Est. 1984

ORIENTAL JOURNAL OF CHEMISTRY
An International Open Access, Peer Reviewed Research Journal

www.orientjchem.org

ISSN: 0970-020 X
CODEN: OJCHEG
2023, Vol. 39, No.(5):
Pg. 1205-1213

Effect of Frying and Reheating Processes on the Fatty acids and Antioxidants of Commonly Used Cooking oils in the Arabian Region: A Comparative Study

NOHA OMER[1], SUHAIR A. ATTA[2], RASHA JAME[3], FATIMAH A. ALOTAIBI[4], JOZAA. N. AL–TWEHER[5], HATEM A. AL-AOH[6], ZAHRA E. SULIMAN[7], and SYED KHALID MUSTAFA[8]*

[1-5,6-8]Department of Chemistry, Faculty of Science, University of Tabuk, P.O. Box 741,
Zip 71491, Tabuk, Saudi Arabia.
[7]Department of Food Science and Technology, Faculty of Science,
Om-Dorman Islamic University, Sudan.
*Corresponding author E-mail: ssyed@ut.edu.sa

http://dx.doi.org/10.13005/ojc/390513

(Received: July 03, 2023; Accepted: October 02, 2023)

ABSTRACT

Vegetable oils like extra virgin olive oil, *Moringa oleifera* oil, sunflower, and corn oils are regularly used for cooking purposes in the Arabian region. Additionally, the consumption of fried food is becoming increasingly popular in this region. The current study is to find out how temperature affects oils without using food of any kind. The fatty acid and antioxidant profiles of these four vegetable oils (extra virgin olive oil, *Moringa oleifera* oil, sunflower oil, and corn oil) have been investigated in terms of temperature during deep-frying and re-heating. In this process, an electric fryer is used for deep-frying and reheating oil without adding any kind of food. The collected vegetable oil samples were heated for six hours on five different time periods to a temperature of up to 175±5°C, and the fatty acid profiles were analysed before and after each cycle by using gas chromatography and were characterized by means of UV and FTIR techniques as well. The composition of oil fatty acids is more affected by re-heating than by deep-frying, as the results indicated. The antioxidant activity of the different oils was assessed using the diphenyl-1-picrylhydrazyl (DPPH) scan; the findings revealed that, whereas antioxidant activity dropped sharply in re-heated oils, it did so gradually for deep-frying samples.

Keywords: Cooking oils, Fatty acid, Antioxidant, Human's health, High temperatures, Stability.

INTRODUCTION

The use of fat or oil for frying is one of the most popular ways to prepare meals since deep-fried foods are a cornerstone of the diet and are readily available from sellers on the street. Despite the fact that fried foods should be avoided due to their high calorie, cholesterol, and saturated fat content, they are growing in popularity. Vegetable oils are a kind of lipid that frequently comes from seeds but occasionally from other fruit portions. They are widely recognized for being healthy due to their abundance of vital unsaturated fatty acids and other different antioxidant substances. The US Department of Agriculture did an assessment for 2018–2019, and it shows that the output of vegetable oils reached 204.21 million metric tons[1]. In Saudi Arabia, the average person consumes 15.7 kg of fats and oils annually, of which 84 percent are vegetable oils and 15 percent are solid fats (butter, margarine, and ghee). The remaining one percent is made up of unrefined animal fats. Vegetable oils are commonly used to cook meals, but they come with a number of physiological limitations and serious threats to health[2,3].

Numerous reactions, especially thermal oxidation, hydrolysis, and polymerization, occur when vegetable oil is repeatedly cooked at high temperatures in the presence of oxygen and water in food[4-5]. Various volatile and non-volatile chemicals, like hydroperoxides and aldehydes, come up as a result[6-7]. Non-volatile compounds accumulate in the oil, and it is typically polar compounds, in addition to their high molecular weight, that have toxic effects on human health[8]. Many research investigations have provided evidence of the high health risks associated with frequently using vegetable oils for deep frying, with the majority of these concerns being cancer[9-12]. Furthermore, re-heating oil results in a considerable alteration in the physical and chemical characteristics of the oil, which lowers the quality of the oil[4,13]. Many saturated compounds, including high-molecular-weight compounds, hydroperoxides, and many monomers and dimers, are also formed[14]. Vegetable oils include antioxidants that are thought to be naturally resistant to oxidative degradation; nevertheless, frequent usage of vegetable oils at high temperatures can reduce their antioxidant content.

Therefore, the poor antioxidant concentration is unlikely to be sufficient to neutralize the free radicals produced during the heating process[15]. In this case, after the sixth session of frying, the antioxidant activity found in the olive oil extract significantly decreased[16]. After the 12th frying step, the entire loss of antioxidant activity caused by deep-fat frying was noticed[16]. Consuming dishes cooked with warmed oil over an extended period of time may seriously weaken one's antioxidant defense system, which may result in diseases like hypertension[17]. The reduction in antioxidant activity seen in heated virgin olive oil and sunflower oil[18]. Vegetable oils' essential antioxidant levels are used to determine the toxicological consequences of heating them[19]. According to a study by Abdul Hamid *et al.,* repeated heating substantially lowered the effectiveness of antioxidants in palm oil and rice bran oil, and Adam *et al.,* discovered that heating decreased the amount of vitamin E in palm and soy oils. Nzikou *et al.,* also stabilized the oxidative and thermal stability of vegetable oils during frying[20-22].

Therefore, the primary objective of this work was to establish the fatty acid composition of these four vegetable oils after re-heating and deep-frying in order to improve understanding of the oils' quality, stability, and applicability for human nutrition. Since no information is currently available with regard to the effect of temperature alone on fatty acid composition and the antioxidant content of vegetable oils, the intent of this study was to predict the antioxidant activity and oxidative stability of oils during re-heating and deep-frying.

