The impact of Senjed (Elaeagnus angustifolia L.) peel aqueous extract on qualitative properties of cold-pressed sesame oil

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September 25, 2021

Abstract

The Senjed peel aqueous extract was added to sesame cold-pressed oil at different concentration of 0, 100, 200, 500 and 750 mg/kg and compared with TBHQ (200 mg/kg). The Senjed peel aqueous extract showed 9.55 ± 0.35% extraction yield, 58.17 ± 2.33% antioxidant activity, 573.31 ± 3.57 (mg GAE/100 g FW) total phenolic content, and 151.33 ± 2.67 (mg CAE/100 g FW) total flavonoid content. The extract preserved 59.08% of antioxidant activity after heating at 185 for 80 min. Increasing the concentration of the extract caused a significant ($p<0.05$) qualitative improvement in the oil samples. At all storage times, the highest FFA%, peroxide and P-anisidine value belonged to oil samples containing 0 ppm of Senjed peel aqueous extract and followed by 100, 200, 500 and 750 ppm, respectively. The highest oxidative stability index was observed in oil samples containing TBHQ and 750 mg/kg concentration of extract (both 15.39 h). Oil samples containing 750 ppm of Senjed peel aqueous extract and TBHQ showed almost similar qualitative characteristics. Results showed that Senjed peel aqueous extract have antioxidant potential for stabilization of oils.

1. Introduction

Sensitivity to oxidation of edible oils with higher unsaturation levels changes organoleptic properties and decreases the shelf life of the oil (Abdelazim et al., 2013). One of the practical strategies that can be used to increase oil oxidative stability during processing and storage is addition of antioxidant compounds. Edible oil industries use chemicals and synthetic antioxidants in preservation of oils. However, health risks of synthetic antioxidants and society's growing demand for products that contribute to improving the quality of life has encouraged researchers to look for naturally-occurring alternatives antioxidants with comparable antioxidative properties and health benefits (Elaigwu et al., 2019; Farag et al., 2007; Iqbal & Bhanger, 2007; Ribeiro & Jorge, 2017). The popularity and desire to consumption of cold-pressed oils is continuously increasing among consumers. Recovery and preserving more bioactive compounds during the pressing process is the advantage of cold-pressed oils over refined oils. Lipid oxidation of oils can not only produce rancid odors, unpleasant flavors and discoloration, but can also decrease the nutritional quality and safety due to degradation products, resulting in harmful effects on human health when it is consumed (Böhm et al., 2013). In addition to fatty acid profile of oils, antioxidant polarity, structure, concentration, and mutual ratios influences oil oxidation mechanisms and rates (Choe & Min, 2006; Sielicka et al., 2014).

The sweet smell and good taste make sesame oil a natural and desirable salad or cooking oil, especially in Asian countries. Depends on variety, genetics, environment, and ecological factors, the oil content of sesame seed from different countries has been estimated to be 50.9 - 55% which contains 80% unsaturated fatty acids (such as oleic acid and linoleic acid) and less than 20% of saturated fatty acids (such as palmitic and stearic acids). Sesame oil also contains significant amounts of sesamol, sesamolin, and sesamin, which have antioxidant activities (Yermanos et al., 1972; Zanjani et al., 2020). For cold-pressed oils rich in polyunsaturated fatty acids (PUFAs), the effectiveness of antioxidants is of particular importance.

Antioxidants such as flavonoids, tannins, coumarins, curcumanoids, xanthons, phenolics, lignans and terpenoids are found in various plant parts (e.g. fruits, leaves, seeds and oils). For this reason, there is growing interest in separating these plant antioxidants and using them as natural antioxidants (Jeong et al., 2004). More than 90 species of the Senjed (*Elaeagnus angustifolia L.*) are mainly distributed in subtropical regions of Asia, Europe and North America1 which are rich in terms of phytochemicals such as flavonoid compounds, sitosteroles, cardiac glycosides, terpenoids, coumarins, phenol carboxylic acids, saponins, carotenoids, vitamins, and tannins. Flavonoids which are mainly present in fruits and vegetables, due to their phenolic hydroxyl groups, are able to chelate metals, reduce lipid peroxidation and have shown a high antioxidant and free radical scavenging activities (Hamidpour et al., 2017; Saboonchian et al., 2014).

