

IMPROVEMENT OF THE SUNFLOWER OIL STABILITY BY BLENDING WITH MORINGA OR SESAME OILS

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ABSTRACT

Vegetable oils can be adjusted by different methods to enhance their commercial applications and to increase their pure quality nutrition. One of the most leisurely ways of creating new innovative products with desirable textured and oxidative properties is the mixing of vegetable fats/oils of various properties. Pure sunflower (SFO) blended with pure moringa (MOO) and sesame (SEO) oils in the ratio of 95:5 and 90:10 w/w. The outcomes showed that the highest acid value was observed at SFO + SEO 10% (0.782). Sunflower oil stabilized when blended with MOO and the levels of conjugated dienes (CD) and trienes (CT) were depressed compared to control. The TPC value was higher when the sunflower blended with moringa oil. The highest scavenging activity percentage was observed in SFO + MOO 5% and SFO + SEO 10% respectively. Meanwhile, the highest induction period at 100 °C was 11.45 hours in the treatment of SFO + MOO 5%. The master fatty acids in the sunflower and moringa oils are combined (SFO:MOO, 90:10), oleic, and palmitic acids. It seems from the current findings that suitable mixing of high linoleic oils with MOO will result in oil mixtures that can satisfy nutritional wants with expanded balance for home cooking and deep-frying.

Keywords: antioxidant; moringa oil; oxidative stability; sesame oil; sunflower oil

INTRODUCTION

External conditions, such as air, light, and temperature, speed up oxidative reactions which may afford up in the development of off-flavors and odors related to volatiles low molecular weight, discoloration. Lipid oxidation is one of the culprits of degradation in fat and oils, contributing to the improvement of off-flavors' and bad flavors, resulting in decreased shelf-life. Oxidative oxidation is a significant financial problem in the food industry meals industry due to the fact it influences many first-class traits such as taste, color, appearance, and nutritional value of foods. It also yields highly harmful compounds (Sikwese and Duodu, 2007). Hydroperoxides are the principal metabolites of lipid oxidation and are commonly referred to as peroxides. A part from that, the dedication of the peroxide amount can also be seen as an oxidative measure of lipid oxidation. Likewise, following the development of peroxides is an extension in UV absorbance at a rate of around 232 nm, which is typical of the conjugated diene systems. Oxidative rancidity is a key factor influencing the quality of refined and packed vegetable oils during storage (Gulla and Waghay, 2012).

The comparatively low shelf-life of most commercially accessible vegetable oils restricts their utility in different applications. Autoxidation is considered to be the foremost route of degradation of edible oil, which causes unpleasant odors and flavors (Merrill et al., 2008). Mixing vegetable oils with different properties is the easiest physical and

economical method for modifying the composition of fatty acids. Production of bioactive ingredients and natural antioxidants, and making something new at a low-cost price (Hashempour-Baltork et al., 2018). Sunflower oil has a significant source of monounsaturated fatty acids for dietary goods and due to its high oxidation resistance. This also has a high degree of natural antioxidants such as tocopherols, rendering this superior to other vegetable oils. Sunflower oil includes high concentrations of unsaturated fatty acids concentrations (77 – 82%) such as linoleic acid (59 – 67.5%) and oleic acid (14.0 – 18.1%), respectively.

Moringa oleifera oil has bright yellow with a sweet, peanut-like nutty flavor. It is oil usually used without any pre-processing (refining, bleaching, and deodorization) due to good nutty flavor, lower peroxide level, which is necessary for most commercial vegetable oils. It can be considered a healthy diet. Other Investigations have also shown that C18:1 rich diets can reduce plasma cholesterol and decrease the risk of cardiovascular disorders. Oils high in monounsaturated fatty acids are attracting more support from the food industry because they have safe properties and greater oxidative stability (Nadeem and Imran, 2016). In the same concern, Lapčíková et al. (2018) cited that free fatty acids increase thermal oxidation of oils, and their unsaturation rather than chain length leads to significant effects upon thermo-oxidative degeneration of oils. The oxidation rate of frying oil increases as the content of unsaturated fatty acids of the oil increases. The content of