MATERIALS AND METHODS

Materials

Extra virgin olive oil, *Moringa oleifera* oil, sunflower oil, and corn oil were the different kinds of vegetable oils used during the current study. The virgin olive oil came from one of the Jordanian oil presses, while the pure corn and sunflower oils came from the Arab Jordanian oils Company, and the Moringa oleifera oil came from Saudi Arabia. Deep frying was performed, but with a few alterations, as described in[23]. In each experiment, 2 L of oil was placed in an electric fryer (Molineux MAX 1.5 kg, model F51-R, produced in China) and heated to 175°C within 10 minutes. After an hour, 100 g of potatoes (with a cross section of 4 mm and a length of 6 cm) were added to the hot oil and cooked for 5 minutes. Before starting the second round of frying, the oil was heated for an hour. Because the oil could only be used for deep-frying for five days at a time, groups of potatoes were cooked in five cycles for each oil. The oils were exposed to temperatures for a total of 30 hours. The oil was cooled at the end of each day (six hours), and 100 cm^3 was kept at 4°C until the day of the analysis. In preparation for the subsequent test, the fryer was cleaned without removing any remaining gum and topped off with 100 cm^3 of new oil[23].

To evaluate the effect of temperature alone, the same method was carried out on oil samples without the addition of potatoes. Following re-heating, 100 cm^3 of the cooled oil was removed and saved for analysis before 100 cm^3 of new oil was added for the following trial. The process of re-heating the oils using the electric fryer at 175+5°C was used to determine the temperature effect alone on the oils without any food items.

Methods

The modified AOCS Official Method Ti 1a–64 was used to evaluate all frying and re-heating oils at room temperature in triplets for conjugated diene and trine[24]. There were no additional dilutions conducted after the 10 µL of oil sample was diluted in 5 cm^3 of n-hexane. Using a UV Spectrophotometer (Duple Beam) Model UV-1800, the conjugated diene and trine content were measured at 233 and 270 nm, respectively. A Nicolet Impact 400 Fourier Transform Infrared Spectrophotometer (Madison, WI) was used to capture FTIR spectra in the 500–4000 cm^{-1} range. A drop of the oil sample was combined with about 0.2 g of KBr to create KBr discs for liquid samples.

Following FAMEs, a GC analysis of the FA composition was carried out, and 150 mg of oil was mixed with 5.0 mL of KOH at 0.50 mol L^{-1} methanol. After the mixture had been heated under reflux for three minutes, 5.0 mL of BF_3 (14%) was added, and it was heated under reflux once again for three minutes. 3.0 mL of isooctane and about 15.0 mL of saturated sodium chloride were added after cooling, vigorously stirred for 15 seconds, and then phase separated. The upper phase was collected in 2.5 liters and then injected into the gas chromatography system. equipped with a capillary column measuring 20 m by 0.25 mm by 0.25 m, a flame ionization detector (FID), and a programmable temperature vaporizer.

Using the 2,2-Diphenyl-1-picrylhydrazyl technique (DPPH), the ability to neutralize free radicals of several phenolic compounds has been assessed. Free radicals in phenolic compounds have been collected using DPPH, an organic chemical made of stable free radical molecules[25]. The absorbance at 515–517 nm dropped because there were more non-radical forms of DPPH when an electron or hydrogen atom was moved to the odd electron in DPPH[26]. We bought DPPH and Trolox from Sigma-Aldrich in the USA. Using spectrophotometric analysis with DPPH, 100 µL of each oil was combined with 3.9 mL of DPPH solution and incubated at room temperature for an hour in the dark to identify the oils' antioxidant activity (Plank *et al.,* 2012). The mixture's absorbance was then determined at 517 nm using Trolox as a positive control. The following equation, where A0 and A1 represent the absorbance of the blank and sample, respectively, was used to calculate the capacity of the sample to scavenge DPPH radicals.

$$\text{Inhibition\%} = A0–A1/A0\times100$$

Each measurement was made three times, and the results are shown as the average value minus the standard deviation. The significance of the difference between means was assessed using the Tukey's multiple comparison test (SPSS Inc., Chicago, IL, version 21) after the data were submitted to one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Spectroscopic characterization:

The distinctive UV absorption bands of the examined oils have absorptions at 233 nm and 270 nm, respectively, and correspond to the oxidation of mono- and polyunsaturated fatty acids with double bonds[27,4]. The best result was for extra virgin olive oil, which exhibited a highly acceptable level of conjugated diene content even after five cycles of frying. UV data demonstrate that deep-frying oils have acceptable amounts of conjugated dienes. Throughout the frying days, the absorption bands at 233 and 269 nm for all the various oil samples grew from one to five cycles of frying time. All oils increased in conjugated diene content while heated to 175±5°C. Conjugated dienes occurred more quickly in sunflower and maize oils than in extra virgin olive oil, and both of these oils had a higher concentration of conjugated dienes than the latter[28]. Conversely, reheated oil findings compared to deep-frying results of the four vegetable oils showed a high concentration of conjugated diene for all reheated oils even after the first cycle; sunflower produced the poorest results, particularly following five cycles of reheating. Four oils are stable at room temperature since there is no evidence for conjugated triene to be present in these oils. The conjugated triene bands at 269 nm observed in the sunflower and maize oils following three cycles of deep frying are evidence of the high linoleic acid content of these oils. As a result of the high oleic acid concentration, there is no sign of this band in extra virgin olive oil and

Moringa oleifera oil even after five cycles of deep frying. The existence of conjugated trine at 269 nm in addition to conjugated dines was present in all re-heated oils, which is proof that oil components degrade over time in the absence of food[29,13].

The oxidation of various fatty acids that make up oils can potentially be evaluated with the FT-IR spectroscopy instrument. The following spectral areas were seen after heating four vegetable oils at 175±50C for one to five cycles:

1. The emergence of bands at 3400 cm^{-1} and 3600 cm^{-1} suggested the formation of hydroperoxides (OO-H stretching)[30]: the disappearance of the band at 3125 cm^{-1} and the emergence of the band at 3550-3450 cm^{-1} suggested the replacement of the hydrogen on a double bond with some other radical, probably suggesting polymerization.
2. The development of aldehydes, ketones, or acids is indicated by the presence of additional bands at 1744 cm^{-1} of ester C=O stretching. This is consistent with observations provided by Wan Sundara and Shahidi[31].
3. Absorption peaks at band alterations in the range of 1050 to 900 cm^{-1} showed cis and trans isomerization, and
4. Absorption peaks at the appearance of bands at 3300 cm^{-1}, 3600 cm^{-1}, and 1460 cm^{-1} indicated the creation of alcohols and hydrocarbons, respectively.

