



Effect of Added Black Cumin Seed (*Nigella sativa L*) Oil on Oxidative Stability of Flaxseed Oil

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Authors' contributions

This work was carried out in collaboration among all authors. Author SA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors ABK and BK managed the analyses of the study. Author EH managed the literature searches. All authors read and approved the final manuscript

Article Information

DOI: 10.9734/AFSJ/2019/v7i429975

Editor(s):

(1) Dr. Chouitah Ourida, Professor, Department of Biology, University of Mascara, Algeria.

Reviewers:

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(4) Tapiwa Edward Manyarara, University of Zimbabwe, Zimbabwe.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/47397>

Original Research Article

Received 07 November 2018

Accepted 28 February 2019

Published 15 March 2019

ABSTRACT

Background: Lipid oxidation has adverse effect on food deterioration and human health. Oxidative reactions limit the shelf-life of fresh and processed foodstuffs which are of great concern in the vegetable oil and fat industry.

Aim: The antioxidant activity of Black Cumin (*Nigella sativa L*) Oil (BCO) as a source of natural antioxidants was compared against a synthetic antioxidant (BHA). Its oxidative stability was evaluated in Flaxseed oil (as the most sensitive oil against oxidation) in concentrations of BHA (200ppm).

Study Design: Oils were analyzed for the composition of fatty acids, tocopherols and for some physicochemical properties [Peroxide (PV), P-Anisidine (AV), TOTOX values, Thiobarbituric acid, Iodine value, Oxidative stability (OS) and Refractive index] to assess the extent of oil deterioration during 30th days of storage.

Place and Duration of Study: Islamic Azad University of Varamin and Tehran University, Tehran,

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Iran, From March 2018 to April 2018.

Methodology: Optimal condition was investigated to protect edible oil like flaxseed oil from oxidative reaction. Black cumin seeds and flaxseeds were pressed separately by cold press. Then BCO was prepared at five concentration levels of 5, 10, 15, 20 and 25% (w/w) and added to Flaxseed oil. In terms of antioxidant activity, they were analyzed by Gas Chromatography and compared with sample containing 200 ppm of synthetic antioxidant (BHA) during 30th days at ambient temperature (22-25° C).

Results and Conclusion: The results showed that different levels of BCO were able to slow down the lipid oxidation well, but the effect of sample contained 5% BCO was higher than other levels and has potential source of natural antioxidant for the application in food industry to prevent lipid oxidation.

Keywords: *Flaxseed oil; black cumin seed oil; cold press; oxidative stability; physicochemical properties; gas chromatography.*

1. INTRODUCTION

Flaxseed oil also known as flax oil an edible oil obtained from the flax plant (*Linum usitatissimum*). Flaxseed oil is used as a nutritional supplement and contains the highest level of α -Linolenic acid (ALA), (51.9–55.2%) among vegetable oils [1]. Since flaxseed oil contains high amount of di- and tri-unsaturated ester, it is easily oxidized and rapidly becomes rancid, with an unpleasant odour. In order to use the nutritional benefits of this oil, antioxidants can be used to enhance its oxidative stability [2].

Lipid oxidation leads to the spread of off-flavors and undesirable tastes which result in shorter shelf life [3]. Oxidative reactions diminish the shelf-life of fresh and processed foodstuffs which are of great concern in the vegetable oil and fat industry. The highly oxidized oils could have toxic effects on human health and, therefore, these oils are not suitable for nutritive purposes because of reaction products [4,5]. Due to unfavorable effects on food degradation and human health, development of the exogenous antioxidants are required to prevent not only the harmful effects of free radicals on health related problems, but also the deterioration of fats and other compounds of food stuffs [6].