Despite studies on the antioxidant properties of various parts of Senjed fruit, literature review showed that the practical use of its extract as an antioxidant in edible oils is very limited. On the other hand, unexpectedly, the oxidative stability of sesame cold-pressed oils produced in Iran is lower (Farmani et al., 2019; Zanjani et al., 2020) than the national standard (INSO, 2016; INSO, 2013) recommendations (13 and 12 h for frying and blend oil, respectively). Therefore, given the presence of potentially useful bioactive compounds in Senjed and the interest in replacing synthetic antioxidants with natural ones, the main objective of this study was to evaluate the effectiveness of Senjed peel aqueous extract as a natural antioxidant at different concentration levels (0, 100, 200, 400, and 600 ppm) compared to widespread synthetic antioxidant TBHQ (200 ppm), on shelf life and oxidative properties of cold-pressed sesame oil.

2. Materials and methods

2.1. Materials and chemicals

Senjed (*Elaeagnus angustifolia* L.) fruit obtained from the traditional market (Azarshahr, Iran) and were separated manually from the peel, then the separated peels were dried in an oven at 40 °C till the constant moisture content of 7.5%. Sesame oil was freshly prepared from a traditional cold-pressed oil manufacture (Azarshahr, Iran). 1,1-Diphenyl-2-picrylhydrazyl (DPPH), gallic acid, (+) catechin 1,1,3,3,-tetramethoxypropane and tert-Butylhydroquinone (TBHQ) were purchased from Sigma Chemical Co. (St. Louis, MO, USA). Folin–Ciocalteau reagent, isooctane solvent and p-anisidine reagent were purchased from E. Merck Co. (Darmstadt, Germany). All other reagents were of analytical grade.

2.2. Preparation of Senjed peel aqueous extracts

Using Soxhlet extractor, 20 g of dried and ground Senjed peel was mixed with 200 ml of double distilled water in a round bottom flask and refluxed for about 8 h at 100 °C. Obtained liquid extracts were separated from the solid residue by vacuum filtration, vacuum-evaporated (Heidolph Rotavapor, Germany, 40 , vacuum 0.6 bar and rpm 50) to obtain the concentrated extract. Semi-dried extracts placed in amber-colored glasses, flushed with nitrogen, and stored at 4 until the analyses.

2.3. Determination of total phenolic content (TPC) in Senjed peel aqueous extracts

Total phenolic compounds in the extracts were determined, using Folin–Ciocalteau reagent, by the method of Hussain et al. (2018) and expressed as mg/g of Gallic acid equivalents (GAE) as a standard. 0.5 mL of extracts (at a concentration of 1–10 mg/mL extracts in water) was mixed with 2.5 mL of 10% Folin-Ciocalteu reagent and 2 mL of 7.5% sodium carbonate solution. After the samples were kept for 30 min at room temperature for incubation, the absorbance was measured at 760 nm in a UV/visible spectrophotometer (Ultrospec 2000; Pharmacia Biotech Ltd., Cambridge, UK).

2.4. Determination of total flavonoid content (TFC) in Senjed peel aqueous extracts

The spectrophotometer assay for the quantitative determination of flavonoid content was carried out as described by Chen et al. (2007). Briefly, the extract (1 mL, 1 mg/mL) was diluted with 1.25 mL distilled water. At zero time, 75 μL 5% $NaNO_2$ were added to the mixture. After 6 min, 150 μL 10% $AlCl_3$ were added. After another 5 min, 1 mL 1 M NaOH were added to the mixture. Immediately, the absorbance

of the mixture, pink in color, was determined at 510 nm versus prepared water blank. Total flavonoids of extracts were expressed on a fresh weight basis as mg/100 g catechin equivalents (CAE).