In several heating cycles, the transmittance % of the majority of peaks got higher, suggesting a reduction in absorption. The cause of this may be the formation of new chemicals and their accumulation during heating and frying, including free fatty acids. The peak of hydroxyl peroxide is decreased by the accumulation in the oil. There is a band at 3007.0 cm^{-1} for maize and sunflower oils, which are the oils with higher amounts of oleic or linoleic acid. However, the larger oleic acid content of *Moringa oleifera* oil and extra virgin olive oil lowers this beak to lower levels about 3004–305 cm^{-1}. All of the FT-IR results of this investigation are in agreement with the findings of a recent study conducted by Zahir *et al.,*[14] and the results for fresh and heated oils likewise revealed identical FT-IR spectra.

Fatty acid decomposition

Fresh sunflower oil and corn oil both had significant amounts of linoleic acid (C18:2), at 58.919 ±1.23% and 55.628±0.54%, respectively, even with *Moringa oleifera* oil and extra virgin olive oil both had significant amounts of oleic acid (C18:1), at 53.230±1.19% and 52.486±0.33%, respectively. It has generally been observed that when the percentage of unsaturated fatty acids rises, the rate of oxidation of warmed oil increases[13]. The findings revealed that all frying oils' fatty acid compositions were significantly broken down ($p<0.05$). In comparison to deep-frying, the re-heating of various oils for one to five cycles accelerated all oils' rate of deterioration. However, the content of fatty acids progressively changed when edible oils were heated to 175±5 for frying. The ratios of saturated and unsaturated fatty acids for extra virgin olive oil, *Moringa oleifera* oil sunflower, and corn oils are shown in Table 1 SFA (27.463±0.55-23.151±0.18, 11.723±0.06-14.959±0.19, 12.287±0.02-18.037±0.07 and 13.602±0.03-14.492±0.13), MUFA (55.296±0.06-63.757±2.48, 52.486±0.12-44.973±0.95, 28.794±0.34-33.903±0.22 and 29.642±0.10 -30.635±0.04), and for PUFA (17.242±0.08-13.452±0.06, 36.367±0.05-39.458±0.14, 59.298±0.34-45.896±0.84 and 56.429±021-54.024±0.13)) respectively.

The findings from the re-heated process at the same conditions pointed to the decomposition of fatty acids decreasing sharply, the ratio of fatty acids was for Extra virgin olive oil, *Moringa oleifera* oil, Sunflower oil and Corn oil as the following; SFA (27.463±0.55-1.966±0.01, 11.723±0.06-3.842±0.01, 12.287±0.02 -3.553±0.11 and 13.154±0.03-3.545±0.08) MUFA (55.296±0.33-5.319±0.06, 52.486±0.12-12.912±0.05, 28.794±0.11-12.065±0.22 and 29.642±0.10-6.223±0.12), and PUFA (17.242±0.15-0.631±0.01, 36.367±0.05-0.00±0.00, 59.298±0.34-1.291±0.02 and 56.429±0.34-1.234±0.01)) (Can be seen in the Table 2.

In literature, the ratio of PUFA to SFA is frequently employed as a measure of how much oil has deteriorated. According to Alireza *et al.,* and Shahidi and Wan Sundara[31-32], linoleic and linolenic acids oxidize to SFA rapidly while SFA chains oxidize very slowly, which explains why the percentage of fatty acids in four vegetable oils decreased with increased heat time.

According to Park and Kim and Ali *et al.,*[33-34], double bonds are broken as a result of oxidation, cyclization, and polymerization processes, which causes the value of MUFA in frying oils to increase with increased heat time in vegetable oils. According to Boskou and Elmadfa[35], the process of desaturation happens via the insertion of a cis double bond between carbons 9 and 10, and MUFA (oleic acid) is also created by the desaturation of saturated fatty acids like stearic acid (C18:0).

All fatty acid levels drastically reduced throughout reheating cycles as a result of the influence of high temperatures in the absence of meals. The term "increasing" and "decreasing" of fatty acid composition during reheating and frying might refer to a variety of products created during the thermal oxidation of oil from the breakdown of hydroperoxides, including volatile and non-volatile molecules. Aldehydes, ketones, short-chain hydrocarbons, lactones, alcohols, and esters are examples of volatiles that are formed along with dimeric, polymeric, and cyclic compounds[8,23,4,5] and nonvolatile oxidized derivatives. The results of the present investigation support the findings of Romano *et al.,*[36] that heated oils thermally deteriorate more quickly than frying oils. No re-heating of oil has decreased significantly ($p>0.05$) in any way. After reheating and frying, several fatty acid fragments are found, although these fragments are not observable.