Traditionally, chemically synthesized compounds, such as butylated hydroxyanisole (BHA) Butylated hydroxytoluene (BHT) and tert-butyl hydroquinone (TBHQ) are widely used as antioxidants in oil products [7]. Nevertheless, it has been found that these synthetic antioxidants have carcinogenic and toxic effects on human health. For example, BHT causes hepatomegaly – the enlargement of the liver [8]. Therefore, research on natural antioxidants with lower toxicity than synthetic compounds has to be carried out. Natural antioxidants are constituents

of many fruits and vegetable, which have attracted a great deal of public and scientific attention due to their anti-carcinogenic potential and other health promoting effects. Consumers have become more health conscious about the use of additives and the quality of diet they take. This has evolved the food industry to replace synthetic antioxidants with antioxidants that are safer and come from natural origins. This has led to an increase in the investigation to find resources that are rich in natural antioxidants [9]. This fact has been proven that many plants contain natural antioxidants [10,11,12]. The antioxidant activity of Chamomile (*Matricaria chamomilla L.*) extract (as natural resources) in sunflower oil has been reported [13]. A study has been reported the antioxidant activity of some plant extracts of the Labiatae family, stored at 75°C [14]. The antioxidant activity of the extract of ajowan seeds in an accelerated storage test using soybean oil was studied [15]. In another research, the antioxidant activity of some selected plant extracts in rapeseed oil was investigated [9]. The antioxidant effects of thyme in rapeseed oil, at 40°C, have also been stated [16]. The antioxidant activity of sage and oregano in salad dressing was investigated [17]. In another study, the effects of heat treatment on the antioxidant activity of extracts from citrus peel was examined [18]. The antioxidant effects of some natural compounds have also been reported under microwave heating of vegetable oils [19]. In another review some characteristics of nigella (*Nigella sativa L.*) seed cultivated in Egypt and its lipid profile were studied [20]. Oxidative stability of virgin olive oil was investigated by addition of *Microalga chlorellavulgaris* biomass [21].

Black Cumin (*Nigella sativa L*) is an annual herbaceous plant belonging to the Ranunculacea family. It mainly contains linoleic acid, oleic acid,

palmitic acid, and other minor components [22]. Aromatics include thymoquinone, dihydrothymoquinone, *p*-cymene, carvacrol, α -thujene, thymol, α -pinene, β -pinene and *trans*-anethole. The seeds also contain thymoquinone. [23]. They have been used for thousands of years as a spice and food preservative. Black cumin seed is widely grown in the Mediterranean countries, Middle East, Eastern Europe and Western Asia. The seeds are used as seasoning for vegetable, legumes and different types of baked products.

In the Middle East, Northern Africa and India, it has been applied for centuries in order to treat asthma, cough, bronchitis, headache, rheumatism, fever, influenza and eczema and for its antihistamine, antidiabetic and anti-inflammatory activities [24].

In this study, the effect of added BCO at different levels (as a source of natural antioxidants) on Flaxseed oil (as the most sensitive oil against oxidation) was studied in order to investigate the physicochemical properties and oxidative stability.

2. MATERIALS AND METHODS

Black cumin (*Nigella sativa* L) and Flaxseed (*Linum usitatissimum*) were purchased from Pakan Bazr Co. Isfahan, Iran. Butylated Hydroxyanisole (BHA), *Potassium iodate*, Acetic acid (glacial), Sodium thiosulfate, Hexane and Acetonitrile HPLC Grade were purchased from Merck Chemical Co, Germany. All others unlabeled chemicals and reagent were used analytical grade.

2.1 Oil Extraction

Black cumin seeds and flaxseeds were cleaned and pressed separately (cold press, P500R, Germany) at room temperature (25°C) without any thermal treatment. Mesilla was stored for one at room temperature to separate oil phase from Mesilla then oil was filtered over anhydrous sodium thiosulphate and cotton filter using glass funnel.

2.2 Samples Preparations

After oils extraction, Black Cumin seed Oil (BCO) was prepared at five concentration levels of 5, 10, 15, 20 and 25% (w/w) and then added to Flaxseed oil. Samples were stored at ambient temperature in amber glass containers until analysis. In terms of antioxidant activity, they

were compared with sample containing 200 ppm of synthetic antioxidant (BHA) during thirty days (1, 10, 20 and 30th) at ambient temperature (22-25°C). In addition, the flaxseed oil was considered as control sample (Table 1).

