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Effect of essential oils of chaville (*Ferulago contracta*), rosemary (*Rosmarinus officinalis*) and lavender (*Lavandula officinalis*) on the thermal stability of camelina oil under accelerated conditions

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ABSTRACT

Due to the beneficial effects of natural antioxidants, such as the essential oils of different plants, including retarding or preventing the oxidation of oil/fat-based foods, as compared to the synthetic ones, they have received much attention. In this study, the effect of the essential oils of chaville, rosemary and lavender (100, 300 and 500 ppm) extracted by the steam distillation method on the thermal stability of camelina oil extracted by the cold press method under accelerated conditions (storage at 65 °C for 14 days) compared to camelina oil containing the synthetic antioxidant TBHQ was investigated. Data were analyzed by one-way analysis of variance (ANOVA) using SPSS software version 22 and the means were compared by the Duncan multiple range test. The results showed that the type of essential oil, storage time as well as their interactive effect had a significant ($p<0.01$) effect on the peroxide, anisidine and TOTOX values, as their values increased significantly ($p<0.05$) with increasing storage time and decreased significantly ($p< 0.05$) as the concentration of essential oil increased. After 14 days of storage under accelerated conditions, the total oxidation value (TOTOX value), when using chaville and rosemary essential oils (500 ppm), indicated that the oxidative stability of camelina oil increased compared to the camelina oil containing synthetic antioxidant TBHQ, and that it was suitable for frying.

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1- Introduction

Plant seed oil has attracted much attention due to its high amount of polyunsaturated fatty acids (PUFAs) which have health benefits [1, 2]. On the other hand, oil seeds are of great importance, being the second largest source of food in the world following grains [3]. One of these sources is camelina seed (*Camelina sativa* L. belonging to the *Brassicaceae* family), which contains approximately 30-40% oil (dry weight). It has been reported that camelina seed oil (CSO) contains high amounts of unsaturated fatty acids (about 90% of fatty acids) as well as some important bioactives such as tocopherols, phytosterols and phenolic compounds [2]. Camelina oil is stable, clear, liquid and golden yellow with a slight mustard aroma. It has similar components to flaxseed oil and seems to be a substitute for flaxseed oil due to its high levels of ω-3 and ω-6 fatty acids (35-40%), protein (35-40%) and γ-tocopherol. In addition to food and therapeutic uses, it is used in industry as a biofuel and in cosmetics [4].

Edible oils are composed of about 92-98% triacylglycerides [1], containing various fatty acids. They also contain some other compounds such as free fatty acids [2], phospholipids [3], phytosterols [4], tocopherols [5], other antioxidants and waxes [6] [5]. Fatty acids free or bound to glycerol, are prone to oxidation. Therefore, one of the main challenges faced by the oil processing industry is maintaining the high quality of the product after processing until consumption [6, 7]. Unpleasant flavor and smell are among the most obvious changes observed during the oxidation process. However, changes in color, viscosity, density and solubility also occur. The changes have significant effects on the nutritional value and sensory quality of edible oils [7]. In the oil industry, various methods are used to prevent oxidation, including the addition of antioxidants [8, 9]. Since synthetic antioxidants have adverse effects on the human body such as mutagenesis and carcinogenesis, some of them are not used anymore. Therefore, it is necessary to produce natural antioxidants which not only improve the oxidative stability of edible oils, but increase their nutritional value. The sources of natural antioxidants are plant extracts or essential oils which can be found in most parts of the plant, such as fruits, nuts, seeds, leaves, roots and shells [9, 10]. For example, essential oils of plants such as chaville, rosemary and lavender can be used as natural antioxidants.

Chaville (*Ferulago contracta*) is a perennial plant belonging to the *Umbelliferace* family. The *Ferulago* genus has about 35 species, 7 of which are found in Iran. *F. contracta* species is exclusively found in Iran, mostly in the western regions, and is facing the danger of extinction [11]. Chaville has antioxidant properties and prevents lipid oxidation in food systems by binding free radicals. Phenolic compounds are the predominant natural antioxidants found in plants, and due to their reducing properties as well as their structure, they play an important role in trapping free radicals, transition metals, and removing singlet oxygen [12, 13].