Table 1: Fatty acid decomposition of frying oils at different frying periods

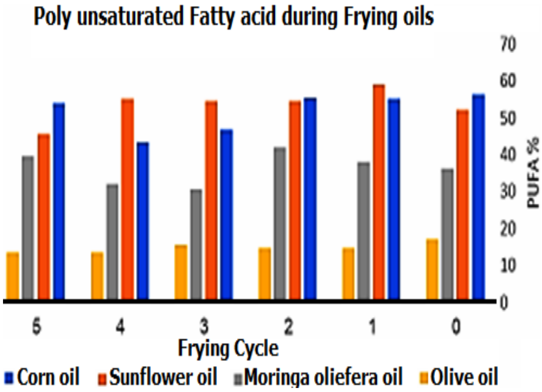
Vegetable oil	Deep fraying cycle	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C22:0	SFA	MUFA	PUFA
Olive oil	0	25.128 ±0.001	2.066 ±0.01	2.335 ±0.07	53.23 ±1.19	16.573 ±0.05	0.669 ±0.07	0.000 ±0.00	0.000 ±0.00	27.463 ±0. 55	55.296 ±0.06	17.242 ±0.08
	1	6.217 ±0.06	0.868 ±0.01	2.233 ±0.01	31.37 ±1.27	8.947 ±1.01	5.808 ±0.11	1.311 ±0.22	0.933 ±0.02	10.791 ±0. 49	32.238 ±1.21	14.755 ±0.11
	2	16.863 ±0.061	1.045 ±0.03	3.170 ±0.02	62.12 ±5.21	14.415 ±0.08	0.431 ±0.01	0.935 ±0.05	0.000 ±0.00	20.968 ±0.161	63.165 ±2.13	14.846 ±0.10
	3	23.52 ±0.061	1.869 ±0.01	2.28 ±0.04	54.959 ±1.17	15.244 ±0.11	0.507 ±0.08	0.335 ±0.8	0.000 ±0.00	26.135 ±0.32	56.828 ±0.36	15.751 ±0.55
	4	28.649 ±0.06	2.276 ±0.03	2.388 ±0.10	53.289 ±1.34	13.017 ±0.12	0.381 ±0.01	0.000 ±0.00	0.000 ±0.00	31.037 ±0. 21	55.565 ±0.08	13.398 ±0.32
	5	18.633 ±0.06	1.197±0.01 1	3.564 ±0.10	62.56 ±3.11	13.452 ±0.89	0.000 ±0.00	0.954 ±0.01	0.000 ±0.00	23.151 ±0.18	63.757 ±2.48	13.452 ±0.06
Moringa oleifera oil	0	6.516 ±0.04	0.000 ±0.00	4.151 ±0.02	52.486 ±0.33	35.791 ±0.07	0.576 ±0.01	0.000 ±0.00	1.056 ±0.02	11.723 ±0.06	52.486 ±0.12	36.367 ±0.05
	1	6.638 ±0.09	0.144 ±0.006	0.611 ±0.05	51.26 ±0.21	38.000 ±0.57	0.11 ±0.01	0.29 ±0.01	0.924 ±0.06	8.463 ±0.107	51.404 ±0.06	38.11 ±0. 49
	2	7.483 ±0.09	0.148 ±0.002	0.148 ±0.05	47.88 ±0.08	41.748 ±0.550	0.138 ±0.03	0.35 ±0.03	1.010 ±0.01	8.995 ±0.100	48.028 ±0.11	41.886 ±0.100
	3	11.63 ±0. 51	0.000 ±0.00	2.775 ±0.01	54.208 ±0.15	29.918 ±0.10	0.737 ±0.02	0.345 ±0.01	0.383 ±0.03	15.137 ±0.12	54.208 ±0.15	30.655 ±0.16
	4	9.831 ± 0. 48	0.000 ±0.00	4.477 ±.055	53.513 ±1.70	32.179 ±0.57	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	14.308 ±0.0 6	53.513 ±1.70	32.179 ±0.57
	5	9.279 ±0.13	0.000 ±0.00	4.786 ±0. 51	44.973 ±0. 95	39.458 ±0.14	0.000 ±0.00	0.000 ±0.00	0.894 ±0.01	14.959 ±0.19	44.973 ± 0.95	39.458 ±0.14
Sunflower oil	0	7.299 ±0.10	0.000 ±0.00	3.906 ±0.01	28.794 ±0.07	58.919 ±1.23	0.379 ±0.06	0.000 ±0.00	1.082 ±0.03	12.287 ±0.02	28.794 ±0.11	59.298 ±0.34
	1	6.446 ±0.04	0.000 ±0.00	4.662 ±0.03	29.522 ±0.77	51.827 ±0.76	0.301 ±0.01	0.410± 0.02	1.26 ±0.03	12.778 ±0.04	29.856 ±0.67	52.128 ±0.22
	2	10.97 ±0.12	0.161 ±0.01	3.088 ±0.01	25.526 ±1.14	54.822 ±0.54	0.259 ±0.01	0.000 ±0.00	0.000 ±0.00	14.219 ±0.17	25.526 ±0.04	55.081 ±0.78
	3	14.08 ±0.11	0.000 ±0.00`	3.143 ±0.01	27.024 ±0.89	54.459 ±0.45	0.003 ±0.01	0.000 ±0.00	0.000 ±0.00	17.223 ±0.05	27.185 ±0.49	54.462 ±0.55
	4	9.04 ±0.08	0.000 ±0.00	3.934 ±0.06	29.289 ±0.07	54.284 ±0.33	0.000 ±0.00	0.68 ±0.02	0.765 ±0.01	14.419 ±0.43	29.289 ±0.07	54.284 ±0.33
	5	8.88 ±0.12	0.000 ±0.00	6.498 ±0.11	33.903 ±10.02	45.896 ±0.12	0.000 ±0.00	0.626 ±0.08	2.033 ±0.02	18.037 ±0.07	33.903 ±0.22	45.896 ±0.84
Corn Oil	0	10.107 ±0.10	0.000 ±0.00	2.684 ±0.06	29.642 ±0. 55	55.628 ±0. 54	0.801 ±0.03	0.363 ±0.11	0.448 ±0.04	13.602 ±0.03	29.642 ±0.10	56.429 ±021
	1	12.354 ±0.06	0.000 ±0.00	2.674 ±0.001	29.837 ±0.12	54.348 ±0. 48	0.787 ±0.06	0.304 ±0.01	0.342 ±0.01	15.37 ±0.11	29.837 ±0.11	55.135 ±0.18
	2	11.689 ±0.10	0.000 ±0.00	2.546 ±0.05	29.263 ±0.55	54.779 ±0.27	0.775 ±0.02	0.303 ±0.03	0.342 ±0.11	15.417 ±0.06	29.263 ±0.21	55.554 ±0.08
	3	8.889 ±0.21	0.000 ±0.00	4.57 ±0.13	38.333 ±0.61	46.867 ±0.21	0.000 ±0.00	0.312 ±0.00	0.879 ±0.01	13.98 ±0.19	38.333 ±0.09	46.867 ±0.03
	4	10.434 ±0.08	0.000 ±0.00	1.917 ±0.01	31.53 ±0.12	42.388 ±0.19	1.188 ±0.01	0.835 ±0.01	0.521 ±0.02	12.821 ±0.08	31.53 ±0.17	43.576 ±0.11
	5	10.806 ±0.11	0.000 ±0.00	2.879 ±0.02	30.635 ±0.18	53.395 ±1.02	0.729 ±0.04	0.388 ±0.01	0.475 ±0.03	14.492 ±0.13	30.635 ±0.04	54.024 ±0.13