linolenic acid is critical to the frying performance, the stability of the oil, and the flavor quality of fried food. Sesame oil is a healthy source of $\omega 6$ fatty acids and has a significant amount of sesamin and sesamol lignans that have various effects on bioactivity and health safety. Despite having 85 percent of unsaturated fatty acids, sesame oil is one of the most stable oxidation vegetable oils. Sesame oil, however, with favorable nutritional and safety effects, is low in $\omega 3$ fatty acids and has limited use in the food industry due to its excessive price (Hashempour-Baltork et al., 2018). Also, tocopherol equivalents have an antiinflammatory function and antiproliferative effects on cancer cells (Dravie et al., 2020). Oils stability can be improved via the mixing of oleic acid oils with high contents (Anwar et al., 2007). Oleic acid is greater resistant to oxidation compared with PUFA, both in normal storage and at high temperatures. In addition to compromising food consistency, at some stage in this process, it may additionally generate workable toxic compounds through the action of free and reactive oxygen species (ROS) which are hazardous to human health and are involved in degenerative diseases such as cancer and early aging (Krishnaiah, Sarbatly and Nithyanandam, 2011). With the consideration of the harmful effects of lipid oxidation on food degradation and human health, there is a want to improve the exogenous antioxidants to avoid not just the assumed deleterious outcomes of free radical in the human body, but additionally, the degradation of fats and other components of meals stuffs (Nyam et al., 2013). It is worthy to know that, the fatty acid content of new vegetable eatable oil may offer an intention for its probability uses for eatable or industrial use (Ahamd et al., 2015). As a consequence, the blending of sunflower oil with oil rich in both oleic acid and natural antioxidants like moringa or sesame oils to improve its oxidation stability was the target of the present investigation. The major goal of the current study was to assess the consequences of the fatty acid content of sunflower, moringa, and sesame oils and the combos of them on the alteration in the peroxide value, acid value, thiobarbituric acid value, phenolic compounds, and antioxidant activity, as well as the fatty acid compositions and their oxidative constancy.

Scientific hypothesis

Assess the outcomes of the fatty acid content of sunflower, Moringa, and sesame oils and the combos of them on the alteration in the peroxide value, acid value, thiobarbituric acid value, phenolic compounds, and antioxidant activity, as considerably as the fatty acid compositions and their oxidative constancy.

MATERIAL AND METHODOLOGY

The commercial varieties of sunflower oil (*Helianthus annuus* L.), moringa oil (*Moringa oleifera*), and sesame oil (*Sesamum indicum*) were obtained from Agriculture Research Center, Giza, Egypt. Pure SFO was blended with pure MOO and SEO oils in the proportion of 95:5 and 90:10 w/w. The oils were extensively stirred to create even mixtures and resulted in seven oil samples, namely; SFO, SFO:MOO (95:5), SFO:MOO (90:10), SFO:SEO (95:5), SFO:SEO (90:10), MOO, SEO stored in a brown bottle and kept in a freezer at -20°C until used for different analysis.

Physico-chemical properties of the oils

Physico-chemical properties of the pure and mixed oils; color index, flow time, refractive index, acid value, peroxide value, and free fatty acids were measured using the standard method of (AOCS, 1996).

Conjugated dienes and trienes determination

A spectrophotometer (Jasco 530 UV-visible Japan) was engaged in measuring the conjugated fatty acids (conjugated dienes and trienes) of various oils. Optical density at 234 and 268 nm were, respectively used for determining conjugated dienes and trienes (AOCS, 1985). The findings are presented as the 232 and 268 nm absorbance values.

Total phenolic compound (TPC)

The method of Folin Ciocalteu was used to evaluate the total phenols content of as Singleton and Rossi (1965) described. The absorbance using (Jasco 530 UV-visible spectrophotometer Japan) was measured at 765 nm. Phenolics content was calculated by a standardized curve gained from the calculation of the absorption of a specified gallic acid concentration and the results were presented as equal gm gallic acid (GAE) per 100 g oil.

Thiobarbituric acid (TBA)

Thiobarbituric acid (TBA) value was evaluated using the method defined by Guillén-Sans and Guzmán-Chozas (1998).

Free radical scavenging activity (DPPH)

The antioxidant functions of the oil samples were calculated using the stable DPPH system as updated by Güllüce et al. (2004). Absorbance was recorded at 517 nm utilizing a UV-visible spectrophotometer (Jasco V-530, Japan). Radical scavenging activity was defined as the inhibition percentage and estimated utilizing the equation below:

$$\% \text{DPPH} = \frac{[\text{Absorbance of Control} - \text{Absorbance of Sample}]}{\text{Absorbance of Control}} \times 100$$

Oxidative stability measurement

Rancimat has been used to assess the oxidative stability of sunflower and blended oils using a 679 Rancimat (Metrohm, Herisau, Switzerland) at 100°C with an airflow rate at 20 L per 1 hour as defined by Pablos-Méndez et al. (1997). The result of the Rancimat test was calculated by induction time measurement.

The protective factor

The protective factor (PF) of the examined oils is extracted as a percentage extension of the induction period (Abramovič and Abram, 2006), according to the following equation: $\text{PF} = \text{IP sample} / \text{IP control} \times 100$.

Fatty acid composition

Gas chromatographic analysis was employed to identify the composition of the fatty acid by preparing the methyl esters as reported by Stahl (1969).