2.5. Evaluation of antioxidant activity of Senjed peel aqueous extracts

The 1, 1-diphenyl-2-picrylhydrazyl (DPPH) assay was performed according to Hussain et al. (2018). The obtained extracts and the synthetic antioxidant TBHQ (0.1 mL of each) was allowed to react with 3.9 mL of DPPH solution (6×10^{-5} M) and absorbance was measured at 515 nm after 30 min. The DPPH scavenging percentage was calculated according to the following formula.

$$\text{DPPHs Scavenging capacity } (\%) = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100 \quad (1)$$

A = absorbance at 515 nm**.**

2.6. Evaluation of thermal stability of Senjed peel aqueous extracts

Thermal stability of Senjed peel aqueous extracts was evaluated by heating at 185 in a vacuum oven (Memmert GmbH, Schwabach, Germany) for 80 min by 10 min intervals in separate crucibles. After each interval, a crucible was removed from the oven, cooled to room temperature and stored at 4 before antioxidant activity evaluation in DDPH assay system following the above-cited method.

2.7. Qualitative properties of cold-pressed sesame oil with Senjed peel aqueous extract

2.7.1. Sample preparation

Aqueous extracts of Senjed peel were added to the 100 mL cold-pressed sesame oil at concentrations of 0 (T0) (as negative control without antioxidant), 100 (T100), 200 (T200), 500 (T500) and 750 ppm (T750) (respectively, 0%, 0.01%, 0.02%, 0.05%, and 0.075% of fat content). Synthetic antioxidant TBHQ was employed at their legal limit of 200 ppm (0.02% of fat content) (as positive control) in cold-pressed sesame oil. All of prepared oil samples were filled in PET containers and stored at 25 +- 5 and 30–35% relative humidity.

2.7.2. Analytical procedures

Moisture content, refractive index, iodine value (IV), and saponification value of oil samples were measured according to the AOCS Ca 2d-25, Cc 7-25, Cd 1d-92, and Cd 3-25 methods, respectively. Measurement of Peroxide value (PV), free fatty acid (FFA), and p-anisidine value (P-AV) were made after a regular interval of 15 days, following the AOCS official methods (AOCS, 2003). Total carotenoid and chlorophyll content were determined according to Jabri-Karoui & Marzouk (2014) using a UV–Vis spectrophotometer (Pharmacia Biotech Ltd., Cambridge, UK) at 470 and 670 nm, respectively, using the following equations:

$$\text{Total chlorophyls } \left(\frac{\text{mg}}{\text{kg}_{\text{oil}}}\right) = \frac{A_{470\ nm} \times 10^6}{613 \times 100 \times d} \quad (2)$$

$$\text{Total carotenoids } \left(\frac{\text{mg}}{\text{kg}_{\text{oil}}}\right) = \frac{A_{670\ nm} \times 10^6}{2000 \times 100 \times d} \quad (3)$$

Where A is the maximum absorption in given wavelength, d is the thickness of the cuvette = 1 cm, 613 and 2000 is the coefficient of specific extinction in cyclohexane of pheophytin and lutein, respectively. Temperature and relative humidity of oil samples storage was 25 +- 5 and 30–35%., respectively.

The protein, fat, moisture, ash, crude fibre and total titrable acidity values of Senjed fruit were estimated using standard methods of analysis (AOAC, 1990). Total soluble sugar (%) content was determined according to Cansev et al. (2011).

2.7.3. Oxidative stability index (OSI)

Oxidative stability index (OSI) of the oil samples determined using 2.5 g oil and Rancimat instrument (Model 743; Metrohm Ltd., Herisau, Switzerland) at 110 with an airflow rate of 9 L h^{-1}according to the AOCS Cd 12b-92 method.

2.8. Statistical analysis

All experiments were performed in triplicate and data is reported as mean +- standard deviation. One-way ANOVA and Tukey's mean comparing test at 5% significance level was performed using the Minitab ver. 20.3 (Minitab, Pennsylvania, USA).

3. Results and discussion

3.1. Chemical composition of Senjed (*Elaeagnus angustifolia* L.)

The proximate chemical composition of Senjed *(Elaeagnus angustifolia* L.) fruits and cold-pressed sesame oil are presented in Table 1.