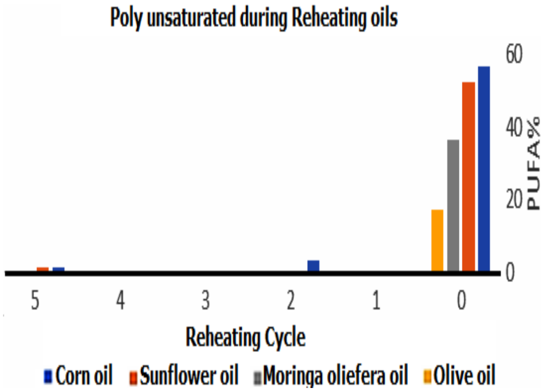
C16:0, Palmitic acid; C18:0, Stearic acid; C16:1, Palmitoleic acid; C18:1, Oleic acid; C18:2, Linoleic acid; C18:3, linolenic acid, eicosonoic, C20:0, SFA-saturated fatty acids, MUFA-monounsaturated fatty acids, PUFA-polyunsaturated fatty acids, Values are mean±S.D (n= 3) at $p<0.05$

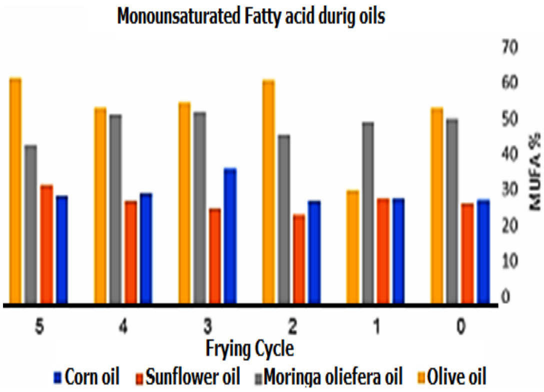
Table 2: Fatty acid decomposition of re-heating oils at different heating periods

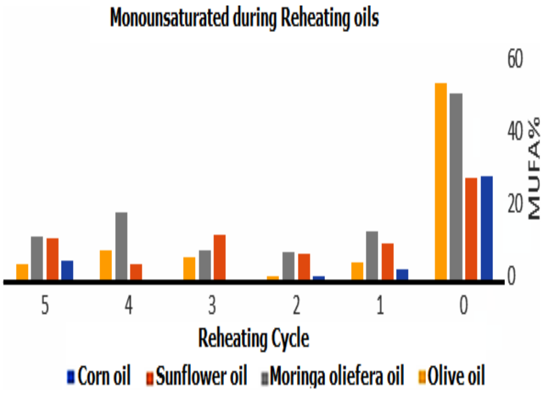
Vegetable oil	Re-heating cycle	C16:0	C16:1	C18:0	C18:1	C18:2	C 18:03	C 20:00	C20:1	C22:0	C 22:01	SFA	MUFA	PUFA
Olive oil	0	25.128 ±0.21	2.066 ±0.01	2.335 ±0.01	53.23 ±0.11	16.573 ±0.11	0.669 ±0.01	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	27.463 ±0.21	55.296 ±0.33	17.242 ±0.15
	1	0.000 ±0.00	5.339 ±0.02	0.000 ±0.00	0.000 ±0.00	0.298 ±0.02	0.000 ±0.00	0.000 ±0.00	0.060 ±0.01	0.090 ±0.01	0.000 ±0.00	0.09 ±0.01	5.399 ±0.02	0.298 ±0.02
	2	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	1.25 ±0.04	0.317 ±0.01	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	1.353 ±0.01	0.737 ±0.01	1.353 ±0.04	1.987 ±0.03	0.317 ±0.01
	3	0.000 ±0.00	4.975 ±0.01	0.000 ±0.00	0.052 ±0.01	0.036 ±0.10	0.000 ±0.00	0.064 ±0.03	0.521 ±0.04	0.391 ±0.02	1.591 ±0.11	0.455 ±0.06	7.139 ±0.12	0.036 ±0.10
	4	0.000 ±0.00	0.724 ±0.02	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	8.100 ±0.10	0.000 ±0.00	8.824 ±0.04	0.000 ±0.00
	5	0.000 ±0.00	0.768 ±0.01	0.289 ±0.03	0.288 ±0.11	0.631 ±0.01	0.000 ±0.00	0.475 ±0.03	1.966 ±0.05	1.202 ±0.05	2.297 ±0.01	1.966 ±0.01	5.319 ±0.06	0.631 ±0.01
Moringa oleifera oil	0	6.516 ±0.04	0.000 ±0.00	4.151 ±0.02	52.486 ±0.33	35.791 ±0.07	0.576 ±0.01	0.000 ±0.00	0.000 ±0.00	1.056 ±0.02	0.000 ±0.00	11.723 ±0.06	52.486 ±0.12	36.367 ±0.05
	1	1.373 ±0.11	0.324 ±0.05	1.181 ±0.01	13.405 ±0.22	0.000 ±0.00	0.000 ±0.00	0.627 ±0.03	0.000 ±0.00	0.822 ±0.01	0.365 ±0.01	4.003 ±0.03	14.094 ±0.06	0.000 ±0.00
	2	0.908 ±0.01	0.268 ±0.02	6.632 ±0.02	7.253 ±0.11	0.317 ±0.01	0.000 ±0.00	0.681 ±0.01	1.116 ±0.01	2.211 ±0.02	0.000 ±0.00	10.432 ±0.11	8.637 ±0.03	0.317 ±0.02
	3	1.077 ±0.02	0.104 ±0.01	0.832 ±0.05	8.871 ±0.02	0.000 ±0.00	0.000 ±0.00	0.437 ±0.02	0.157 ±0.02	0.855 ±0.03	0.000 ±0.00	3.201 ±0.02	9.132 ±0.02	0.000 ±0.00
	4	2.376 ±0.014	0.000 ±0.00	1.483 ±0.11	18.049 ±0.07	0.000 ±0.00	0.000 ±0.00	0.000 ±0.01	1.424 ±0.04	0.029 ±0.01	0.000 ±0.00	3.888 ±0.03	19.473 ±0. 11	0.000 ±0.00
	5	1.918 ±0.02	0.31 ±0.01	1.404 ±0.01	12.602 ±0.11	0.000 ±0.00	0.000 ±0.00	0.52 ±0.01	0.000 ±0.00	0.691 ±0.02	0.000 ±0.00	3.842 ±0.01	12.912 ±0.05	0.000 ±0.00
Sunflower oil	0	7.299 ±0.15	0.000 ±0.00	3.906 ±0.02	28.794 ±0.08	51.827 ±0.13	0.259 ±0.01	0.000 ±0.00	0.000 ±0.00	1.082 ±0.01	0.000 ±0.00	12.287 ±0.22	28.794 ±0.34	59.298 ±0.34
	1	2.429 ±0.05	0.029 ±0.01	0.000 ±0.00	10.534 ±0.11	0.093 ±0.01	0.000 ±0.00	0.076 ±0.03	0.000 ±0.00	0.073 ±0.01	0.097 ±0.01	2.607 ±0.02	10.66 ±0.33	0.093 ± 0.01
	2	2.671 ±0.04	0.000 ±0.00	0.000 ±0.00	8.114 ±0.12	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	2.671 ±0.04	8.114 ±0.12	0.000 ±0.00
	3	3.833 ±0.05	0.000 ±0.00	1.781 ±0.06	13.043 ±0.33	0.222 ±0.02	0.000 ±0.00	0.287 ±0.03	0.000 ±0.00	0.484 ±0.01	0.347 ±0.03	6.385 ±0.11	13.39 ±0.22	0.222 ±0.02
	4	0.362 ±0.01	0.563 ±0.04	0.563 ±0.02	4.450 ±0.03	0.058 ±0.01	0.000 ±0.00	0.066 ±0.01	0.030 ±0.01	0.071 ±0.01	0.057 ±0.01	1.1.062 ±0.05	5.1 ±0.02	0.058 ±0.01
	5	0.832 ±0.02	0.000 ±0.00	0.853 ±0.04	4.949 ±0.06	1.234 ±0.04	0.000 ±0.00	0.755 ±0.01	1.374 ±0.11	1.966 ±0.05	5.742 ±0.02	3.553 ±0.11	12.065 ±0.22	1.291 ±0.02
Corn Oil	0	10.107 ±0.02	0.000 ±0.00	2.684 ±0.01	29.642 ±0.01	55.628 ±0.34	0.801 ±0.02	0.363 ±0.01	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	13.154 ±0.15	29.642 ±0.12	56.429 ±0.34
	1	0.000 ±0.00	2.948 ±0.01	0.000 ±0.00	0.323 ±0.01	0.298 ±0.03	0.000 ±0.00	0.000 ±0.00	0.333 ±0.03	0.520 ±0.05	0.000 ±0.00	0.52 ±0.05	3.604 ±0.11	0.298 ±0.03
	2	0.454 ±0.07	0.000 ±0.00	0.216 ±0.01	1.632 ±0.03	0.023 ±0.01	0.000 ±0.00	0.025 ±0.01	0.022 ±0.01	0.079 ±0.05	0.035 ±0.01	0.558 ±0.02	1.689 ±0.01	3.242 ±0.13
	3	0.000 ±0.00	2.703 ±0.07	0.000 ±0.00	0.000 ±0.00	0.401 ±0.03	0.000 ±0.00	0.15 ±0.07	0.241 ±0.01	0.202 ±0.07	0.000 ±0.00	3.055 ±0.11	0.241 ±0.01	0.401 ±0.03
	4	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.000 ±0.00	0.496 ±0.03	0.000 ±0.00	0.000 ±0.00	0.054 ±0.07	0.506 ±0.01	0.000 ±0.00	0.506 ±0.01	0.054 ±0.07	0.496 ±0.03
	5	0.824 ±0.07	0.000 ±0.00	0.000 ±0.00	4.949 ±0.07	1.234 ±0.01	0.000 ±0.00	0.755 ±0.01	1.274 ±0.08	1.966 ±0.06	0.000 ±0.00	3.545 ±0.08	6.223 ±0.12	1.234 ±0.01

