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Oxidative stability of *Opuntia ficus-indica* seeds oil blending with *Moringa oleifera* seeds oil☆

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Abstract – Enhancement of the oxidative stability of cactus seeds oil by blending with moringa seeds oil was investigated during storage period for four weeks at 50 °C. Blends (25, 50 and 75%) of moringa seeds oil with cactus seeds oil were prepared. Fatty acids composition, induction period, peroxide value, specific extinction coefficients (K232 and K270) and tocopherols were studied. Blending moringa seeds oil with cactus seeds oil at 25:75% increases the induction period to 4.06 h while it was 3.16 h in 100% cactus seeds oil. Peroxide values decreased due to increase moringa seeds oil amount in blends. Also, adding moringa seeds oil to cactus seeds oil caused a decrease in K232 and K270 values during the storage period in comparison with 100% cactus seeds oil. α-tocopherol values decreased during storage for all oil blends, while the content of γ-tocopherol in all samples (except moringa seeds oil) increased during storage period reaching the highest level after the third week then it started to decrease. Therefore, the obtained results provided a potential approach to utilize moringa oil to increase the oxidative stability of edible oils.

Keywords: oxidative stability / *Opuntia ficus-indica* seeds oil / *Moringa oleifera* seeds oil / blending oils

Résumé – Stabilité oxydative de l'huile de graines d'*Opuntia ficus-indica* en mélange avec de l'huile de graines de *Moringa oleifera*. L'amélioration de la stabilité oxydative de l'huile de graines de cactus (*Opuntia ficus-indica*) par mélange avec de l'huile de graines de moringa (*Moringa oleifera*), a été étudiée sur une période de stockage de quatre semaines à 50 °C. Des mélanges (25, 50 et 75 %) d'huile de graines de moringa et d'huile de graines de cactus ont été préparés, et la composition en acides gras, la période d'induction, l'indice de peroxyde, les coefficients d'extinction spécifiques (K232 et K270) et les teneurs en tocophérols ont été suivis au cours du stockage. Le mélange à 75 % d'huile de graines de moringa a vu sa période d'induction augmenter à 4,06 h, contre 3,16 h pour l'huile de graines de cactus à 100 % (contrôle). L'augmentation du taux d'huile de graines de moringa dans les mélanges s'est traduite par une diminution de l'indice de peroxyde et des valeurs K232 et K270. La teneur en α-tocophérol a également diminué au cours du temps dans tous les mélanges, alors que la teneur en γ-tocophérol a augmenté (sauf pour l'huile de graines de moringa) pour atteindre un maximun après la troisième semaine, et diminuer ensuite. En conclusion, les résultats obtenus ont montré que l'ajout d'huile de moringa à des huiles comestibles constituait une approche potentielle pour améliorer leur stabilité oxydative.

Mots clés : stabilité oxydative / huile de graines d'*Opuntia ficus-indica* / huile de graines de *Moringa oleifera* / mélanges d'huiles

☆ Contribution to the Topical Issue "Minor oils from atypical plant sources / Huiles mineures de sources végétales atypiques"

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1 Introduction

Oxidative reactions effect the shelf life of processed foods and the fresh one. The main problem in deterioration edible oil is lipid oxidation which has bad effect on color, texture and aroma (Bodoira *et al.*, 2017). In addition, many harmful substances may be formed by further oxidation (Shahidi and Zhong, 2010). Also, irreversible damages occur when a reaction take place between radical oxygen species and with biological molecules like proteins or lipids (Cabiscol *et al.*, 2000). Preventing oil oxidation, causes an enrichment of the functional compounds which are useful for human health (Anwar *et al.*, 2007; Frankel and Huang, 1997). Mixing different oils helps in increasing the level of natural antioxidants in the mixtures and increase quality for the oils. As well, it is an economical method to enhance physicochemical characteristics of these oils (Chu and Kung, 1997; Chu and Kung, 1998), and nowadays many countries use this method to improve edible oils (Ramadan *et al.*, 2008). Diets which have high content of oleic acid are in a relation with lowing the bad cholesterol in blood and this may reduce coronary heart diseases (Nestel *et al.*, 1994). Furthermore, it can help in treatment diabetes and cancer (Poudyal *et al.*, 2012). Vegetable oils which have a high amounts of oleic oil are more favorable from a nutritional point of view because its resistance to oxidation than others contain polyunsaturated fatty acids which have poorer oxidative stability and shorter shelf-life (Bordon *et al.*, 2019). Therefore, it is necessary to look for economical and practical methods to increase the oxidative stability and the shelf life of the vegetable oils. One of these methods is blending two or more oils which have different properties to produce new desirable products. Many advantages can be obtained by mixing vegetable oils such as adjusting fatty acid profiles and the amounts of bioactive compounds and natural antioxidants in the new blends. All of these advantages give the new products better quality, enhance oxidative stability and increase the shelf life of the produced blends (Hashempour-Baltork *et al.*, 2016). For example, studies report the blending of some common oils like sunflower oil with canola or palm oil (Farag *et al.*, 2010) and the combination of hydrogenated soybean oil with soybean oil, or high-oleic sunflower oil with corn oil (Naghshineh *et al.*, 2010). Other researches have examined the effect of blending untraditional oils with common one like adding walnut to virgin olive oils (Torres *et al.*, 2011), among others.