Identification of the fatty acids methyl esters

The fatty acid methyl esters for different samples have been analyzed consistent with the IUPAC (1987) approach, using (HP 6890 gas chromatography instrument, Hamilton, USA) fitted with Innowax-crosslinked polyethylene glycol column 30 m; i.d. 0.32 mm; 0.5 µm film thickness. Fatty acid samples were recognized by comparing the fatty acid retention times peak regions with those of standard ones. These standards consist of, myristic acid (C14:0), palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), arachidic acid, oleic acid (C18:1), linoleic acid (C18:2), linolenic acid (C18:3), arachidic acid (C20:0) and behenic acid (C20:1).

Cox value

The oils' Cox value (oxidizability) was defined by the unsaturated C18 fatty acid percentage, using the formula proposed by **Fatemi and Hammond (1980)**:

$$\text{Cox value} = (1 [18:1\%] + 10.3[18:2\%] + 21.6 [18:3]) / 100$$

The ODR and LDR are quantified by **Pleines and Friedt (1988)** and estimate the effectiveness of desaturation from oleic to linoleic (ODR) and from linoleic to linolenic acid (LDR) within the desaturation process. They were computed as follows:

$$\text{ODR} = \%C18:2 + \%C18:3 / \%C18:1 + \%C18:2 + \%C18:3$$

$$\text{LDR} = \%C18:3 / \%C18:2 + \%C18:3$$

Statistical analysis

Results were focused on statistical analysis by the variance method analysis and the means of three samples ± SD were evaluated by the least significant difference (LSD) at a frequency level of 0.05 according to (Duncan's Multiple Range Test).

RESULTS AND DISCUSSION

One of the simplest procedures for making new specific products is the mixing of two or more oils with different characteristics. Blending different types of vegetable oils can not only adjust the profile of fatty acids but can also increase the degrees of bioactive lipids and natural antioxidants within the mixtures and provide higher great oils, in addition, to a progressed dietary fee at lower-priced (**Aladedunye and Przybylski, 2013**).

Physico-chemical properties of oils

Colour

Bearing on the changes in oil color, it was obvious that the blending caused a slight increase in color, as it increased from 0.099 in SFO to 0.111, 0.124, 0.107, and 0.120 for SFO + 5% MOO, SFO + 10% MOO, SFO + 5% SEO, SFO + 10% SEO, respectively (Figure 2, Table 1). The color of the oils is particularly due to the presence of the pigments that are collected along with the oil throughout refining and are effectively getting rid of during the bleaching processing of oil (**Basuny and Al-Marzouq, 2016**). Vegetable oils with a low index of color are better fitted for both edible and domestic purposes. Moreover, **Padmavathy, Siddhu and Sundararaj (2001)** stated that sensory attributes of vegetable oils could color and taste might be enhanced by

mixing, as the mixtures would fulfill the main objective of storage stability.

Flow time

With frying time and oil temperature of the oil changes considerably. It is viewable from (Table 1), the relative flow time (as an indicator for viscosity) of oil at 60 °C was measured as a relative flow time and considered an indicator of oil viscosity. Data in (Table 1) show that the flow time value for sunflower was the highest (2.690 g.cm⁻³) when compared with MOO (1.872 g.cm⁻³) and SEO (0.953 g.cm⁻³). So, when MOO and SEO were added to the SFO its flow time decreased. There is a relationship between the viscosity level and the degree of unsaturation oil. It means that blinding sunflower oil in different parts of MOO and SEO reduces the changes in viscosity values through the frying process. This means that a higher level of SEO (10%) mixed with SFO resulted in the greatest change in SFO viscosity (1.654 g.cm⁻³). This can be explained by the fact that polyunsaturated fatty acids appear to be oxidized easily and form polymer compounds (**Bracco, Dieffenbacher and Kolarovic, 1981**).

Refractive index

From the obtained results as shown in Table 1 that, there are no substantial differences between pure or blended oils. The variation in refractive indices could be due to specific gravity, molecular weight, increase in saturation, and linearly autoxidation stage. The refractive index of the used oils in the present investigation is in the agreement with the findings of **Mishra and Sharma (2011)** cited that no significant modifications were noted in the refractive index of, the refined rice bran oil and blended with refined sunflower oil. Otherwise, **Adel, Shaker and Mounir (2015)** studied whether mixing palm oil with different quantities of sunflower or soybean oil resulted in the significant refractive index values decrease significantly. These reductions may be ascribable to the increase of monounsaturated fatty acids of palm oil in the blended oils.

Acid value

Low acidity oils are considered acceptable for edible application and have to be explored for economic, nutritional, and health reasons. The acid value developments for sunflower, oil without, and with the addition of MOO and SEO shown in Table 1 it could be noticed that the acid values of sunflower before blending and when added to Moringa and sesame oils were 0.501, 0.421, 0.393, 0.670, and 0.782 for sunflower oil, sunflower oil +5% Moringa oil, sunflower oil +10% Moringa, sunflower oil +5% sesame, and sunflower oil 10% sesame, respectively.