The yield of the Senjed peel aqueous extract was 9.55 +- 0.35%. The yield of ethanolic, methanolic and aqueous sesame seed extracts was in the range of 13.37–29.48%. Methanol had the highest yield (29.48%), and the lowest yield was detected in water extracts (13.37%) (Hussain et al., 2018). Percent yield of potato peels extract obtained with different organic solvents was as follow: Ethanol 10.20%, Methanol 14.75%, Acetone 5.88%, Hexane 13.00%, Petroleum ether 21.00% and Diethyl ether 15.25% (Zia-Ur-Rehman et al., 2004). Soluble sugars (47.73%), crude fibre (21.05%), moisture (19.48%) and titrable acidity (7.53%) were the most common constituents of Senjed fruit, respectively. Considering the positive correlation between the titrable acidic level with total organic acid and phenolic acid (Wang & Fordham, 2007), Ayaz & Bertoft (2001), reported that among determined seven phenolic acids in *Elaeagnus angustifolia* L., 4-hydroxybenzoic acid (45.8 mg/100 g dry wt) and cafeic acid (32 mg/100 g dry wt) were the most abundant, whereas ferulic acid (2.3 mg/100 g dry wt) and benzoic acid (11.6 mg/100 g dry wt) were least abundant**.** Crude fibre content of Senjed fruit in this study (21.05%) was in the range of total dietary fibre content of flours from peeled and unpeeled oleaster (*Elaeagnus angustifolia* L.) (20.67% to 30.65%) that reported by Sahan et al. (2015).

The mean fat content of the Senjed fruits in this study was 0.47 %. Russian olive (*Elaeagnus angustifolia* L.) fruit samples had low fat content (0.49%), and according to the reports of, oleic acid, linoleic acid and linolenic acid, including up to 92.8 % of the fruit lipid content (Kusova & Luk'yanchikov, 1990). An abundance of palmitoleic acid in fruit peel oil and a high amount of linoleic acid and palmitic acid in seeds oil of E. angustifolia L. was reported (Sahan et al., 2015).

The FFA%, peroxide value, iodine value, and saponification value of the prepared cold-pressed sesame oil was 0.643%, 1.17meq$_{O2}$/Kg$_{\mathrm{Oil}}$, 111.81 (g_I/100g_{oil}), and 193.15 (mg$_{\mathrm{KOH}}$/g_{oil}) that was below the maximum allowable norm of Codex (Alimentarius, 1999) for cold-pressed oils. The FFA%, peroxide value, and iodine value of the sesame seed cold-pressed oil of several African countries has been reported in the range of 0.9-1.8%, 0.06-6.9 meq O_2/kg, and 105-117 (g_I/100g_{oil}), respectively (Gharby et al., 2017; Khalid Sabahelkhier et al., 2008; Nzikou et al., 2009; Ogbonna & Ukaan, 2013). The high iodine value of the sesame oil samples confirmed the high levels of unsaturated fatty acids (UFAs) in their fatty acid profile, which is desirable from a nutritional perspective, but makes them sensitive to autoxidation. Oil oxidative index (OSI) of cold-pressed sesame oil in this study was 8.93 +- 0.53 h that was lower than national reference for frying (13 hours) and blend oils (12 hours) at the temperature of 110degC. Assessment of oil oxidative index (OSI) in 8 cold-pressed sesame oil samples in Zanjan province of Iran showed that the induction periods was within the range of 7.53 +- 0.1 - 9.48 +- 0.1 hours in the cold-pressed sesame oil samples and 18.96 +- 0.26-20.91 +- 0.01 hours in the refined samples (Zanjani et al., 2020). Farmani et al. (2019) reported that OSI of sesame oil from local extraction stores in Mazandaran province of Iran was 8.14 +- 1.14 h.