Cactus plant (*Opuntia ficus-indica*) of the Cactaceae family, grows native in Mexico and has been used since many of years as source of food. Genus Opuntia contains about 1500 species of cactus which are widespread in Africa, Mediterranean countries, Northern Mexico, Southwestern United States, and other areas (Matthäus and Özcan, 2011). Taoufik *et al.* (2015) reported that oil content of the seeds from many regions in Morocco ranged between 5.4% and 9.9%. It contains high content of unsaturated fatty acids, in which linoleic acid is the main fatty acid (58.79%) (Ghazi *et al.*, 2013). Saturated fatty acids are occurring at lower percentages and comprise palmitic and stearic acids (Ramadan and Mörsel, 2003; Gharby *et al.*, 2015; Mouden *et al.*, 2016). About the pharmacological activity, the oil from cactus seed showed relevant antioxidant and antimicrobial activity (Ramírez-Moreno *et al.*, 2017), α-glucosidase inhibitory activity, cytotoxicity against human tumor cell lines also anti-inflammatory and analgesic activities (Chahdoura *et al.*, 2017).

Moringa oleifera which belongs to family Moringaceae is an effective remedy for malnutrition. It is the most utilized and famous species in this family. Its original homeland is India and then spread to many countries (Morton, 1991; Mughal *et al.*, 1999). As regards moringa seeds oil, it is a good source of oil and oleic acid is the major fatty acid (Salama *et al.*, 2020). The oxidative stability of moringa seeds oil depends on its fatty acid composition (high amount of oleic acids and low amount of polyunsaturated fatty acids) beside its tocopherol content (antioxidant substances) (Al-Juhaimi *et al.*, 2017; Salama *et al.*, 2020). Also, these types of oil (oleic type) are desirable in nutrition due to its effect on coronary heart disease (Abdulkarim *et al.*, 2007). Moringa oil is stable during frying due to its high content of oleic acid which produce low content of conjugated dienes and trienes in comparison to vegetable oils rich in ployunsturated fatty acid.

Therefore, the aim of this research was using *Moringa oleifera* seeds oil to enhancement the oxidative stability of *Opuntia ficus-indica* seeds oil. To our knowledge, this is the first work to study the effect of blending *Moringa oleifera* to *Opuntia ficus-indica* to increase its oxidative stability.

2 Materials and methods

2.1 Materials

Moringa oleifera seeds were collected from Crop Research Institute, Agricultural Research Center, Sakha, Kafrelsheikh City, Egypt at summer 2017. Cold press cactus (*Opuntia ficus-indica*) seeds oil were obtained from Tiznit City, Morocco at summer 2017.

2.2 Reagents

Petroleum ether (40–60), heptane and tert-butyl methyl and cyclohexane for spectroscopy were from Merck (Darmstadt, Germany). Tocopherols standard compounds were procured from Merck (Darmstadt, Germany). Fatty acid methyl esters standard was obtained from Restek (Bad Homburg, Germany).

2.3 Sample preparation

Moringa seeds were sun-dried to dryness, then the seeds were ground using mill (IKA, model A11 BS000, Germany) and stored at 4 °C until usage.

2.4 Extraction of oil

To determine the oil amount, DGF-B-I-5 (2013) method was followed. In brief, the crushed moringa seeds (5 g) were extracted in a Twisselmann apparatus using 75 mL petroleum ether for 6 h. Rotary evaporator (model RV 10C S93, IKA-Werke GmbH & Co. KG, Stauffen, Germany) at 40 °C and 25 Torr was used to eliminate the solvent. The residual solvent was removed by a stream of nitrogen.

2.5 Effect of blending moringa seeds oil (MSO) on the stability of cactus seeds oil (CSO)

The oils blends were formulated by blending MSO with CSO at ratios of 100:0, 75:25, 50:50, 25:75 and 0:100%, respectively. The oils were mixed to obtain uniform blends. MSO, CSO and oil blends were put in a dark glass bottles (50 mL each). The bottles were filled completely with bure and blends oils and tightly closed. Temperature is one of the most important factors that affect lipid oxidation. So, 50 °C for up to one month was used to accelerate the oxidation reaction in a forced draft air oven. Immediately after each week, oil samples were withdrawn for triplicate analyses. The oxidation state evolution was measured by several parameters, tocopherols content, peroxide value, specific extinction coefficients and induction period.