Rosemary (*Rosmarinus officinalis*) belongs to the *Laminaceae* or *Labiatae* family. The leaves and flowering branches of the plant have medicinal properties. The flowering plant or its dry leaves are used to extract the essential oil [14, 15]. The main compounds include 8,1-cineole, borneol, camphor, bornyl acetate, α- and β-pinene, which show varying amounts depending on the geographical conditions of the plant cultivation area. Chemical compounds include rosmarinic acid, caffeic acid and salicylate, as well as other natural compounds including flavonoids and phenolic acids, diterpenes, triterpenes, tannins, bitter substances, resin, saponin, protein, fat, carbohydrate, fiber, some salts and vitamins [16].

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Lavender (*Lavandula officinalis* L.) belongs to the *Lamiaceae*. It is perennial, evergreen and native to Europe. Since it does not grow in Iran, it needs to be cultivated. The height of the plant is 30 to 60 cm, and the flowers are terminal complex clusters on the stem. Depending on the environmental and weather conditions of the region, the flowering time has been reported to be from late spring to September. Its essential oil, which is obtained by distillation of its flowers and flowering branches, is a yellow or pale yellow liquid, relatively bitter and pungent [17]. In addition to more than 16% of linalyl acetate, compounds such as butyric, propionic and valeric acids, as well as free linalool and gerambol are found in its essential oil [18].

There are various methods of extracting essential oils, such as solvent extraction, hydrolyzing enzymes, carbon dioxide and distillation [19]. Given the extensive use of essential oils in the food industry, it is necessary to find the best extraction method to improve the quality of essential oils in order to select the most suitable and environmentally friendly chemical compound for any specific application [20]. Among the extraction methods, hydrodistillation and steam distillation are the most common methods of extracting essential oils from plants [21]. In a study, the essential oils of three plants, chaville, rosemary and lavender, were extracted by two methods, hydrodistillation and steam distillation. The results showed that the efficiency and antioxidant compounds of the essential oils extracted by the steam distillation method were significantly ($P < 0.05$) higher than those of the essential oils obtained by the hydrodistillation method [22]. Since different plants have different chemical composition and the method of extracting the essential oil affects the quantity, quality and antioxidant nature of the essential oil [23, 24], and also considering different references [22], in the present study, the thermal stability of camelina oil extracted by the cold press method containing essential oils of chaville, rosemary and lavender (100, 300 and 500 ppm) extracted by the steam distillation method was investigated and compared with camelina oil containing 75 and 150 ppm of synthetic antioxidant TBHQ and the oil sample without any antioxidants under accelerated conditions (65 °C for 14 days).

2-Materials & Methods

2.1. Materials

Rosemary and lavender were obtained from the National Botanical Garden of Iran, and the cluster chaville plant in the flowering stage was obtained from Shafa Company (Kordestan, Iran). Chemicals including sodium hydroxide, acetic acid, etc. were purchased from a Merck company (Germany) representative.

2.2. Methods

2.2.1. Preparation of cluster chaville, rosemary and lavender plants and extraction of their essential oil

Chaville, rosemary and lavender were prepared, and their essential oils were extracted by the steam distillation method. The essential oil of 150 g of the sample dried in the shade was extracted in triplicate for 3 h. It should be noted that in this method, the plant should not be powdered or packed densely in the container, because it prevents the penetration of steam into the plant tissue [22].

2.2.2. Oil extraction from camelina plant

Camelina seeds were purchased from Seed and Plant Improvement Institute (Karaj) in July 2021 and sent to Shirreza factory (Yazd).

After removing the impurities and cleaning the seeds, oil was extracted by the cold press machine (rod-shaped meal). After settling the impurities, the oils were filtered and kept in dark containers in a freezer at -18 °C until analysis [25].

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The fatty acid composition of the camelina oil, analyzed by the gas chromatography technique, included myristic acid (0.07), palmitic acid (5.98), palmitoleic acid (0.1), stearic acid (2.39), oleic acid (17.2), linoleic acid (20.47), arachidic acid (1.7), linolenic acid (29.1), gadoleic acid (3.14), behenic acid (0.04), C20:2 (1.6), C22:2 (0.15), erucic acid (3.5), C22:0 (0.94), C24:1 (0.6), C22:5 (0.37), C24:0 (0.2) and total trans (T. Oleic + T. Le + T Ln) (0.18). Then, total oxidation value including peroxide, anisidine and TOTOX values under accelerated conditions (65 °C for 14 days) were measured.