3.2. Total phenolic and flavonoid content of extracts

The active compounds of natural sources such as phenolic and flavonoids compounds have shown to have antioxidant activities due to their ability to donate the electrons and scavenge the free radicals. Many factors such as climate, soil and ecological conditions are involved in the amount of these plants secondary metabolites (Saboonchian et al., 2014). Average TPC of aqueous extracts of the exocarp (peel) of Senjed fruit were measured as 573.31 +- 3.57 mg GAE/100 g FW. Hassanzadeh & Hassanpour (2018) reported

that TPC of peel and pulp methanolic extract*of Elaeagnus angustifolia* L. fruits from different locations of East and West Azerbaijan provinces of Iran was in the range of 444.74 – 669.86 and 423.91 – 561.00 (mg GAE/100 g FW), respectively. Cansev et al. (2011) reported that average TPC of aqueous, acetone and methanolic extracts of the mesocarp and exocarp in oleaster fruit was 778.11, 558.52, 390.44; and 361.24, 413.95, 524.40 (mg GAE/100 g FW), respectively. They concluded that extraction procedures using water showed much more antioxidant capacity and total phenolic content compared to methanol and acetone extraction procedures for tested samples ($p<0.05$).

TPC of oleaster fruits crust and crumb methanolic extracts grown in different locations of Turkey reported as in the range of 13.43-22.30 and 10.58-16.44 (mg GAE/g DM), respectively (Simsek & Sufer, 2021). TPC in seed, flesh and peel of different genotype of oleaster methanolic extracts ranged from 2.14 to 6.26 +- 0.04, 0.14 to 1.54, and 0.12 to 2.59 (mM QE/mg extract), respectively (Faramarz et al., 2015). A review of literature shows that the content of phenolic compounds in the exocarp (peel or crust) of *Elaeagnus angustifolia* L. fruit is higher than its mesocarp (flesh, pulp or crumb). The nature and polarity of solvent systems markedly influenced the phenolic contents of extracts. The results imply that the aqueous extract of Senjed peel could be effective in the antioxidant and free radical scavenging activity. The amount of the total phenolics of the aqueous extract of *Phellodendron amurense* was 70 µg mg^{-1} (Velmurugan et al., 2018).

TFC of the extracts obtained from the peel of Senjed fruit was 151.33 ± 2.67 mg CAE /100 g FW. Hassanzadeh & Hassanpour (2018) reported that TFC of *Elaeagnus angustifolia* L. fruits peel and pulp methanolic extract in five different locations of East and West Azerbaijan provinces of Iran was in the range of 73.69 – 226.5 and 94.27 – 209.42 mg CAE/100 g FW, respectively. TFC of the methanolic extracts obtained from the crust and crumb of oleaster fruit varied between 5.99 ± 0.45 and 16.24 ± 1.49 mg CE/g DM, and 3.10 ± 0.01 and 6.54 ± 2.68 mg CE/g DM, respectively (Simsek & Sufer, 2021). The TFC in methanolic extracts of seed, flesh and peel of different genotype of oleaster fruit ranged from 4.7 to 17.6, 0.62 to 1.90, 0.64 to 1.13 (mM QE/mg extract), respectively (Faramarz et al., 2015). TFC of the extracts obtained from the crust and crumb of oleaster fruit varied between 5.99 to 16.24, and 3.10 and 6.54 (mg CE/g DM), respectively (Simsek & Sufer, 2021).

After 24 days of storage, the trolox equivalent (TE) of soybean and cottonseed oils fortified with 400 mg/kg rosemary extract was significantly higher than the TE of oils fortified with 200 mg/kg of the synthetic antioxidants BHA and BHT (Yang et al., 2016).

3.3. Antioxidant activity of Senjed peel aqueous extracts

The free radical (DPPH) scavenging activity (%) of aqueous extracts obtained from exocarp (peel) of Senjed (*Elaeagnus angustifolia*L.) fruits was 58.17%. The free radical (DPPH) scavenging activity DPPH of aqueous, acetone and methanolic extracts of the mesocarp and exocarp in oleaster fruit are measured as 28.03, 27.16, 27.82; and 27.62, 27.95, 27.84 (µmol Trolox/g FW), respectively ((Cansev et al., 2011). In the study of Hassanzadeh & Hassanpour (2018), the mean antioxidant capacity of peel and pulp extracts obtained by 85% methanol based on the DPPH assay was 74.71 and 53.76%, respectively. According to Faramarz et al. (2015), the mean antioxidant capacity of peel, pulp and seed based on the DPPH assay in different genotype of *E. angustifolia* L. was 86.95, 91.78 and 35.83%, respectively. Also, according to Incilay (2014), the antioxidant capacity for leaf, flower, peel and fruit of*E. angustifolia* L. fruit was 1.036, 1.65, 1.28 and 2.51 µg trolox/g, respectively.