2.6 Fatty acids determination

To determine fatty acids DGF-C-VI 10 (2013) and DGF-C-VI 11d (2013) were used. One drop, approximately, from the oil sample was dissolved in n-heptane (1 mL). After that, sodium methylate (50 μg) (Merck, Darmstadt, Germany) was added to the tube and for 60 s the tube was agitated at room temperature. Centrifuge was used (3000 × g for 5 min) after adding 100 μL of water to the tubes and carefully the lower aqueous phase was removed. HCL (1 mol with methyl orange; Merck, Darmstadt, Germany) (50 μL) was used and the lower phase was eliminated after shortly mixing to the solution. Adding sodium hydrogen sulphate (20 mg) (monohydrate, extra pure; Merck, Darmstadt, Germany) to the tube and at 3000 × g for 5 min the sample was centrifuged. The top phase (n-heptane) was taken to a vial and injected in GC (HP5890, Agilent Technologies Sales & Services GmbH & Co. KG, Waldbronn, Germany) with CP-Sil 88 a capillary column, (ID 0.25 mm, 100 m long, 0.2 μm film thickness). The temperature program was prepared as follows: From 155 °C; reached to 220 °C (1.5 °C/min), injector 250 °C, 10 min isotherm; detector 250 °C; hydrogen as carrier gas 36 cm/s; split ratio 1:50; hydrogen as detector gas 30 mL/min; 300 mL/min air and 30 mL/min nitrogen; manual injection volume less than 1 μL. The peak areas were computed by the integration software, and percentages of fatty acid methyl esters (FAME) were obtained as weight percent by direct internal normalization.

2.7 Tocopherols determination

For identification and determination of tocopherols, DGF-F-II 4a (2013) was used. 150 mg of oil were dissolved in n-heptane (1 mL) followed by two stages of filtration the first one syringe filter 1.0 μm and the second 0.45 μm. After filtration the sample was directly injected to the HPLC. The HPLC analysis was conducted using a Merck-Hitachi low-pressure gradient system, fitted with pump (L-6000), a Merck-Hitachi F-1000 fluorescence spectrophotometer, and a Chem-Station integration system. The samples (20 μL) were injected by auto sampler (Merck 655-A40) onto a Diol phase HPLC column 25 cm × 4.6 mm ID with 1.3 mL/min as a flow rate of n-heptane and tert-butyl methyl ether were used as a mobile phase.

2.8 Determination of peroxide value

By definition peroxide value (PV) is a measure of total peroxides of the oil (meq.O_2 kg^{-1} oil). Acetic acid-isooctane mixture (60:40 v/v) was used to dissolve 5 g from the oil sample. To this solution, 0.5 mL of saturated potassium iodide (KI) was added and mixed for 1 minute. Boiled Millipore water (100 mL) was used and the titration (pH metric titration) was done until the first equivalence point with alcoholic (KOH) = 0.1 mol/L. The titration was done automatically using METHROM Titrando 888 controlled by a software (Tiamo), facilitating the calculation of peroxide value as mEq of active oxygen/kg oil.

2.9 Specific extinction coefficients (K232 and K270)

The absorbance at 232 nm or 270 nm gives a sign about the oxidation products. 250 mg of oil were weighed into a 25 mL volumetric flask and diluted to 25 mL with cyclohexane (spectrophotometric grade).

The sample was homogenized using vortex for 30 s and then resulting solution was placed into a quartz cuvette. Absorbance was measured at 232 and 270 nm in a double beam spectrophotometer using the pure cyclohexane as a blank. The specific extinctions were calculated as follows:

$$K\lambda = \frac{E\lambda}{C \times S},$$

where:

- $K\lambda$: specific extinction at wavelength λ;
- $E\lambda$: absorption or extinction at wavelength λ;
- C: the solution concentration in g/100 mL;
- S: quartz cell length (cm).

2.10 Rancimat method

Induction time is a test designed to measure the relative stability of an oil sample. To measure the induction time Metrohm® 743 Rancimat was used. Oil (3.6 g) was weighed and put in a heating block at 110 °C or 120 °C. Air was forced through the sample at 20 L/hour. Volatile components which develop as a result of oxidation are captured in water and a conductivity metre was used in measuring. As the oil oxidized, the changes in the conductivity were recorded by the Rancimat. The point of inflection on the curve recorded when the oil had lost the ability to resist oxidation was reported as induction time in hours.

2.11 Statistical analysis

The data were statistically analyzed by software of SPSS (Version 16.0, SPSS Inc., Chicago, IL) to test the variance by one-way analysis of variance (ANOVA) method (Steel and Torrie, 1980).