2.2.3. Peroxide value

The peroxide value was measured according to the Iranian national standard No. 4179, calculated using Equation 1 and reported in mEqO2/Kg.

$$PV = \frac{1000 \times N \times V}{W} \quad (1)$$

Where N is the concentration of sodium thiosulfate solution, V is the volume difference of thiosulfate solution consumed and W is the weight of the sample (g).

2.2.4. Anisidine value measurement

Anisidine value was measured according to the Iranian national standard No. 4093. First, 0.5 g of oil reached the desired volume in a 25 mL flask. Then, 5 mL of the solution was mixed with 1 mL of 0.25% p-anisidine solution in glacial acetic acid and after 10 min its absorbance was read at a wavelength of 350 nm using a spectrophotometer (PerkinElmer Lambda 25 UV/Vis, USA). Finally, the p-anisidine value was calculated for each sample using Equation 2 and expressed in mL/g [27].

$$p - anisidine\ value = \frac{(25 \times (1.2As - Ab)}{m} \quad (2)$$

Where, as is the absorption of solution before reaction with p-anisidine solution, Ab is the absorption of solution after reaction with p-anisidine solution and m is the mass of sample.

2.2.5. Total oxidation value (TOTOX value) under accelerated conditions

Since the peroxide value is not sufficient for measuring the oxidation rate of oils, the TOTOX value, which is a measure of total oxidation, was also considered. To do so, the oil samples were placed in an oven at 65 °C for 14 d and the peroxide and anisidine values were measured on days 0, 7 and 14. The TOTOX value was calculated using Equation 3 [28].

$$\text{TOTOX value} = (AV + 2PV) \quad (3)$$

2.2.6. Statistical analysis

9 treatments including refined camelina oil samples containing the essential oils of chaville, rosemary and lavender plants (100, 300 and 500 ppm), 2 treatments including refined camelina oil samples containing synthetic antioxidant TBHQ (75 and 150 ppm) and a sample without any antioxidants (control) were prepared (Total = 12). The peroxide, anisidine and TOTOX values were measured in triplicate. Data were analyzed by one-way analysis of variance (ANOVA) using SPSS software version 22. Means were compared using the Duncan multiple range test and the results were reported as mean ± SD.

3- Results & Discussion

3.1. Results of peroxide value measurement under accelerated conditions

Peroxide value is a measure of peroxides and hydroperoxides produced in the initial stage of oxidative changes. Hydroperoxides, as the primary product of oil oxidation, can be converted into volatile or non-volatile secondary products which degrade the oil. The changes in the peroxide value of refined camelina oil without antioxidants containing different concentrations of essential oils of chaville,

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rosemary and lavender compared to the control sample during 14 days of storage under accelerated conditions are presented in Table 1. It was found that the type of essential oil, storage time and their interactive effect significantly ($p<0.01$) affected the peroxide value, as after 14 days of storage, the lowest (4.600) and highest (10.000) peroxide values were observed for the oil sample containing the synthetic antioxidant TBHQ (150 ppm) and the oil sample without antioxidants (control), respectively.

The peroxide value increased significantly ($p\leq 0.05$) as the storage time increased and decreased significantly ($p\leq0.05$) with increasing concentration of essential oils. The reason could be the high temperature of the environment which accelerated the production of primary oxidation products, i.e. hydroperoxides, and as a result, it caused an increase in the peroxide value and a decrease in the oxidative stability index of the oil, indicating the start of the oxidation chain reactions [9].

Table 1 Changes in the peroxide value of refined *Camelina sativa* oil (CSO) containing *Ferulago contracta* (FC), *Rosmarinus officinalis* (RO) and *Lavandula officinalis* (LS) essential oils (100, 300 and 500 ppm) and comparing it with samples containing synthetic antioxidant TBHQ (75 and 150 ppm) and without antioxidant (CSO) in accelerated conditions