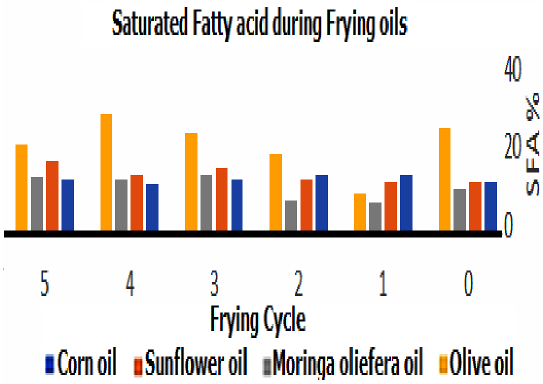
C16:0, Palmitic acid; C18:0, Stearic acid; ; C16:1, Palmitoleic acid; C18:1, Oleic acid; C18:2, Linoleic acid; C18:3, linolenic acid, Eicosonoic, C20:0, SFA-saturated fatty acids, MUFA-monounsaturated fatty acids, PUFA-polyunsaturated fatty acids, Values are mean±S.D (n= 3) at $p<0.05$

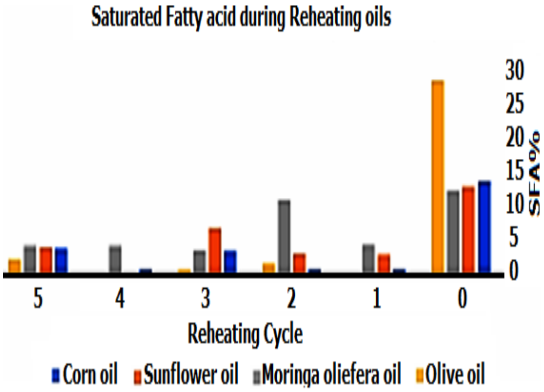












Changes in antioxidant activity during Frying and Reheated oils

The results showed that the antioxidant activity of the studied oils decreased significantly with increased frying time. Among all the studied oils, the best findings towards deep frying conditions were in corn oil, whereas the value decreased clearly from 80.656±0.50% to 8.169±0.240% for sunflower oil, and this may be due to the degradation of biologically active compounds as the result of the exposure to high temperatures. This lowering is attributed to the destruction of antioxidant compounds during the frying process. The same results were obtained by Gomez-Alonso *et al.,* and Abdul Hamid *et al.,*[16,20].

When a lengthy frying duration was employed for several consecutive frying sessions as compared to when various frying conditions were used, the effect on the antioxidant activity in all of the vegetable oils used for the experiment was more noticeable. The antioxidant activity results for the four frying oils. The value changed from 83.217±0.001 to 26.224±0.006 for corn oil, and from 62.694±0.026 to 6.883±0.015 for Extra virgin olive oil, and from 58.755±0.047 to 5.699±0.006 for *Moringa oleifera* oil, whereas the value decreased sharply from 80.656±0.50% to 8.169±0.240 for sunflower oil. The best finding occurred in the corn oil case.