Table 1. Fatty acids composition (% of total FA) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends.

Fatty acids	MSO:CSO oil blends %				
	(100:0)	(75:25)	(50:50)	(25:75)	(0:100)
Saturated FA					
Palmitic	5.90 ± 0.139^{e}	6.91 ± 0.015^{d}	8.50 ± 0.045^{c}	10.06 ± 0.140^{b}	11.75 ± 0.025^{a}
Stearic	4.45 ± 0.112^{a}	4.68 ± 0.025^{a}	4.34 ± 0.012^{b}	3.94 ± 0.031^{c}	3.45 ± 0.010^{d}
Arachidic	3.21 ± 0.046^{a}	2.85 ± 0.006^{b}	2.03 ± 0.006^{c}	1.19 ± 0.012^{d}	0.35 ± 0.015^{e}
Behenic	6.49 ± 0.082^{a}	5.43 ± 0.031^{b}	3.69 ± 0.020^{c}	1.98 ± 0.006^{d}	0.20 ± 0.006^{e}
Lignoceric	1.36 ± 0.023^{a}	1.06 ± 0.006^{b}	0.75 ± 0.015^{bc}	0.45 ± 0.015^{cd}	0.13 ± 0.006^{d}
Palmitoleic	1.42 ± 0.040^{a}	1.23 ± 0.026^{b}	0.97 ± 0.015^{c}	0.78 ± 0.015^{d}	0.64 ± 0.006^{e}
Oleic	65.78 ± 1.054^{a}	53.02 ± 0.026^{b}	41.19 ± 0.051^{c}	28.88 ± 0.080^{d}	16.25 ± 0.015^{e}
Vaccenic	6.15 ± 0.045^{a}	6.28 ± 0.025^{b}	5.70 ± 0.015^{c}	5.17 ± 0.006^{d}	4.56 ± 0.012^{e}
Linoleic	0.62 ± 0.010^{e}	15.21 ± 0.040^{d}	29.75 ± 0.015^{c}	44.98 ± 0.093^{b}	60.64 ± 0.086^{a}
Linolenic	0.17 ± 0.000^{d}	0.15 ± 0.006^{d}	0.18 ± 0.00^{c}	0.20 ± 0.006^{b}	0.22 ± 0.012^{a}
Gondoic	2.29 ± 0.012^{a}	1.74 ± 0.015^{b}	1.23 ± 0.00^{c}	0.75 ± 0.021^{d}	0.22 ± 0.010^{e}
SFA	21.41	20.93	19.31	17.62	15.88
MUFA	75.64	62.27	49.09	35.58	21.67
PUFA	0.79	15.36	29.93	45.18	60.86
PUFA/SFA	0.04	0.73	1.55	2.56	3.83
Total USFA	76.43	77.63	79.02	80.76	82.53
Total FA	97.84	98.56	98.33	98.38	98.41
Cox value	0.82	2.19	3.26	5.02	6.50

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a row are significantly different at $P \leq 0.05$.

3 Results and discussion

3.1 The change in fatty acids composition

Table 1 shows the fatty acids composition of pure oils (MSO and SCO) and their blends. Oleic, linoleic, behenic acids were the major fatty acids changed in blends. MSO contained high amount of oleic acid reached about 65.78%. While, the major fatty acid in CSO was linoleic acid (60.64%). This high value of linoleic acid may be the reason which make CSO more susceptible to oxidative rancidity. Data reveals that MSO and CSO contained SFA, MUFA, and PUFA (21.41 and 15.88%), (75.64 and 21.67%) and (0.79 and 60.86%), respectively. CSO had greater cox value than MSO reached 6.50 and 0.82, respectively and adding MSO at 25, 50 and 75% caused a gradual decreased reached 5.02, 3.26 and 2.19. On the other hand, PUFA/SFA was higher in SCO (3.83) than MSO (0.04). It is known that cox value and the ratio of PUFA/SFA consider as a parameters of tendency of oils to undergo oxidation (Fatemi and Hammond, 1980; Mendez *et al.*, 1996).

Blending MSO at a ratio of 75% caused an increase in oleic acid in cactus seeds oil from 16.25% to 53.02%, while linoleic acid decreased from 60.64% to 15.21%. An increasing in palmitic and oleic acids had occurred as a result of blending MSO with CSO at different ratios, which has a good effect on oxidative stability as mentioned by Abdel-Razek *et al.* (2011). Many studies mentioned near effects of blending oils. Anwar *et al.* (2007) and Li *et al.* (2014) who reported that adding MSO to soybean and sunflower oils caused a decrease in linoleic acid and an increase in oleic acid in oil blends. Also, Guiotto *et al.* (2014) found that blending of chia oils with sunflower kernel oil caused modifications in the blends' fatty acid profile.