Treatments	Storage		
	Day 1	Day 7	Day 14
Blank-CSO	0.784 ± 0.010^{Ca}	7.980 ± 0.200^{Ba}	10.000 ± 0.020^{Aa}
CSO-RO-100	0.000 ± 0.000^{Cb}	7.600 ± 0.110^{Bb}	8.400 ± 0.060^{Ad}
CSO-RO-300	0.000 ± 0.000^{Cb}	6.600 ± 0.010^{Bd}	7.451 ± 0.020^{Ae}
CSO-RO-500	0.000 ± 0.000^{Cb}	6.226 ± 0.012^{Be}	7.200 ± 0.040^{Ag}
CSO-LS-100	0.000 ± 0.000^{Cb}	7.058 ± 0.110^{Bc}	8.980 ± 0.100^{Ab}
CSO-LS-300	0.000 ± 0.000^{Cb}	6.274 ± 0.040^{Be}	8.723 ± 0.010^{Ac}
CSO-LS-500	0.000 ± 0.000^{Cb}	6.100 ± 0.050^{Be}	7.307 ± 0.010^{Af}
CSO-FC-100	0.000 ± 0.000^{Cb}	6.272 ± 0.000^{Be}	6.800 ± 0.010^{Ah}
CSO-FC-300	0.000 ± 0.000^{Cb}	6.104 ± 0.010^{Be}	6.600 ± 0.050^{Ai}
CSO-FC-500	0.000 ± 0.000^{Cb}	3.000 ± 0.190^{Bfg}	5.882 ± 0.010^{Aj}
CSO-TBHQ-75	0.000 ± 0.000^{Cb}	3.100 ± 0.070^{Bf}	5.050 ± 0.200^{Ak}
CSO-TBHQ-150	0.000 ± 0.000^{Cb}	2.900 ± 0.030^{Bg}	4.600 ± 0.070^{Am}

Different small letters in each column and different capital letters in each row indicate statistically significant ($p \leq 0.05$) differences.

Also, it was found that during the storage, there was a significant difference in the peroxide value between different treatments containing different concentrations of the essential oils. The oil samples containing higher essential oils content showed higher oxidative stability and the peroxide value decreased because with increasing concentration of essential oils, the amount of phenolic compounds increased, resulting in the production of more active groups to inhibit free radicals [29]. Our results are in agreement with the results obtained by Moradi et al. (2022) who reported that the natural antioxidant concentration (400 ppm of the essential oil of chaville) and temperature had a significant ($p<0.01$) effect on the peroxide

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value of sunflower oil and decreased the peroxide value [30]. The results obtained in this study are consistent with the results obtained by Ghezelsofloo and Seyyed-Alangi (2016) who investigated the effect of essential oil of celeriac on improving the oxidative stability of soybean oil at accelerated oxidation temperature (63 °C) and reported that as the storage time increased, a higher peroxide value was observed [31]. The results of the present study are consistent with the results obtained by other researchers. Dehlei et al. (2016) attributed the reduction of peroxide value to phenolic compounds and other antiradical compounds [32]. In previous studies, the addition of rosemary extract [33], strawberry leaf extract [34] and olive leaf extract [35] to sunflower oil reduced the peroxide value and increased the stability of sunflower oil against oxidation reactions. The peroxide value cannot be an indicator of oil oxidation, because it indicates the presence of primary oxidation products and does not indicate the amount of secondary products. Due to the decomposition of hydroperoxides at high temperatures and the formation of secondary compounds such as aldehydes, a test such as the anisidine value, which is an indicator of oxidation, seems necessary [36].

3.2. Results of anisidine value measurement under accelerated conditions

The p-anisidine value is a measure of the production of secondary products of oxidation of edible oils and fats, which are produced during the decomposition of hydroperoxides into carbonyls, aldehydes and ketones, resulting in a rancid aroma in the oil [37]. The changes in the anisidine value of refined camelina oil without antioxidants containing different concentrations of the essential oils of chaville, rosemary and lavender compared to the control sample during 14 days of storage under accelerated conditions are presented in Table 2. The results showed that the type of essential oil, storage time as well as their interactive effect significantly ($p < 0.01$) affected the anisidine value. As the storage time of the samples increased, the anisidine value increased significantly ($p<0.05$) and as the concentration of essential oils increased, it decreased significantly ($p<0.05$) as after 14 days of storage, the lowest (9.900) and highest (25.892) anisidine values were found for the oil sample containing 500 ppm of the essential oil of chaville and the oil sample without antioxidants containing 100 ppm of the essential oil of lavender, respectively, which were significantly ($p \leq 0.05$) different from other treatments, indicating the effect of heating on increasing the rate of production of secondary oxidation products. In general, the addition of essential oil caused a significant ($p<0.05$) decrease in the anisidine value of the oil samples after 14 days of storage compared to the control sample, as on day 14, the T10 treatment (camelina oil containing 500 ppm of the essential oil of chaville) was more effective in preventing the production of secondary oxidation products compared to the synthetic antioxidant TBHQ and other different concentrations of the studied essential oils. Our results were in agreement with the results obtained by Moradi et al. (2022) who reported that the lowest anisidine value was observed for the sunflower oil sample containing 400 ppm of the ethanolic extract of chaville compared to other treatments containing the synthetic antioxidant TBHQ and aqueous extract of chaville [30]. Our results are in consistence with the results obtained by Tahami et al. (2011) who stated that the antioxidant effect of fennel seed extract on the stability of sunflower oil in the first week (300 ppm) indicated a higher efficiency compared to synthetic antioxidants, which decreased the anisidine value (first week = 7 and fourth week = 17.5) [38].