Velmurugan et al. (2018) reported that the aqueous extract of *P. amurense* possesses good DPPH scavenging activity. When compared to the positive control of L-ascorbic acid it has less activity but there is little difference at a concentration of 500 µg. DPPH activity results reveal that the Senjed peel aqueous extract possesses hydrogen donating ability and, may act as primary antioxidants. The effectiveness of antioxidant activity depends on the inhibition reaction between a peroxyl radical and the antioxidant. The electron-attractive inductive effect of the alpha carbonyl group in the para position should in fact destabilize the phenoxyl radical and reduce the radical scavenging ability of compounds (Kajiyama & Ohkatsu, 2001). The following possible mechanism can be applied for DPPH radical scavenging activity. The dimer formation

during the reaction between two phenoxyl radicals can influence the antioxidant property of the extract. These dimers may initially reduce DPPH radical scavenging (Bortolomeazzi et al., 2007).

3.4. Thermal stability of Senjed peel aqueous extracts

Effect of heating (at 185) on thermal stability of Senjed peel aqueous extracts for different intervals is shown in Fig. 1. Up to 30 min heating time, extracts were almost stable, but after 40 min a gradual decrease in antioxidant activity was observed with the increase in heating period. The decrease in antioxidant activity was not significant ($p<0.05$) up to 40 min but became pronounced after 50 min heating time. At the 80 min heating interval, extracts exhibited 34.37% antioxidant activity (59.08% remaining antioxidant activity). Iqbal & Bhanger (2007) reported that the decrease in antioxidant activity methanolic extracts of garlic was not significant ($p< 0.05$) up to 40 min but became pronounced after 50 min heating time at 185 . The stability of some phenolic antioxidants against thermal oxidation was reported by Hamama & Nawar (1991) as follow: BHT > PG > BHA > TBHQ after 60 min heating at 185 . Comparing the results, it is observed that the thermal stability of Senjed peel aqueous extracts is higher than synthetic antioxidants. Liu et al. (2016) reported that as heating temperature and heating time increased, losses of TBHQ in palm oil increased due to increasing volatility of TBHQ. Losses of antioxidant activity, after longer heating times at high temperatures, may be due to vaporization and volatility, and various chemical reactions occurring during oxidation, leading to the formation of hydroperoxides, hydrolysis, polymerization, chemical decomposition, which lead to deterioration in oils and fats giving rancidity (Liu et al., 2016; Warner & Knowlton, 1997). These results reveal that Senjed peel aqueous extracts is a potential source of natural antioxidants, which is applicable in food systems even at high processing temperatures.

3.5. Qualitative properties of cold-pressed sesame oil with Senjed peel aqueous extract

3.5.1. Free fatty acids (FFA)

Free fatty acids (FFA) are the main products of oil hydrolytic, enzymatic and thermal hydrolysis that considered as an important marker to measure the rancidity and oxidative deterioration of the food/lipids. In addition to treatment, the effect of storage time on FFA% was also significant ($p<0.05$) as the value of FFA% increased as the storage period increased. Except for day 0 of storage, on the 15th, 30th and 45th day, there was significant difference between the treatments in terms of FFA% ($p<0.05$). The FFA% decreased as the concentration of extract was increased. The highest FFA% contents (5.21%) were observed in control group (T0) ($p<0.05$) on the 45th day while T750 and TTBHQ showed the lowest FFA contents (2.81% and 2.73%, respectively) on the same day of storage. Totally, except T0, FFAs content in cold-pressed sesame oil treatments was lower than Codex Alimentarius standards (Alimentarius, 1999) (Acid value: 4.0 mg KOH/g Oil). These results signify anti-oxidation activity of the Senjed peel aqueous extract.