Table 2. Induction period (IP) of *Moringa oleifera* and cactus (*Opuntia ficus-indica*) seeds oils and blends.

Samples	Blends ratio %	Induction period (hrs)
MSO:CSO	100:0	10.58 ± 0.326^{a}
MSO:CSO	75:25	8.95 ± 0.152^{b}
MSO:CSO	50:50	5.79 ± 0.118^{c}
MSO:CSO	25:75	4.06 ± 0.087^{d}
MSO:CSO	0:100	3.16 ± 0.040^{e}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; Means having the different case letter(s) within a row are significantly different at $P \leq 0.05$.

3.2 The change in induction periods (IP)

The investigated samples sensitivity to oxidation was measured by the rancimat test. The end point of this test can be determined by induction period (IP) to the inflection point in the oxidation curve (Mendez *et al.*, 1997). The length of IP is considered a relative measure of the oils stability. IP results of MSO, CSO and blends were displayed in Table 2.

It was found that CSO was extremely susceptible to oxidation (3.16), while MSO had the highest IP (10.58). Blending with MSO improved clearly the oxidative stability. IP of oil blends significantly increased as a result of adding MSO to CSO. Mixing 25% of MSO to CSO increased its the thermal stability reached about 4.06 in comparison with pure CSO (3.16). Abdel-Razek *et al.* (2011) reported that, mixing olive oil (IP 31.1) with soybean oil (IP 9.63) and sunflower oil

Table 3. Determination of peroxide value (meq.O_2/kg oil) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends during storage at 50 °C for four weeks.

Samples	Blending ratio (%)	Storage time (week) at 50 °C				
		0	1	2	3	4
MSO:CSO	100:0	0.43 ± 0.026^{e}	7.70 ± 0.223^{d}	8.95 ± 0.115^{d}	9.02 ± 0.080^{e}	11.05 ± 0.026^{e}
MSO:CSO	75:25	0.78 ± 0.070^{d}	8.30 ± 0.157^{c}	10.67 ± 0.231^{d}	12.60 ± 0.333^{b}	12.94 ± 0.217^{d}
MSO:CSO	50:50	1.64 ± 0.036^{c}	8.90 ± 0.040^{b}	11.89 ± 0.290^{c}	17.35 ± 0.072^{c}	20.85 ± 0.190^{c}
MSO:CSO	25:75	1.86 ± 0.045^{b}	8.68 ± 0.290^{bc}	12.94 ± 0.026^{b}	19.67 ± 0.327^{b}	25.22 ± 0.195^{b}
MSO:CSO	0:100	2.06 ± 0.189^{a}	10.22 ± 0.245^{a}	18.05 ± 0.046^{a}	33.16 ± 0.280^{a}	39.53 ± 0.361^{a}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a column are significantly different at $P \leq 0.05$.

Table 4. Specific extinction coefficients (K232) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends during storage at 50 °C for four weeks.

Samples	Blends ratio (%)	Storage time (week) at 50 °C				
		0	1	2	3	4
MSO:CSO	100:0	2.61 ± 0.006^{e}	2.67 ± 0.024^{d}	2.56 ± 0.210^{e}	2.36 ± 0.050^{e}	2.33 ± 0.031^{e}
MSO:CSO	75:25	2.73 ± 0.038^{d}	2.96 ± 0.182^{cd}	3.05 ± 0.222^{d}	3.16 ± 0.020^{d}	3.32 ± 0.035^{d}
MSO:CSO	50:50	2.81 ± 0.023^{c}	3.16 ± 0.171^{bc}	3.34 ± 0.021^{c}	4.23 ± 0.075^{c}	5.26 ± 0.167^{c}
MSO:CSO	25:75	3.04 ± 0.067^{b}	3.46 ± 0.242^{ab}	3.71 ± 0.006^{b}	4.88 ± 0.042^{b}	6.07 ± 0.012^{b}
MSO:CSO	0:100	3.13 ± 0.046^{a}	3.71 ± 0.142^{a}	4.96 ± 0.067^{a}	6.55 ± 0.055^{a}	8.98 ± 0.036^{a}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a row are significantly different at $P \leq 0.05$.

(IP 10.1) caused an increase in IP for new blends. Also, Guiotto *et al.* (2014) studied the effect of making blends between sunflower and chia oils. They found that blending sunflower oil to chia oil led to increase IP from 3.0 h for chia oil to 7.6 h for (80:20% sunflower:chia) and to 9.2 h for (90:10% sunflower: chia). These previous results confirm that the presence of oleic acid in the oil leads to an increase in the thermal stability of pure oils and its blends.