The results of previous studies also revealed that the addition of rosemary plant extract to sunflower oil [33] and the use of

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mangosteen peel [37] could reduce the of p-anisidine value and increase the stability of sunflower oil under accelerated conditions against secondary oxidation products.

Table 2- Changes in the anisidine value of refined Camelina sativa oil (CSO) containing Ferulago contracta (FC), Rosmarinus officinalis (RO) and Lavandula officinalis (LS) essential oils (100, 300 and 500 ppm) and comparing it with samples containing synthetic antioxidant TBHQ (75 and 150 ppm) and without antioxidant (CSO) in accelerated conditions

Treatments	Storage		
	Day 1	Day 7	Day 14
Blank-CSO	5.576 ± 0.060^{Ca}	7.948 ± 0.030^{Bb}	16.158 ± 0.030^{Ah}
CSO-RO-100	1.106 ± 0.010^{Cc}	4.757 ± 0.040^{Bc}	16.305 ± 0.080^{Ag}
CSO-RO-300	0.000 ± 0.000^{Ch}	4.554 ± 0.040^{Bd}	16.289 ± 0.070^{Ag}
CSO-RO-500	0.000 ± 0.000^{Ch}	2.398 ± 0.080^{Bf}	15.038 ± 0.050^{Ai}
CSO-LS-100	0.321 ± 0.010^{Ce}	2.308 ± 0.010^{Bg}	25.892 ± 0.080^{Aa}
CSO-LS-300	0.210 ± 0.008^{Cf}	1.892 ± 0.010^{Bh}	24.770 ± 0.060^{Ab}
CSO-LS-500	0.123 ± 0.002^{Cg}	1.709 ± 0.080^{Bi}	16.83 ± 0.020^{Af}
CSO-FC-100	0.000 ± 0.000^{Ch}	1.750 ± 0.004^{Bk}	19.705 ± 0.010^{Ae}
CSO-FC-300	0.000 ± 0.000^{Ch}	1.290 ± 0.000^{Bk}	12.558 ± 0.040^{Aj}
CSO-FC-500	0.000 ± 0.000^{Ch}	0.634 ± 0.060^{Bj}	9.900 ± 0.090^{Ak}
CSO-TBHQ-75	1.758 ± 0.040^{Cb}	9.646 ± 0.050^{Ba}	24.444 ± 0.050^{Ac}
CSO-TBHQ-150	1.054 ± 0.020^{Cd}	3.730 ± 0.060^{Be}	21.141 ± 0.050^{Ad}

Different small letters in each column and different capital letters in each row indicate statistically significant ($p \leq 0.05$) differences

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3.3. Results of TOTOX value measurement under accelerated conditions

The anisidine value determines the amount of aldehydes, especially 2-alkynals in animal and vegetable oils and fats. It is obvious that in some cases, oil oxidation is in the early stages where the volatile compounds of aldehydes and ketones, which are identified by the anisidine value, have not been formed yet. Whereas, peroxide is the first product of the oxidation reaction. When determining the stability of products containing fat, it is observed that the peroxide value first increases and then decreases as a result of the decomposition of hydroperoxides. The TOTOX value determines both the amount of hydroperoxides and the products of their breakdown. It tends to increase continuously and is a better measure of the progressive oxidative degradation of fat [30], as a lower TOTOX value indicates greater stability of the oil against oxidation [39].

The changes in the TOTOX value of refined camelina oil without antioxidants containing different concentrations of essential oils of chaville, rosemary and lavender compared to the control sample during 14 days of storage under accelerated conditions are presented in Table 3. The results showed that the type of essential oil, storage time and also their interactive effect had a significantly ($P<0.01$) affected the

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TOTOX value. Also, the results showed that as the storage time increased, the TOTOX value increased significantly ($p < 0.05$) and as the concentration of essential oils increased, it decreased significantly ($p < 0.05$), as after 14 days of storage, the lowest (21/664) and highest (43.852) TOTOX values were observed for the oil sample containing 500 ppm of the essential oil of chaville and the oil sample without antioxidants containing 100 ppm of essential oil of lavender, respectively, being significantly ($p \leq 0.05$) different from other treatments.