Results of treatments (Fig. 2), revealed that T750 had better effect on reduction of FFA contents (e.g. 0.91, 1.72 and 2.81% on day 15, 30 and 45) comparing to the FFA% values of the positive reference group (TTBHQ) (0.75, 1.35 and 2.73% on day 10, 20 and 30) respectively.

Totally, except T0, FFAs content in cold-pressed sesame oil treatments was lower than Codex Alimentarius standards (Acid value: 4.0 mg KOH/g Oil), so we deduced that Senjed peel aqueous extract as a potential natural active ingredient, can improve the shelf life of oils and fats. Previously, Hussain et al. (2018); Iqbal & Bhanger (2007); Elaigwu et al. (2019), Jung et al. (2021), and Shahid et al. (2018) also claimed that antioxidant activity of sesame seed extracts, garlic extracts, leaf extracts of Neem, rosemary and garlic, and cinnamon extract exhibited the comparable reduction effect on FFA contents in different oil as compared with synthetic antioxidant.

3.5.2. Peroxide value (PV)

The PV measurement is a good indicator for the evaluation of oil quality in the initial stage of oil oxidation process (Hussain et al., 2018). By increasing the storage time, a gradual increase in peroxide value of all samples was observed (Fig. 2). At all stages, highest PV was observed for negative control sample (T0) followed by T100, T200, T500 and T750 respectively. Senjed peel aqueous extract at all concentrations

decreased the peroxide value of the cold-pressed sesame oil which concluded the good antioxidant and stabilizing ability. A regular increase in PV as a function of storage time was observed for all the samples at all intervals, but this increase was very slow for stabilized samples with Senjed peel aqueous extracts. PV of TTBHQ was lower than T750 initially; but became almost equal at the 45th day of storage. Generally, change in peroxide values

were in a concentration-dependent manner and the values for all samples correspond to normal Codex values (Alimentarius, 1999), which recommended a maximum PV of 15 meq $O_2 kg^{-1}$. A pattern similar to the results of our study was also observed by Hussain et al. (2018) and Iqbal & Bhanger (2007) that studied the effect of methanolic extract of sesame seed and garlic extracts on the stability of sunflower oil. They suggested that sesame seed extracts (1000 µL/100 ml oil) and garlic extract (1000 ppm) can be considered as BHT alternative.

3.5.3. P-anisidine value (P-AV)

P-anisidine value measures the secondary oxidation product of the oil and is important to check the oxidative quality of fats and oils. P-anisidine value for all the samples were determined up to 45 days of storage (Fig. 3). The results indicated that the use of Senjed peel aqueous extract resulted in significant inhibition of P-anisidine value. The negative control group (T0) exhibited the highest P-anisidine value (i.e. 2.98, 6.31 and 9.51 on 15, 30 and 45th day of storage) whereas the least P-anisidine value (i.e. 1.23, 2.55 and 3.11 on 15, 30 and 30th day of storage) were observed with positive control group TTBHQ. It is observed that the P-anisidine value increased slightly but steadily as storage time extended and indicated that P-anisidine value reduced as the concentration of extracts increased. According to Elaigwu et al. (2019), an acceptable P-anisidine value for well-refined oils is between 1 and 10 mmol kg^{-1}, whereas oils with high levels of polyunsaturated fatty acids might have higher levels even when fresh. Comparing the antioxidant potential of the positive control group (TTBHQ) with all treatments, T750 group represented the lowest P-anisidine value which was close to the TTBHQ group. Thus, Senjed peel aqueous extracts could be considered as a good natural antioxidants to stabilize the cold-pressed sesame oil.

3.5.4. Oxidative stability index (OSI)

The results showing the effect of Senjed peel aqueous extract compared to positive control (TBHQ) and negative control (T0) samples on the oxidative stability of cold-pressed sesame oil are presented in Fig. 4. There was statistically significant differences between different treatments ($p<0.05$). As expected, samples without the addition of any antioxidants (T0) were oxidized easily, and indicated the lowest OSI values (9.05 h). In contrast, samples containing synthetic antioxidants (TTBHQ) and the highest concentration of extract (T750) showed the highest index of oxidative stability index (both 15.39 h). As can be seen, with increasing the concentration of the extract, the oxidative stability of the oil samples increases and at a concentration of 750 ppm, it is equivalent to a sample containing synthetic antioxidant TBHQ. Except T100 treatment, the OSI values of oils with added Senjed peel aqueous extract or synthetic antioxidants were found to be significantly larger ($p< 0.05$) than that of the negative control oils (T0). Incorporation of soybean, cottonseed and rice bran oils with rosemary extract resulted significantly ($p< 0.05$) higher OSI values than that of oil with added synthetic antioxidant (BHA + BHT) (Yang et al., 2016).