The acid value was relatively low for sunflower oil and 10% Moringa oil. Mixing sunflower oil with several parts of Moringa oil significantly decreases the acid values. This reduction was increased by bringing up the mixing of Moringa ratio oil. Compared to sunflower oil Moringa oil, has higher oxidative stability as a result of the higher content of oleic acid (monounsaturated) and lower content of polyunsaturated fatty acid substance.

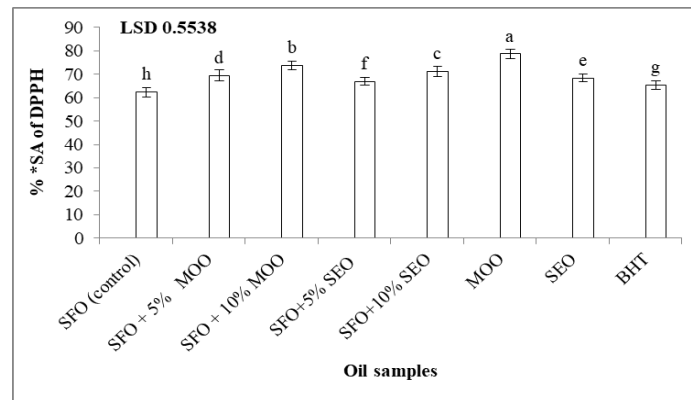


Figure 1 Percentage of DPPH radical sunflower oil scavenging activity and its blends with moringa or sesame oils. Note: SA = Scavenging activity, SFO = Sunflower oil, MOO = *Moringa olefera* oil and SEO = Sesame oil, BHT = Butylated hydroxyl toluene. Means with different letters above bars varied considerably at $p < 0.05$. Bars \pm standard deviation ($n = 3$).

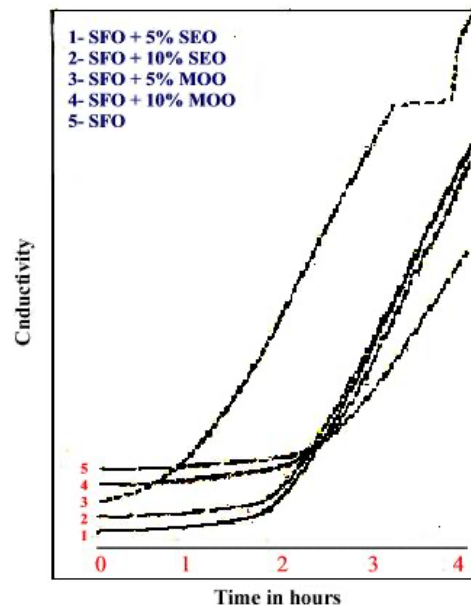


Figure 2 Effect of blending of sesame oil (5 and 10%) and moringa (5 and 10%) on the oxidative stability of sunflower at 100 °C. Note: SEO = sesame oil, MOO = *M. olefera*, and SFO = Sunflower oil.

An increment in the number of acidities was partly due to the hydrolysis and further oxidation of the formed byproducts (Wanasundara, Wanasundara, and Shahidi, 2001). The low acid number of Moringa oil measures up to sunflower oil point out a potential low free composition of fatty acid that means less vulnerability to rancidity.

Peroxide value

Peroxide value (PV) is a measure of the content of the acid composition of peroxides and hydroperoxides suggesting less sensitivity to physicochemical and antioxidant possessions that require rancidity. The data in (Table 1) resulted in a substantial difference in PV ($p > 0.05$), this was observed between control and SFO samples containing PVs reduced MOO and SEO. Sunflower

oil significantly ($p > 0.05$) had the highest peroxide value (0.720 meq.O₂ per kg of oil), though the most reduced value (0.615 and 0.530 meq.O₂ per kg of oil) was found in sunflower oil blend in Moringa oil were enlisted at level 5 and 10 percent, respectively. Blowing up the MOO proportion within the mixes brought an increase in the antioxidant strength and subsequently delayed the rise in PV. These findings are consistent with the level of unsaturation oil, easily unsaturated fatty acids respond with oxygen to form peroxides (Marina et al., 2009). Similarly, Mariod et al. (2005) tested the impacts of various mixes of sunflower kernel oil and *Sclerocarya birrea* oil on the progress of PV and detailed that the mixes of 10 percent. Berry oil with sunflower kernel oil showed a significant progression in oxidative stability compared to pure sunflower kernel oil.

The decline in PV, as established by mixing, was largely due to the decrease of unsaturated C18:2 at the disbursement of C18:1 (Reynhout, 1991). The increase of oleic acid content of Moringa oil coupled with its high unsaturated and little peroxide may meet the requirements of Moringa oil for use in industries, such as food, biofuel generation, Agrochemicals, paint, and varnish manufacture (Aly, Maraei and Ali, 2016).