3.3 The change in peroxide value

The results of blending MSO and CSO on peroxide value during accelerated oven test storage at 50 °C for four weeks were represented in Table 3. Peroxide value is considered as a parameter for the production of lipid oxidation primary products (hydroperoxides) (Ramadan and Mörsel, 2004; Mohdaly *et al.*, 2010). The results showed that peroxide values increased as a result of increment storage time for all oil samples.

The initial value of PV of CSO was the highest one among all samples reached 2.08 meq.O_2 kg^{-1} oil. Peroxide values decreased as a result of increasing MSO. Pure CSO exceeded the limit of PV (15.0 meq.O_2 kg^{-1} oil) for safety consumption of oils (Codex Alimentarius, 2001) after the end of the second week. On the other hand, pure MSO did not reach this limit until the end of the storage period. This may be due to the high content of oleic acid and low amount of linoleic and linolenic acids in MSO and on the contrary in CSO. Adding 25 and 50% from MSO to SCO delay reaching the limit of PV (15.0 meq.O_2 kg^{-1} oil) for the end of third week in comparison with pure CSO which reached this limit at the end of second week. While, adding 75% from MSO showed similar to pure MSO. By the end of storage period, PV reached 39.53, 25.22, 20.85, 12.94 and 11.05 meq.O_2 kg^{-1} oil for MSO:CSO (0:100%), MSO:CSO (25:75%), MSO:CSO (50:50%), MSO:CSO (75:25%) and MSO:CSO (100:0%), respectively.

The obtained results were in the same trend of those reported by Anwar *et al.* (2007). They found that adding moringa oil (20%) to soybean oil decreased peroxide values. The same effect was observed by adding olive oil (high in oleic acid) to sunflower (high in linoleic acid) and soybean (high in linoleic acid) which caused slowdown in the increase in PV (Abdel-Razek *et al.*, 2011). In general, increasing the amount of linoleic acid and/or decreasing the level of oleic acid caused a decrease in the oxidative stability of oil blends (Naghshineh *et al.*, 2010).

3.4 The change in specific extinction coefficients (K232 and K270)

The formation of hydroperoxides has a relationship with double bonds conjugated in polyunsaturated fatty acids, which measured by absorption using the UV spectrum (Ramadan and Mörsel, 2004). For evaluation the stability of fan and oil, measuring conjugated diene (CD) and triene (CT) are good parameters. The more CD and CT, the less oxidative stability (Mohdaly *et al.*, 2010). These absorptions are expressed as specific extinctions E (the extinction of 1% solution of the oil in the specific solvent in a 10 mm cell) conventionally indicate by K (also referred to as extinction coefficients).

Table 5. Specific extinction coefficients (K270) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends during storage at 50 °C for four weeks.

Sample	Blend ratio (%)	Storage time (week) at 50 °C				
		0	1	2	3	4
MSO:CSO	100:0	0.20 ± 0.006^{c}	0.21 ± 0.012^{d}	0.18 ± 0.00^{d}	0.20 ± 0.010^{d}	0.20 ± 0.010^{d}
MSO:CSO	75:25	0.17 ± 0.000^{d}	0.18 ± 0.00^{e}	0.18 ± 0.006^{d}	0.18 ± 0.006^{e}	0.18 ± 0.00^{e}
MSO:CSO	50:50	0.22 ± 0.010^{b}	0.23 ± 0.012^{c}	0.24 ± 0.012^{c}	0.25 ± 0.010^{c}	0.24 ± 0.006^{c}
MSO:CSO	25:75	0.23 ± 0.010^{b}	0.25 ± 0.00^{b}	0.30 ± 0.006^{b}	0.30 ± 0.015^{b}	0.30 ± 0.00^{b}
MSO:CSO	0:100	0.32 ± 0.010^{a}	0.33 ± 0.00^{a}	0.31 ± 0.012^{a}	0.37 ± 0.006^{a}	0.37 ± 0.006^{a}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a row are significantly different at $P \leq 0.05$.

Table 6. α-tocopherol content (mg/100 g) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends during storage at 50 °C for four weeks.

Sample	Blending ratio (%)	Storage time (week) at 50 °C				
		0	1	2	3	4
MSO:CSO	100:0	20.92 ± 0.710^{a}	11.02 ± 0.387^{a}	11.18 ± 0.897^{a}	13.98 ± 0.608^{a}	11.28 ± 0.021^{a}
MSO:CSO	75:25	16.02 ± 0.176^{b}	8.95 ± 0.053^{b}	9.28 ± 0.158^{b}	11.37 ± 1.289^{b}	10.14 ± 0.590^{b}
MSO:CSO	50:50	14.55 ± 0.435^{c}	6.83 ± 0.081^{c}	6.72 ± 0.087^{c}	9.71 ± 1.163^{c}	8.42 ± 0.195^{c}
MSO:CSO	25:75	7.25 ± 0.079^{d}	4.00 ± 0.236^{d}	3.97 ± 0.120^{d}	4.73 ± 0.017^{d}	4.62 ± 0.227^{d}
MSO:CSO	0:100	1.01 ± 0.056^{e}	1.26 ± 0.309^{e}	1.08 ± 0.006^{e}	0.99 ± 0.070^{e}	0.96 ± 0.050^{e}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a column are significantly different at $P \leq 0.05$.