Table 3: The antioxidant activities during frying process [Using five cycles in 30 hours]

Deep fraying time	Olive oil	*Moringa oleifera* oil	sunflower oil	corn oil
0 h	62.694±0.026	58.755±0.047	80.656±0.050	83.217±0.001
6 h	25.265±0.009	43.385±0.014	33.851±0.006	79.545±0.006
12 h	19.970±0.006	26.943±0.006	13.817±0.002	57.867±0.006
18 h	12.859±0.013	16.148±0.006	12.254±0.005	56.469±0.006
24 h	8.472±0.014	9.326±0.005	12.103±0.006	55.594±0.020
30 h	6.883±0.015	5.699±0.006	8.169±0.240	26.224±0.006

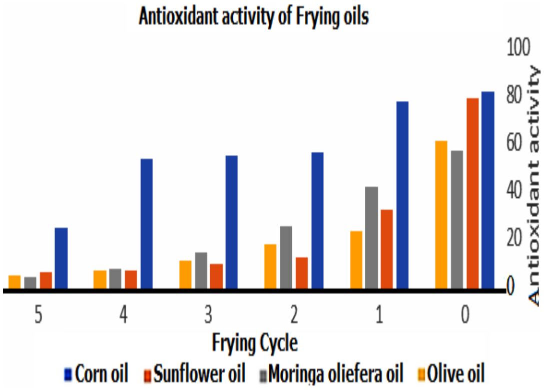
Antioxidant Activity, DPPH oil assay, one-way ANOVA experiment where unheated and Deep fraying oils are considered Mean values within each column followed by different oils (Extra virgin olive oil, *Moringa oleifera* oil, Sunflower and Corn) are significantly ($P<0.05$) different. (Mean=34.006, stander deviation=26.136)

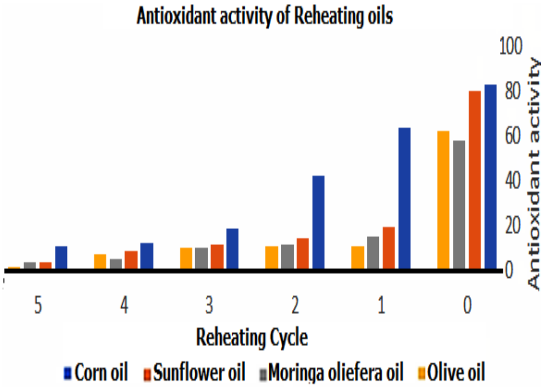
Table 4: The antioxidant activities during re-heating process [Using five cycles in 30 hours]

Re-heating time	Olive oil	*Moringa oleifera* oil	sunflower oil	corn oil
0 h	62.694±0.026	58.755±0.047	80.656±0.050	83.217±0.001
6 h	11.226±0.011	15.371±0.043	19.894±0.053	64.221±0.006
12 h	10.881±0.020	11.572± 0.023	14.523±0.010	42.436±0.006
18 h	10.708±0.031	10.363±0.033	11.744±0.049	19.062±0.006
24 h	7.772±0.055	5.643±0.025	8.808±0.007	12.557±0.006
30 h	1.900±0.023	3.972±0.011	4.145±0.005	11.195±0.006

Antioxidant Activity, DPPH oil assay, one-way ANOVA experiment where unheated and re-heated oils are considered Mean values within each column followed by different heating oils (Extra virgin olive oil, Moringa oleifera oil, sunflower and corn) are significantly ($P<0.05$) different. (mean= 24.305, stander deviation=25.533.

The effect on the antioxidant activity in all of the vegetable oils applied for the experiment was more pronounced when a long reheating time was used for numerous consecutive reheating sessions as compared to when different reheating conditions were used. The antioxidant activity results for the four re-heated oils. The value changed from 83.217±0.001 to 11.195±0.006 for corn oil, and from 62.694±0.026 to 1.900±0. 023% for Extra virgin olive oil, and from 58.755±0.047 to 3.972±0.011 for *Moringa oleifera* oil, whereas the value decreased sharply from 80.656±0.50% to 4.145±0.005% for sunflower oil. The best finding occurred in the corn oil case.





The antioxidant activities during the frying process of the four oils are presented in Table 3. The highest value was found in unheated corn oil and in sunflower oil compared with Extra virgin olive oil, *Moringa oleifera* oil, and this is probably due to the higher presence of tocopherol content in sunflower and corn oils[37-38]. The results are in agreement with a study done by Kalantzakis *et al.,* and GIUFFRÈ *et al.,*[39-40]. The overall findings of this study indicate that the various vegetable oils used for deep-frying or reheating lower antioxidant activity, but more research is required to determine the mechanism underlying the decline.

CONCLUSION

The outcomes of the current investigation show that the chemical properties and antioxidant activity of oils changed significantly with heat time during frying and re-heating. This study also demonstrated that the antioxidant activity of the tested oils decreased noticeably over the course of deep-frying. The corn oil case showed the highest antioxidant activity, indicating good stability at high temperatures, whereas the Extra virgin olive oil value was only marginally higher than sunflower oil. As a result, we advised using corn oil for frying in homes and restaurants. The value significantly decreased throughout the re-heating process as compared to the frying, indicating the important role that temperature plays when there is no food present. The maize oil example showed the greatest results among all four re-heated oils after five rounds of re-heating.

ACKNOWLEDGEMENT

The authors would like to convey their gratitude to the Department of Chemistry, Faculty of Science, University of Tabuk, Saudi Arabia, and acknowledge the financial support from the Deanship of Scientific Research (DSR), University of Tabuk, Tabuk, Saudi Arabia, under grant no. S-1437-0151.

Conflict of interest

The author declare that we have no conflict of interest.