Table 3 Changes in the TOTOX Value of refined *Camelina sativa* oil (CSO) containing *Ferulago contracta* (FC), *Rosmarinus officinalis* (RO) and *Lavandula officinalis* (LS) essential oils (100, 300 and 500 ppm) and comparing it with samples containing synthetic antioxidant TBHQ (75 and 150 ppm) and without antioxidant (CSO) in accelerated conditions

Treatments	Storage		
	Day 1	Day 7	Day 14
Blank-CSO	7.145 ± 0.080^{Ca}	23.908 ± 0.430^{Ba}	36.158 ± 0.010^{Ac}
CSO-RO-100	1.106 ± 0.010^{Cc}	19.957 ± 0.240^{Bb}	33.105 ± 0.040^{Ae}
CSO-RO-300	0.000 ± 0.000^{Ch}	17.754 ± 0.260^{Bc}	31.191 ± 0.110^{Af}
CSO-RO-500	0.000 ± 0.000^{Ch}	14.850 ± 0.066^{Bf}	29.438 ± 0.130^{Ah}
CSO-LS-100	0.511 ± 0.008^{Ce}	16.426 ± 0.025^{Bd}	43.852 ± 0.280^{Aa}
CSO-LS-300	0.321 ± 0.010^{Cf}	14.441 ± 0.009^{Bg}	42.217 ± 0.040^{Ab}
CSO-LS-500	0.123 ± 0.002^{Cg}	13.909 ± 0.180^{Bh}	31.451 ± 0.050^{Af}
CSO-FC-100	0.000 ± 0.000^{Ch}	12.469 ± 0.024^{Bi}	33.305 ± 0.030^{Ae}
CSO-FC-300	0.000 ± 0.000^{Ch}	12.209 ± 0.022^{Bi}	25.758 ± 0.060^{Ai}
CSO-FC-500	0.000 ± 0.000^{Ch}	6.634 ± 0.440^{Bk}	21.664 ± 0.070^{Aj}
CSO-TBHQ-75	1.054 ± 0.020^{Cd}	15.446 ± 0.110^{Be}	34.544 ± 0.450^{Ad}
CSO-TBHQ-150	1.758 ± 0.040^{Cb}	9.9300 ± 0.200^{Bj}	30.341 ± 0.190^{Ag}

Different small letters in each column and different capital letters in each row indicate statistically significant ($p \leq 0.05$) differences.

Since the TOTOX value represents the total oxidation of oil, and heat changes the rate of total oxidation, high temperature can affect the TOTOX value. In addition to increasing the TOTOX value, it can also lead to an increase in the peroxide and anisidine values [30].

Similarly, Mazaheri Kalharoodi et al. (2013) stated that the addition of fennel seed extract (100, 200, 300, 400, 500, 600, 700 and 800 ppm) to soybean oil reduced the TOTOX value of oil samples [40]. Our results are in agreement with the results obtained by Moradi et al. (2022) who reported that the lowest peroxide, anisidine and TOTOX values were found for the sample containing 400 ppm of the essential oil of chaville and the highest peroxide, anisidine, TOTOX values were observed for the control sample. The results demonstrated the beneficial effect of the essential oil of chaville on the stability of sunflower oil and its superiority over synthetic antioxidants [30]. Similar results were obtained in another study. Ranjbar and Kiaeifar (2021) evaluated the antioxidant effect of phytochemical compounds of the extract and essential oil

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of lavender on the stability of sunflower oil and stated that the methanolic extract with the lowest amount of peroxide, anisidine and TOTOX values had the best effect on inhibiting the oxidation of sunflower oil. The effect of aqueous extract and essential oil was similar to that of synthetic antioxidant. The effect of hexane extract was lower than that of synthetic antioxidants, and its aqueous extract and essential oil can also be used as antioxidants similar to synthetic antioxidants [41]. Ganjloo et al. (2018) studied the effect of pea pod extract on the oxidative stability of sunflower oil under accelerated conditions. The results revealed that after storage for 24 days under accelerated conditions, the maximum peroxide, anisidine and TOTOX values were found for the control sample (sunflower oil sample without synthetic antioxidant and pea pod extract) (185, 37 and 407 $mEqO_2$/kg of oil, respectively). The values observed for the oil sample containing the minimum concentration of the ethanolic extract of pea pod were 128.2, 28 and 260 $mEqO_2$/kg of oil. The results suggested that the addition of ethanolic extract of pea pod at a concentration of 1000 ppm to sunflower oil was more effective than the synthetic antioxidant BHT at the maximum permitted concentration (200 ppm) [28].

