm^{-1} of C-H_2 and C-H_3 aliphatic group and at 1377 cm^{-1} of C-H bending vibrations of CH_2 groups were observed.

FTIR capability using finger print make a first differentiation and representative finger print (1159-721 cm^{-1}) in the infrared spectra. The major peaks in these spectra that arise from the stretching vibration of C-O at 1159-1095 cm^{-1} and at 721-722 cm^{-1} represent –CH_2, -CH=CH- overlapping the CH_3 rocking and the out-plane vibration of cis disubstituted olefins. The changes in the spectra shows that there are several changes during the oxidation process. Zahir et. Al,2014had done an experiment on Mustard and corn oil and do a FTIR analysis. From the result, each type of oil sample shows very similar FTIR-spectra. However, the height of some peaks indicates a difference quality of the oil.

IV. Conclusion

This experiment is conducted to determine the physical and chemical properties of palm oil and sunflower oil to judge the quality of the oil in repeated frying of fries and to compare the techniques of the frying process by using electric deep fryer and pan fryer. Frying by using same oil for many times is a general practice in cooking process. There are many possible chemical reaction that may be occurred during the frying process. These reactions will cause production of harmful compound such as polymer and ketone which change the quality of the oil. The FTIR analysis shows that the peaks at 1743 cm-1 represents secondary oxidation such as an aldehyde and ketone has been formed. The frying oil will be reused until the color of the oil become darker. There is no specific statement that said how many times the frying oil can be reused. The analysis of the colour for both palm oil and sunflower oil had been performed and the colour for both oil were changes from first frying to 4th frying cycle. As the frying cycle increase the colour of the oil also increase. However, the oil colour of pan frying is darker compare to deep frying process. Basically, the colour of the oil shows the quality of the oil. If the colour is dark the quality of oil is bad. While for FFA analysis, the value of FFA of palm oil is lower compare to sunflower oil. However, the oil that fry by using pan fryer shows a bad performance as the FFA value is higher for both oil. For peroxide value, the sunflower oil shows a higher value for deep frying while for the pan frying the value of PV is decrease. It may due to the formation of secondary oxidation product. The analysis of the oil is performed for 1st frying oil and final frying oil only. It is to compare the quality of an oil from initial frying and final frying process. From the analysis, it can conclude that palm oil shows a better-quality oil compared to sunflower oil. Other than that, electric deep fryer shows a better performance of oil compare to pan fryer.

Acknowledgment

Thank you to my supervisor, Dr. Shariff Abdul Bari Ali to give a support and advise, Sime Darby research, Teluk Panglima Garang to give permission to use an equipment and laboratory to me to complete my experiment, my parents and friends who also give a support.

References

1. Khaled AY, Aziz SA, Rokhani FZ. Capacitive sensor probe to assess frying oil degradation. *Inf Process Agric*. 2015;2(2):142-148. doi:10.1016/j.inpa.2015.07.002.

2. Ramadan, M.F., Afify Amer, M.M., Sulieman Abd El-Rahman M, And. No Title. 2006;(Correlation between physicochemical analysis Affected, radical scavenging activity of vegetable oil blends as by frying of French fries.):Eur. J. Lipid Sci. Technol. 108, 670–678.

3. Paul SR. *Food Engineering*. VOL III. California: Department of Biological and Agricultural Engineering, University of California, Davis, California, USA; 2009.

4. Bansal G, Zhou W, Barlow PJ, Lo HL, Neo FL. Performance of palm olein in repeated deep frying and controlled heating processes. *Food Chem*. 2010;121(2):338-347. doi:10.1016/j.foodchem.2009.12.034.

5. Debnath S, Rastogi NK, Gopala Krishna AG, Lokesh BR. 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*. 2012;90(2):249-256. doi:10.1016/j.fbp.2011.05.001.

6. Zhang W, Li N, Feng Y, Su S, Li T, Liang B. A unique quantitative method of acid value of edible oils and studying the impact of heating on edible oils by UV – Vis spectrometry. 2015;185:326-332. doi:10.1016/j.foodchem.2015.04.005.

7. Abdulkarim SM, Long K, Lai OM, Muhammad SKS, Ghazali HM. Frying quality and stability of high-oleic Moringa oleifera seed oil in comparison with other vegetable oils. *Food Chem*. 2007;105(4):1382-1389. doi:10.1016/j.foodchem.2007.05.013.

8. Aladedunye F, Przybylski R. Frying stability of high oleic sunflower oils as affected by composition of tocopherol isomers and linoleic acid content. *Food Chem*. 2013;141(3):2373-2378. doi:10.1016/j.foodchem.2013.05.061.

9. Zahir E, Saeed R, Hameed MA, Yousuf A. Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier Transform-Infrared (FT-IR) Spectroscopy. *Arab J Chem*. 2014. doi:10.1016/j.arabjc.2014.05.025.