Conjugated dienes and conjugated trienes

Quantity of CD and CT may be a sound test for determining the oxidative stability of the oils. Lipids with dienes show strong absorption at 232 nm, as absorbed by conjugated trienes at 270 nm. The increment in CD and CT substances is proportional to the oxygen absorption. The low CD and CT levels will increment the oxidative strength of the oil's absorptivity at 232 and 270 nm in SFO and oil mixes, due to the appearance of primary and secondary items of oxidation. Arrangement of aldehydes, ketones (rancid off-flavor compounds), and other oxidation items taken after by an increment of at 270 nm in absorptiveness (Table 2). Referable to the formation of CT as well as unsaturated ketones and aldehydes, the variation of absorptivity at 270 nm provided and pattern similar to that of absorptivity at 232 nm displayed. The elevated substance of conjugated oxidative items in SFO can be ascribed to its high content of linoleic acid (60% of total fatty acids), samples of SFO oil stabilized when combined with MOO, and reduced the CD and CT levels compared to control samples as displayed in Table 2, moreover, demonstrated that MOO is superior to SEO. Estimation of CD and CT may be a good parameter for determining the oils oxidative stability. The formation of high contents of CD may be related to the presence of higher contents of polyunsaturated fatty acids. Siddiq et al. (2005) explored the antioxidant effectiveness of methanolic extract of *Moringa oleifera* leaves for stabilizing SFO under rapid aging using the capacity of CD and CT contents. Iqbal and Bhanger (2007) also, identified the antioxidant action of garlic extracts in SFO, evaluated under speeded up situations, using CD and CT as oxidative degradation indicators. Barakat and Ghazal (2016) saw a promising potential in the nutrition aspects of moringa seeds oil. The increased content of unsaturated fatty acids may have a healthy effect on human nutrition from moringa seeds oil.

Phenolic content of pure and blend oils

Total phenolic contents (TPC) of various oil tests were assessed as phenolics may act as cancer prevention agents and secure lipids from peroxidation. Oils mixtures differing in TPC values, presenting 26.17, 31.28, 22.17, and 24.27 mg Gallic acid equivalents (GAE) per 100 grams of MOO 5%, MOO 10%, SEO 5%, and SEO 10%, respectively (Table 2). The TPC was superior when sunflower blended with Moringa oil than with sesame oil. These results recommend that moringa oil contains noteworthy amounts of phenolic components that under the accelerated oxidative conditions may mostly contribute to the oil stability. The constancy of the oil is not only associated with the overall volume of phenolics but moreover with the concentration of choosing phenols. Without a doubt, the concentration of phenolic content in oilseed is a critical calculate whereas assessment of the oil quality because these compounds have been connected with oil color and the shelf-life, and especially its

oxidation resistance (Cheikh-Rouhou et al., 2006). Since of the ability of phenolic compounds to give hydrogen molecule or an electron to create steady radical intermediates that can serve as vital antioxidants agents, consequently, and they can prevent deterioration by quenching the radical reactions caused by lipid oxidation (Abdelazim, Mahmoud and Ramadan-Hassanien, 2013; Koski et al., 2003). Phenolic compounds have much influence on stability and may prevent deterioration through quenching of radical reactions responsible for lipid oxidation (Koski et al., 2003). Moreover, it has been found that the natural antioxidants of the blends give better results concerning the oxidative stability and quality parameters. The mixing not only stabilizes the eatable oils but also assists to promote and strengthen oil's nutritional and functional properties, integrating the positive features of the two oils into one, thus increasing the consumer viabilities.

Thiobarbituric acid (TBA)

The thiobarbituric acid corrosive test is typically carried out to regulate the secondary oxidation substances that are mindful of the off-flavor. The TBA test refers to the aldehyde level shown within the oil by the response of malonaldehyde with TBA. The changes within the TBA levels (absorbance at 530 nm) of sunflower oil mixed with separate amounts of moringa and sesame oils are indicated in (Table 2). The most noteworthy ($p > 0.05$) TBA level was reported for sunflower, while, sunflower oil and its blind with MOO at level 10% (v/v) had ($p > 0.05$) significantly the most reduced values was 0.097 as absorbance at 532 nm. The TBA value is considered a strong chemical consistency parameter for assessing the oxidative state of new eatable oils and fats for calculating the degree of oxidation that occurred (Lalas and Tsaknis, 2002).

Free radical scavenging activity (DPPH)

The DPPH radicals have been utilized to prove the potential of SFO and its mixes to resist lipid peroxidation. The provided data listed in (Figure 1) can be indicated that mixing SFO with MOO and SEO expanded the scavenging activity percentage of SFO. The scavenging activity of the oil blends increased with increasing the ratio of MOO and SEO oils added. The highest scavenging activity percentage was observed in SFO + MOO 5% and SFO + SEO 10% (73.71 and 71.21%) respectively. Moringa oil is wealthy with oleic acid monounsaturated (~79%) and very low in PUFA (Ogunsina et al., 2014), and this is following our results, this oil contains an abundance of antiradical molecules such as tocopherols, phenolics, and carotenoids to avoid the peroxidation of its PUFA substance and extinguishing free radicals within the human body. Moreover, sesame oil has the prevalent oxidative constancy and the useful physiological impacts are linked to tocopherols and lignans, particularly sesamin and sesamolin (Hashempour-Baltork et al., 2018).