REFERENCES

1. United States Department of Agriculture, **2019**. Table 3: Major Vegetable Oils: World Supply and Distribution (Commodity View). [http://www.fas.usda.gov/ oilseeds/Current/].
2. Juarez, M.D.; Masson, L.; and Samman, N, *Grasas Aceites*., **2005**, *56*, 53–58.
3. Leclercq, S.; Milol, C.; Reineccius, G.A, *Flavour Frag*., **2008**, *23*, 333–339.
4. Choe, E.; Min D. *J Food Sci*., **2007**, *72*(5), 77–R86.
5. Omer, N.M.A.; El Mugdad A., A., Mariod, A. A and Mohammed, M. *Journal of Natural and Medical Sciences*., **2014**, *16*(1), 1-17.
6. Aladedunye, F.; R. Przybylski. R, *Food Chem.,* **2013**, *141*, 2373–2378.
7. Zhang, Q.; Saleh, S.A; Chen, J.; Shen, Q, *Chem Phys Lipids*., **2012**, *165*, 662-681.
8. Abdulkarim, M.S.; Long,K.; Lai, M.O.; Muhammad, S.K.; Ghazali, M.H, *Food Chem*., **2007**, *105*, 1382–1389.
9. Soriguer, F.; Rojo-Martínez, G.; Dobarganes, M.C.; Almeida, M.J.; Esteva, I.; Beltrán, M; Adana, S. M.; Tinahones, F; Gómez-Zumaquero, M.J;García-Fuentes, E.; González-Romero, S, *Am J Clin Nutr*., **2003**, *78*, 1092-1097.
10. Farag, S.R.; Abdel-Latif, S.M.; Basuny, M.M.A.; Abdel-Hakeem, S.B, *Agric Biol J N Am*., **2010**, *1*, 501-509.
11. Eshak, G.M.; Ghaly, I.; Khalil, K.B.W.; Farag, M.I.; Ghanem, Z.K, *J Am Sci*., **2010**, *6*, 175-188.
12. Corbett, P, *Inform*., **2003**, *14*, 480–481.
13. Pineda, M.; Ferrer-Mairal, A.; Vercet,A.; Yagu, C, CyTA-*Journal of Food*., **2011**, *9*(4), 301–306.
14. Zahir, E.; Saeed, R.; Abdul Hameed, M.; Yousuf, A, *Arabian Journal of Chemistry*., **2014**, *51*, 1-7.
15. Choe, E.; Min, B. D. *Compr Rev Food Sci F.*, **2009**, *8*(4), 345–358.
16. Gomez-Alonso, S.; Fregapane, G.; Salvador, D.M, *J. Agric. Food Chem*., **2003**, *51*, 667–672.
17. Leong, X.F.; Ng, C.Y.; Jaarin, K.; Mustafa, R.M, *Austin J Pharmacol Ther.,* **2015**, *3*(2), 1–7.
18. Andrikopoulos, K.N.; Dedoussis, G.; Falirea, A.; Kalogeropoulos, N.; Hatzinikola, H, *Int J Food Sci Nutr*., **2002**, *53*, 351-363.
19. Evuen, U.F.; Apiamu, A.; Ugbeni, O. C, *Int J Eng Res Tech*., **2013**, *2*(3), 1-6.
20. Abdul Hamid, A.; Dek, S, P. M.; Tan, P, C.; Zainudin, A, M, M.; Fang, K, W, E, *Antioxidants.,* **2014**, *3*, 502-515.
21. Adarnt, K.S.; Sulaimanr, A.N.; Top, M.; Gapor, A, *Malays J Biochem Mol Biol*., **2007**, *15*, 76-79.
22. Nzikou, M.J.; Mato, L.; Moussounga, E.J; Ndangui, B. C.; Pamboutobi, P.N.; Bandzouz, M.E.; Kimbonguila, A.; Linder, M.; Desobry, S, *Res. J. Appl. Sci*., **2009**, *4*, 94–100.
23. Mariod, A.A.; Malthaus, B.; Eichner, K.; Hussein, H. I, *Journal of the American Oil Chemists Societ*., **2006**, *83*, 529–530.
24. A.O.A.C. 1980, Methods Ca Sa-40, Cc 9a-48, Cd 8-53, and Ti la-64. In Official and tentative Methods.3rd edition. Champaign,IL,: AOCS.
25. Lee, Y.L.; Huang, G.W.; Liang, Z.C.; Mau, J, *LWT-Food Sci. Technol*., **2007**, *40*, 823–833.
26. Ancerewicz, J.; Miglavaca, E.; Carrupt, P. A.; Testa, B.; Bree, F.; Zinin, R.; Tillement, J. P.; Labidelle, P.; Goyot, S.D.; Chauvet-Monges, A.M.; Crevent, A.; Le Ridant, A, *Free Rad. Biol. Med*., **1998**, *25*, 113–120.
27. Farmer, E, H., Sutton, D. A., *Journal of Agriculture. Food Chemistry*., **2002**, *51*, 623-627.
28. Farhoosh, R.L.; Tavassoli-Kafrani, M.H, *Food Chemistry*., **2011**, *125*, 209–213.
29. Smith SA, King RE, Min DB. *Food Chemistry*., **2007,** *1*;*102*(4), 1208-1213.
30. Nayak, K, P.; Dash, U.; Rayaguru, K.; Krishnan, R.K, *Journal of Food Biochemistry*., **2007**, *103*, 1494–1501.
31. Shahidi F, Wanasundara UN. *Chemistry, Nutrition and Biotechnology*., **2002**, *17*, 387-403.
32. Alireza S, Tan CP, Hamed M, Che Man YB. *International food Research Journal*., **2010**, *17*(2), 295-302.
33. Park JM, Kim J M. *Korean Journal for Food Science of Animal Resources*., **2016**, *36*(5), 612.
34. Ali MA, Islam MA, Othman NH, Noor AM. *Journal of Food Science and Technology*., **2017**, *1*;*54*(13), 4335- 4343.
35. Boskou D, Elmadfa I. CRC press; **2016** Apr 19. second edition.
36. Romano, R., Giordano, A., Vitiello, S., Grottaglie, L, L., Musso, S, S., *Journal of Food Science*., **2012**, *77*(5), 519-531.
37. Schwartz H, Ollilainen V, Piironen V, Lampi AM. *Journal of Food Composition and Analysis*., **2008**, *1*;*21*(2), 152- 161.
38. Xiang, Yi.; Tan1, Y, X.; Nithyanandam, R.; 2ndEURECA–Antioxidant Potential of Edible Oils in Malaysia., **2014**.
39. Kalantzakis, G.; Blekas, G.; Pegklidou K. Boskou D. *Eur. J. Lipid Sci*., **2006**, *108*, 329.
40. Giuffre, A. M, Caracciolo, M., Zappia,C, M., Capocasale, M., Poianam M. *J. Food Sci*., **2018**, *30*, 17-739.