4- Conclusion

In this study, the oxidative properties of refined camelina oil containing essential oils of chaville, rosemary and lavender (extracted by the steam distillation method) compared to the camelina oil sample containing synthetic antioxidant TBHQ and without any antioxidants (control) were investigated. The results showed that the type of essential oil, storage time and their interactive effect significantly ($p < 0.01$) affected the peroxide, anisidine and TOTOX values. As the storage time increased, the peroxide, anisidine and TOTOX values increased significantly ($p < 0.05$) and with increasing concentration of essential oils, they significantly ($p < 0.05$) decreased. In general, the addition of natural (essential oil of chaville, rosemary and lavender) and synthetic (TBHQ) antioxidants to the refined camelina oil samples compared to the control sample (without any antioxidants) reduced the rate of oxidation, and increased concentration of essential oils as well as storage under accelerated conditions caused the heat stability of the camelina oil. After 14 days of storage under accelerated conditions (65 °C), the TOTOX value (total oxidation) indicated that the essential oil of chaville and rosemary (500 ppm) could increase the oxidation stability of the camelina oil and the camelina oil was suitable for frying.

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مقاله علمی_پژوهشی

بررسی اثر اسانس گیاهان چویل (*Ferulago contracta*) ، رزماری (*Rosmarinus officinalis*) و اسطوخودوس (*Lavandula officinalis*)بر پایداری حرارتی روغن کاملینا تحت شرایط تسریع شده

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چکیده

امروزه به دلیل اثرات مطلوب آنتی‌اکسیدان‌های طبیعی از قبیل اسانس گیاهان مختلف و به تأخیر انداختن یا جلوگیری از اکسیداسیون موادغذایی بر پایه روغن یا چربی، به جای آنتی‌اکسیدان‌های سنتزی، مورد توجه زیادی قرار گرفته است. در این مطالعه اثر استفاده از اسانس گیاهان چویل، رزماری و اسطوخودوس استخراج شده به روش تقطیر با بخار آب (در سه سطح ۱۰۰، ۳۰۰ و ۵۰۰ پی‌پی‌ام) بر پایداری حرارتی روغن کاملینای استخراج شده به روش پرس سرد، در شرایط تسریع شده (نگهداری روغن در دمای ۶۵ درجه سانتیگراد به مدت ۱۴ روز) در مقایسه با روغن کاملینای حاوی انتی اکسیدان سنتزی TBHQ مورد بررسی قرار گرفت. تجزیه و تحلیل داده‌ها توسط آزمون‌های آماری آنالیز واریانس یک‌طرفه (ANOVA) در نرم‌افزار SPSS25 و مقایسه میانگین‌ها با استفاده از آزمون چنددامنه‌ای دانکن انجام گرفت. نتایج نشان داد که نوع اسانس، زمان نگهداری و همچنین اثر متقابل آنها تأثیر معنی‌داری ($p<۰/۰۱$) بر عدد پراکسید، انیزیدین و توتوکس داشت بطوریکه با افزایش زمان نگهداری نمونه‌ها عدد پراکسید، آنیزیدین و توتوکس افزایش معنی‌داری ($p<۰/۰۵$) و با افزایش میزان غلظت اسانس‌ها، کاهش معنی‌داری ($p<۰/۰۵$) یافت. بعد از ۱۴ روز نگهداری در شرایط تسریع شده، با توجه به نتایج مربوط به اکسایش کل (عدد توتوکس)، با استفاده از اسانس چویل و رزماری (در سطح ۵۰۰ پی‌پی‌ام) میزان مقاومت اکسایشی روغن کاملینا نسبت به نمونه‌های روغن کاملینای حاوی آنتی اکسیدان سنتزی TBHQ، افزایش یافت و ماندگاری و استفاده از روغن کاملینا جهت سرخ کردن، مناسب گردید.

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