Table 1 Physico-chemical possessions of sunflower oil and blending with moringa and sesame oil.

Oil samples	Physico-chemical properties				
	Color Index Abs at 430 nm	Flow time g.cm ⁻³	Refractive index	Acid value mg KOH.g ⁻¹ oil	Peroxide value meq.O ₂ .kg ⁻¹ oil
SFO (control)	0.099 ^d ±0.03	2.690 ^a ±0.08	1.472 ^a ±0.06	0.501 ^d ±0.08	0.720 ^a ±0.03
SFO + 5% MOO	0.111 ^c ±0.06	2.011 ^c ±0.07	1.470 ^a ±0.08	0.421 ^c ±0.06	0.615 ^b ±0.07
SFO + 10% MOO	0.124 ^b ±0.05	2.270 ^b ±0.09	1.470 ^a ±0.04	0.393 ^c ±0.04	0.530 ^c ±0.05
SFO + 5% SEO	0.107 ^c ±0.02	1.952 ^d ±0.07	1.469 ^a ±0.03	0.670 ^c ±0.02	0.672 ^b ±0.04
SFO + 10% SEO	0.120 ^b ±0.05	1.654 ^c ±0.02	1.464 ^a ±0.01	0.782 ^b ±0.06	0.561 ^c ±0.03
MOO	0.149 ^a ±0.02	1.872 ^d ±0.02	1.468 ^a ±0.05	0.270 ^f ±0.01	0.260 ^c ±0.02
SEO	0.146 ^a ±0.04	0.953 ^f ±0.01	1.471 ^a ±0.03	0.930 ^a ±0.07	0.341 ^d ±0.04

Note: Values are mean of three replication ± standard deviation. Letters after the values denote within-column significant differences ($p < 0.05$). Abbreviations: SFO = Sunflower oil, MOO = *M. oleifera* oil and SEO = Sesame oil.

Table 2 Oxidation products of sunflower oil and blending with moringa and sesame oil.

Oil samples	Products of oxidation assays			
	CD Abs at 232 nm	CT Abs at 270 nm	Phenolic content gm.100gm ⁻¹ oil	TBA Abs at 530 nm
SFO (control)	2.414 ^c ±0.43	1.207 ^b ±0.68	21.15 ^d ±0.25	0.136 ^a ±0.18
SFO + 5% MOO	2.188 ^c ±0.12	1.719 ^a ±0.17	26.165 ^c ±0.15	0.117 ^c ±0.56
SFO + 10% MOO	1.951 ^d ±0.81	1.379 ^b ±0.71	31.276 ^b ±0.17	0.097 ^d ±0.26
SFO + 5% SEO	3.137 ^a ±0.56	1.804 ^a ±0.53	22.174 ^d ±0.46	0.129 ^b ±0.47
SFO + 10% SEO	2.836 ^b ±0.19	1.820 ^a ±0.12	24.268 ^c ±0.26	0.121 ^b ±0.28
MOO	1.683 ^d ±0.42	0.820 ^c ±0.27	44.183 ^a ±0.53	0.045 ^d ±0.54
SEO	2.314 ^c ±0.57	1.461 ^b ±0.28	24.890 ^c ±0.19	0.112 ^b ±0.21

Note: Values are sum of 3 replicates ± standard deviation. Letters after the values denote within-column significant differences ($p < 0.05$). Abbreviations: CD = Conjugated diene, CT = Conjugated triene, T.B.A = Thiobarbituric acid, Scavenging activity = SA, SFO = Sunflower oil, MOO = *Moringa oleifera* oil and SEO = Sesame oil.

Table 3 Effect of blending of sesame or moringa oils (5 and 10%) on oxidative stability of sunflower oil at 100 °C.

Oxidative Stability (OS)	Sunflower oil	Sesame oil		Moringa oil	
	control	5%	10%	5%	10%
*IP (hrs)	4.33	8.01	9.32	11.45	10.35
**PF %	-	1.85	2.15	2.64	2.39

Note: IP = Induction period determined by Rancimat method, **PF = Protection factor.