4. Conclusion

From the present study, it was concluded that Senjed peel aqueous extract can stabilize cold-pressed sesame oil effectively at a concentration of 750 ppm. It inhibits the thermal deterioration of oil by improving its hydrolytic stability, inhibit the lipid oxidation and reduce the loss of polyunsaturated fatty acids (PUFAs). Senjed peel aqueous extract at concentration of 750 ppm has stabilization efficacy comparable to the common synthetic antioxidant TBHQ at its legal limit. Therefore, Senjed peel aqueous extract can be recommended as the potent source of natural antioxidant for the stabilization of food and food product, especially edible vegetable oils rich in unsaturated fatty acids.

Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Table 1. Chemical composition of Senjed (Elaeagnus angustifolia L.) fruit and cold-pressed sesame oil.

Cold-pressed sesame oil	Cold-pressed sesame oil	Senjed *(*Elaeagnus angustifolia L.*)* fruit	Senjed *(*Elaeagnus
Moisture and volatile matter (%)	0.27 ± 0.03	Protein (%)	4.69 ± 0.85
Refractive index (25)	1.465 ± 0.001	Fat (%)	0.49 ± 0.01
Iodine value ($g_I/100g_{\text{oil}}$)	111.81 ± 1.57	Moisture (%)	19.48 ± 0.17
Saponification value ($\text{mg}_{\text{KOH}}/g_{\text{oil}}$)	193.15 ± 2.65	Ash (%)	1.22 ± 0.02
OSI (h)	8.93 ± 0.54	Crude fibre (%)	21.05 ± 0.17
FFA (%, Oleic acid)	0.643 ± 0.02	Total titratable acidity (%)	7.53 ± 0.37
PV ($\text{meq}_{O2}/\text{Kg}_{\text{Oil}}$)	1.17 ± 0.03	Total soluble sugar (%)	47.73 ± 4.37
p-AV	0.85 ± 0.01	Yield of peel extract (%)	9.55 ± 0.35
Total chlorophylls ($\text{mg}/\text{Kg}_{\text{Oil}}$)	1.715 ± 0.001		
Total carotenoids ($\text{mg}/\text{Kg}_{\text{Oil}}$)	43.51 ± 0.129		

Data are mean ± SD of three replications.

Table 2. Total phenolic, flavonoid and antioxidant activities of Senjed peel (*Elaeagnus angustifolia* L.) aqueous extract.

Total phenolic content (TPC) (mg GAE/100 g FW)	Total flavonoid content (TFC) (mg CAE/100 g FW)	DPPH scavenging (%)
573.31 ± 3.57	151.33 ± 2.67	58.17 ± 2.33

GAE: Gallic acid equivalent, CAE: Catechin equivalent, FW: fresh weight.

Figure legends

Figure 1. Effect of heating treatment (185) on antioxidant activity of Senjed peel aqueous extracts as a function of heating time. Mean values followed by the same superscript letters are not significantly different ($p>0.05$). Data are mean +- standard deviation (n = 3).

Figure 2. Effect of different concentrations of Senjed peel extracts on free fatty acid (%FFA) content of cold-pressed sesame oil.

Figure 3. Effect of different concentrations of Senjed peel aqueous extracts on peroxide value of cold-pressed sesame oil.

Figure 4. Effect of different concentrations of Senjed peel aqueous extracts on P-anisidine value of cold-pressed sesame oil.

Figure 5. Effect of different concentrations of Senjed peel aqueous extracts on oxidative stability index (OSI) of cold-pressed sesame oil. Mean values followed by the same superscript letters are not significantly different ($p>0.05$).

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