The conjugated diene (K232) results of MSO and CSO and blends at 50 °C during storage for four weeks were given in Table 4. Absorption at 232 nm measure the primary products of oxidation. The results were in the same trend of PV results (Tab. 3). Increasing storage time caused an increase in absorption at 232 nm and this was due to conjugated dienes formation. MSO and CSO had initial K232 value reached 2.61 and 3.13, respectively. CSO had higher final K232 values in comparison to the others reached up to 8.98. MSO/CSO blends have smaller values than those of pure CSO. Adding MSO to CSO caused a decrease in K232 values during storage period. Conjugated dienes and trienes high content in CSO may be due to the high level of linoleic acid which broke down to form conjugated hydroperoxides. K232 and K270 values from pure MSO were unchanged greatly throughout the storage period.

In addition, K270 refers to the absorbance of the conjugated trienes and secondary products of oxidation (Manai-Djebali *et al.*, 2012; Bachari-Saleh *et al.*, 2013). The results in Table 5 showed that, MSO had lower K270 than CSO at zero time (0.20 and 0.32, respectively) and also after one month of storage (0.20 and 0.37, respectively). The storage at 50 °C for four weeks led to little in the K270 values (Tab. 5). This result can be illustrated by the fact that the secondary compounds have not yet been formed and the oxidation stops at hydroperoxides formation.

These results were in the same trend of others reported by Torres *et al.* (2006) who mentioned that K232 values increased suddenly from day 6 (144 h of storage at 60 °C), whereas K270 values increased gradually along all the storage period of soybean and jojoba oils and their blends. Also, K232 values of sunflower, black cumin oils and their blends increased by the end of the storage period (16 days) due to the formation of conjugated diene and the values reached up to 69.22 for sunflower oil, 46.70–56.72 for blends and 17.71 for black cumin oil (Kiralan *et al.*, 2017).

3.5 The change in tocopherols

Vitamin E contains a group of compounds which are fat-soluble with antioxidative activity (Dörmann, 2007). Tocopherols consider as good antioxidants and play role as radical scavengers (Mène-Saffrané and DellaPenna, 2010). Generally, nuts, vegetable oils and seeds are a good source of tocopherols (Dörmann, 2007). Vegetable oils tocopherols have an important function in protecting fatty acids especially polyunsaturated against oxidation and improving the oxidation stability (Kiralan *et al.*, 2017).

α- and γ-tocopherols were the highest tocopherols in MSO and CSO and the values were within the ranges reported by others (Taoufik *et al.*, 2015; Gharby *et al.*, 2015; Al-Juhaimi *et al.*, 2017; Salama *et al.*, 2018). α- and γ-tocopherols in MSO and CSO and their blends during storage for four weeks at 50 °C were presented in Tables 6 and 7. α-tocopherol content in MSO was considerably higher than in CSO (20.92 and 1.01 mg/100 g, respectively), while γ-tocopherol was higher in CSO than in MSO (45.45 and 5.77 mg/100 g, respectively) (Tables 6 and Tabs. 6 and 7). The amount of α-tocopherol in

Table 7. γ-tocopherol content (mg/100 g) of moringa (*Moringa oleifera*) and cactus (*Opuntia ficus-indica*) seeds oils and blends during storage at 50 °C for four weeks.

Sample	Blending ratio (%)	Storage time (week) at 50 °C				
		0	1	2	3	4
MSO:CSO	100:0	5.77 ± 0.278^{a}	3.50 ± 0.06^{e}	3.75 ± 0.322^{e}	4.05 ± 0.211^{e}	4.82 ± 0.059^{d}
MSO:CSO	75:25	16.58 ± 0.179^{d}	17.28 ± 0.237^{d}	20.72 ± 3.562^{d}	21.77 ± 2.423^{d}	19.78 ± 0.310^{c}
MSO:CSO	50:50	25.88 ± 0.709^{c}	29.98 ± 0.358^{c}	29.66 ± 0.177^{c}	39.69 ± 5.523^{c}	34.86 ± 0.052^{b}
MSO:CSO	25:75	39.03 ± 0.731^{b}	42.05 ± 0.777^{b}	42.48 ± 0.308^{b}	52.46 ± 1.552^{b}	52.55 ± 1.357^{a}
MSO:CSO	0:100	45.45 ± 0.460^{a}	50.92 ± 4.374^{a}	53.74 ± 0.603^{a}	60.12 ± 1.063^{a}	52.93 ± 0.782^{a}

MSO: Moringa (*Moringa oleifera*) seeds oil; CSO: cactus (*Opuntia ficus-indica*) seeds oil; values are means ± SD; means having the different case letter(s) within a column are significantly different at $P \leq 0.05$.