Impact of mixing of sesame or moringa oils (5 and 10%) on the constancy of sunflower oil at 100 °C

Confidence of the oxidative steadiness (OS) record by Rancimat is the most commonly used procedure to determine the susceptibility of consuming fats and oils under accelerated conditions. Oxidative steadiness, classified under specified conditions as oxidation resistance is one of the most imperative measures of eatable oils' consistency, quality of eatable oils' consistency (Vidrih, Vidakovič, and Abramovič, 2010). The stability of oxidation was due to the presence of natural antioxidants in seeds which indicated resistance to oxidation. Findings of the induction period at 100 °C and the obtained results are shown in Table 3 and graphically represented in (Figure 1). The induction period at 100 °C indicating remarkable stability of Moringa oil when mixed with sunflower oil at a concentration of 5% 11.45 h. This resistance to oxidative rancidity may be credited to the presence of endogenous phenolic antioxidants and a high considerable concentration of tocopherols. Studies report great oxidative soundness of seed fat of diverse species of Moringaceae, which

incorporate *M. Oleifera* (Anwar and Bhangar, 2003; Lalas and Tsaknis, 2002). In this concern, Padmavathy, Siddhu and Sundararaj (2001) detailed that mixing vegetable oils not only enhances the sensual consistency, moreover improves the capacity soundness of the eatable oils. In the expansion, oil gotten from the combination of chia and sesame oils has a superior proportion ratio of ω-3:ω-6 fatty acids, by precocious oxidative stability fluctuating among 6 and 8 hours at 110 °C and storability at 25 °C involving 80 and 123 days (Rodríguez et al., 2020).

The protective factor (PF)

Represents the oxidation resistance of oils as rate expansion of the IP. The most noteworthy PF% was obtained in the case of the blending of 5% and 10% of MOO. In the case of the PF, the value is more prominent than one, heighten the sample's stabilizing power. Without a doubt, the probability of utilizing the oils assisting or combining with other oils could be a rule of *M. oleifera* devastates valorization (Barakat and Ghazal, 2016).

Table 4 Change of the fatty acids composition (relative content, %) of sunflower and oil blends.

Fatty acids	SFO	SFO + 5% MOO	SFO + 10% MOO	SFO + 5% SEO	SFO 10% SEO	MOO	SEO
C _{14:0} Myristic acid	ND	ND	ND	ND	ND	ND	0.08 ±0.03
C _{16:0} Palmitic acids	4.35 ±0.27	4.42 ±0.39	4.68 ±0.81	5.25 ±0.3	6.80 ±0.62	4.90 ±0.31	8.90 ±0.31
C _{16:1} Palmitoleic acid	3.1 ±0.64	3.01 ±0.31	3.08 ±0.73	2.91 ±0.21	2.78 ±0.83	2.90 ±0.23	0.26 ±0.61
C _{18:0} Stearic acid	3.18 ±0.09	3.61 ±0.21	4.34 ±0.18	3.91 ±0.91	4.82 ±0.65	4.50 ±0.38	5.21 ±0.69
C _{18:1} Oleic acid	23.41 ±0.32	29.83 ±0.42	37.32 ±0.5	25.31 ±0.72	28.90 ±0.81	74.60 ±0.43	35.86 ±0.15
C _{18:2} Linoleic acid	60.30 ±0.85	55.81 ±0.02	51.34 ±0.43	55.8 ±0.17	52.90 ±0.19	5.01 ±0.19	41.20 ±0.27
C _{18:3} Linolenic acid	0.13 ±0.11	0.18 ±0.04	0.27 ±0.26	0.96 ±0.43	1.64 ±0.21	1.20 ±0.24	4.9 ±0.07
C _{20:0} Arachidic acid	1.90 ±0.59	2.15 ±0.21	2.31 ±0.04	1.40 ±0.12	0.94 ±0.19	2.70 ±0.06	0.51 ±0.54
C _{22:0} Behenic acid	0.71 ±0.76	0.73 ±0.21	0.77 ±0.1	0.68 ±0.21	0.63 ±0.63	1.30 ±0.23	0.43 ±0.03
SFA	10.14	10.91	12.10	11.24	13.19	13.4	15.13
MUFA	26.51	32.84	40.40	28.22	31.68	77.50	36.12
PUFA	60.43	55.18	51.61	56.76	54.54	6.21	46.10
PUFA/SFA	5.96	5.06	4.27	5.05	4.13	0.46	3.05
Cox value	6.47	6.09	5.72	6.20	6.10	1.52	5.66
ODR	0.72	0.65	0.60	0.69	0.65	0.08	0.46
LDR	0.002	0.003	0.005	0.02	0.03	0.20	0.11

Note: Results are given as the average of triplicate determinations ± standard deviation. SFO = Sunflower oil, MOO = Moringa oleifera oil and SEO = Sesame oil, SFA = Saturated fatty acids. MUFA = Monounsaturated fatty acids, PUFA = Polyunsaturated fatty acids, USFA = Unsaturated fatty acids, ODR = oleic desaturation ratio, LDR linoleic desaturation ratio. N.D. = not detected.

Composition of fatty acids of the sunflower oil and moringa or sesame oil blends

The unrefined vegetable oils are typically more oxidatively steady than the comparing refined and prepared oils. Mixing of vegetable oils and fats has risen as a conservative way of altering the physicochemical properties of vegetable oils, other than improvement in oil stability (Ramadan and Wahdan, 2012). Concerning their oxidative stability and the presence of minor contents of the fatty acid contents, such as carotenoids, tocopherols, metal particles, polar lipids, and the original sum of hydroperoxides. The composition of SFO fatty acids and oil mixes is presented in (Table 4). Mixing sunflower oil with MOO and SEO modified the major fatty acids in the mixtures. Whereas significant improvements were noted in the contents of oleic acid (C18:1) and linoleic acid (C18:2) of mixed oils. The most elevated rate of linoleic acid 60.3 % (C18:2) was noted in sunflower oil comparing to MOO and SEO. The key fatty acids in the mixtures of sunflower oil and Moringa oil (SFO: MOO, 90:10), oleic and linoleic acids with 37.32% and 51.34% respectively. Blending SFO achieved a substantial rise from 26.51% to 32.84% and 40.40% in the MUFA substances of the SFO:MOO mixtures 95:5 and 90:10, respectively. On the other hand, the PUFA substances were diminished from 60.43 to 55.18 and 51.61% for SFO:MOO blends 95:5 and 90:10, respectively. Qualifying in the saturated fatty acids

(SFA) is more remarkable in the sunflower oil when blended with sesame oil than Moringa oil. The relation between the content polyunsaturated and saturated FA is stated as the P/S index. This assessment is a critical factor in determining the nutritional value of definite oil. Oils and fats with a greater number of P/S index than one are regarded to have a nutritious rate (Zambiasi et al., 2007). Sunflower oil had the most noteworthy polyunsaturated fatty acids rate, whereas Moringa oil had the greatest rate of monounsaturated and most reduced polyunsaturated. Which makes it attractive in terms of quality steadiness cooking and frying. The increased consumption of healthy fats (monounsaturated/oleic) is also associated with a diminished chance of the incidence of coronary heart diseases (Ahmad et al., 2015). Additionally, high-oleic oils contain low levels of saturated fatty acids. High-oleic oils can therefore be seen as alternative health to somewhat hydrogenated vegetable oils (Abdulkarim et al., 2005). Within the same regard Allam (2001), examined the oxidative stability of (SFO), mixed with nine oils, and characterized by their corrosive oleic acid substance. Ogunsina et al. (2014) cited that combining *Moringa oleifera* oil with sunflower oil and soya bean oil in various amounts may lead to an increment in oleic acid and a decreased in linoleic acid. Other authors appear a wide spectrum of important fatty acids in the normal sunflower oil (Vidrih, Vidakovič and Abramovič, 2010). The oleic desaturation ratio (ODR) and linoleic desaturation ratio (LDR) of values showing, the productivity of the

desaturation frameworks from C18:1 to C18:2 and from C18:2 to 18:3, respectively, are appeared in Table 4. The major sum of ODR in the blends oil (0.69) was found in sunflower with sesame oil 5% to be moderately high relative to that of LDR (0.2). Such quantities justify clarify the watched high substance of C18:2 and low content of C18:3 observed in the present work. Moderately higher normal means of ODR and LDR clarify the increment of C18:2 substances. The high ODR values suggest that the biosynthesis pathway was effective within the forming of PUFA (C18:2 and C18:3) from the desaturation of MUFA (C18:1). Nonetheless, the low LDR sums indicate that this process was not so effective in the forming of C18:3 from the desaturation of C18:2. Consequently, C18:3 substance was decreased and C18:2 expanded to reach a concentration greater than C18:1.t of C18:1. Besides, oleic and linoleic acids are the main constituents of samples. The combination of vegetable oils and fats has developed as a temperate method of altering the physicochemical properties of vegetable oils, in addition to improving oxidative stability (Anwar et al., 2007). Without a doubt, the probability of utilizing the *M. oleifera* oils assisting or combining with other oils could be a rule of *M. oleifera* devastate valorization (Barakat and Ghazal, 2016).

CONCLUSION

The obtained results from this investigation revealed that the highest acid value was observed at SFO + 10% SEO. Sunflower oil alleviated when blended with MOO and the levels of conjugated dienes (CD) and trienes (CT) were depressed relative to control. The TPC value was greater when the sunflower blended with moringa oil. The highest percentage of scavenging activity was found in SFO + MOO 5% and SFO + SEO 10% respectively. Meanwhile, the longest induction period at 100 °C was 11.45 hours in the treatment of SFO + MOO 5%. When sunflower and moringa oils are combined (SFO:MOO, 90:10), the master fatty acids are oleic and palmitic. The natural antioxidants of the mixed oils have been found to provide superior results concerning oxidative stability and quality parameters. The mixing oils do not only stabilize the eatable oils but, furthermore provides the progress and upgrades the dietary and useful qualities of the oils by integrating the positive characteristics of the two oils into one, hence thus enhancing their economic possibility. The current study illustrated that *M. olifera* oil found in Egypt contains an excellent potential for eatable and commercial application. Overall, mixing vegetable oils allows the food industry more freedom to have useful properties or required dietary requirements.

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