MSO was higher than the amount measured in canola, corn and soybean oils (12.0, 17.3 and 7.1 mg/100 g, respectively). Also, γ-tocopherol in CSO was higher than its amount in canola, corn, sunflower and soybean oils (12.2, 25.9, 9.2 and 27.3 mg/100 g, respectively) (Grilo *et al.*, 2014).

From Table 6, α-tocopherol amount in the samples were in the following order: MSO > (MSO:CSO, 75:25) > (MSO: CSO, 50:50) > (MSO:CSO, 25:75) > CSO during storage for four weeks at 50 °C. α-tocopherol level decreased during the first and second weeks for pure oils and their blends. After that, by the end of the third week the amount of α-tocopherol increased in (MSO), (MSO:CSO 75:25), (MSO:CSO, 50:50) and (MSO:CSO, 25:75) reached about 13.98, 11.37, 9.71 and 4.73 mg/100 g, respectively. Generally, the amount of α-tocopherol decreased during storage period in comparison with zero time. These results were in harmony with those reported by Kiralan *et al.* (2017), Capitani *et al.* (2011) and Abramovic *et al.* (2007) in which α-tocopherol decreased during storage period in black cumin and sunflower oils, wheat germ oil and *Camelina sativa* oil, respectively. After the third week and by the end of storage period α-tocopherol started to decrease again in all samples. Only pure CSO decreased over the storage period.

Réblová (2006) reported that α-tocopherol activity at 90 °C was higher than its activity at 80 °C in pork lard and decreased by increasing temperature. Also, Marinova and Yanishlieva (1996, 1998) and Yanishlieva and Marinova (1996) stated that the α-tocopherol activity increases with increasing temperature in the temperature range from 20 to 100 °C. The effect of temperature range from 90 to 120 °C on the antioxidant activity of α-tocopherol was studied by Nakatani *et al.* (2001). They mentioned that α-tocopherol antioxidant activity was constant or slightly decreases with increasing temperature in the temperature range from 90 to 120 °C. In addition, Sabliov *et al.* (2009) studied the effect of temperature on α-tocopherol degradation and found that α-tocopherol heated at 40, 60, and 120 °C degraded at a non-significantly different rate, with halftime values of 8.2, 10.1, and 8.2 h, respectively. Another explanation, may be due to the stability of α-tocopherol at high temperatures if no oxygen is present (Shin *et al.*, 1997; Verleyen *et al.*, 2001) and that what happened in our study in which the bottles were filled completely with bure and blends oils and tightly closed. All these previous studies may contribute to explain what had happened in our experiment in which α-tocopherol level increased by the end of the third week and by increasing the storage period at 50 °C for another week it started to decrease, taking into consideration that the temperature in our study was 50 °C.

As for γ-tocopherol, different effect had been observed. The amounts of γ-tocopherol in (MSO:CSO 75:25), (MSO: CSO, 50:50), (MSO:CSO, 25:75) and (MSO:CSO, 0:100) were 16.58, 25.88, 39.03 and 45.45 mg/100 g at zero time. These amounts started to increase and reached the highest amount by the end of third week. This effect was different with the effect happened in α-tocopherol which started to decreased after the first week. At the end of the fourth week, γ-tocopherol levels were lower than its amount in the third week. For pure MSO, γ-tocopherol decreased during the storage period. This increase may explain the decrease in oxidation products (related with K232 and K270 values) in the oil samples. Also, γ-tocopherol provides a more stable and more efficient antioxidant for food lipids than α-tocopherol (Wanger *et al.*, 2004) and α-tocopherol loss its antioxidant activity higher than γ-tocopherol (Evans *et al.*, 2002; Isnardy *et al.*, 2003).

4 Conclusion

It is well known that, MSO has high natural antioxidants especially tocopherols and polyphenols, besides high level of oleic acid. All of these compounds have a role in protecting oils from oxidation. Adding 25% from MSO to CSO caused a reduce in the production of hydroperoxides and this may decrease the production of secondary oxidation products. Blending MSO in different ratios with CSO improves the oxidative stability of CSO as approved by the results of peroxide value, K232 and K270. Adding 75, 50 and 25% of MSO to CSO increase its shelf life in comparison with 100% SCO.

Conflict of interest

The authors declare that they have no conflicts of interest in relation to this article.

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