Table 1. Treatments examined in the study

Samples	BHA	BCO
Control (C)	0%	0%
B	200 PPM	0%
A1	0%	5%
A2	0%	10%
A3	0%	15%
A4	0%	20%
A5	0%	25%

Key: Control sample contained Flaxseed oil, B sample contained 200 ppm BHA as of synthetic antioxidant, A1 sample contained 5% BCO, A2 sample contained 10% BCO, A3 contained 15% BCO, A4 contained 20% BCO, A5, contained 25% BCO

2.3 Analytical Methods

2.3.1 Identification of fatty acid composition, triacylglycerol's and tocopherols of BCO

To determine the fatty acid composition, the methyl ester derivative was prepared according to AOAC standard No. 969/33. Then they were analyzed by Younglin ACME 6100 Gas Chromatography equipped with a flame ionization detector on a 100-metre (cp sill 88) capillary column in accordance with AOCS cele - 91 [25]. The temperature of the injector, capillary column and detector were 240, 198, and 280°C, respectively. The carrier gas flow rate (nitrogen) was 14 mL / min, Pressure 10 psi and the injection rate was 1 μ L [26]. Fatty acid composition was expressed as weight percent (%) of total fatty acid methyl ester.

Tocopherols (α , β , γ and δ tocopherols) were analyzed by high-performance liquid chromatography (HPLC) with UV -visible detection in accordance with AOCS 8-89 (1993). For this purpose, a 5-60 SI column with a diameter of 4.5 \times 250 mm and a particle size of 5 μ m was used with fluorescence detector. The mobile phase consisted of acetonitrile/distilled water (95:5, v/v) at a flow rate of 0.6 mL/min and the injection volume 20 μ L. Tocopherols were identified and quantified using Calbiochem tocopherols (Merck, Darmstadt, Germany) as external standards. The amount of tocopherols in the oils was calculated as mg tocopherols per kg oil.

2.3.2 Determination of physical and chemical properties of samples

Iodine value was evaluated by *Hanus method*. Reflective index (RI) measured using Abbe' Refractometer at 20 °C and conducted according to AOCS Cc 7-25 (AOCS, 2005).

2.3.2.1 Oxidation stability tests

Peroxide values (PV) of oil samples were according to AOCS Cd 8-53 (AOCS, 2005). P-Anisidine value assay was carried out according to AOCS Cd 18-90 (AOCS, 2005). Total oxidation (TOTOX) values of oil samples were determined using the following equation: [27]

$$\text{Total oxidation (TOTOX) value} = 2 \times \text{PV} + \text{AV}$$

2.3.2.2 Oxidative Stability (OS)

In addition, Oxidation stability was measured with a Rancimat 743 apparatus (Metrohm Co., Basilea, Switzerland) according to AOCS Official Method (1997) Cd 12b-92 to determine the induction time for samples. The temperature was set at 110 °C and 20 L/h air flow, the oil sample was 2.5 g and the stability was expressed as oxidation induction time (h). Measurement of Thiobarbituric acid was carried out using butanol as a mobile solvent coupled with the Thiobarbituric acid reagent at a wavelength of 530 nm in compliance with AOCS Cd 19-90. (AOCS, 2005).

2.4 Statistical Analysis

The results of all tests were analyzed by comparison of mean values using a factorial model at $p < 0.01$ with SPSS software (version 21). Duncan's multiple range tests were conducted to determine the statistical differences among different means. In addition, all charts were drawn using Excel software. All tests were performed in three replications.

3. RESULTS AND DISCUSSION

3.1 Fatty Acids, Tocopherols' Composition of BCO

Table 2 reports the results of BCO fatty acid composition. According to the consequences the major fatty acids in BCO were Palmitic (C16:0, Behenic (C22: 0) and Stearic (C18:0) as saturated fatty acids, while oleic (C18: 1) and

linoleic (C18: 2n-6) were the main unsaturated fatty acids. Likewise, measurable amounts of myristic and arachidic (C20:0) as saturated fatty acids as well as palmitoleic (C16:1) as mono-unsaturated fatty acids and Linoleic acid as a polyunsaturated fatty acid were detected. These results are in agreement with previously published data [28,29,30]. The total saturated and unsaturated fatty acids in BCO extracted by cold press were 19.14 and 80.73%, respectively.

Table 2. Fatty acid composition of BCO as affected by cold press

Fatty acids	Percentage (%)
C14:0	0.07
C16:0	10.44
C18:0	3.56
C20:0	0.44
C22:0	4.63
C20:1	0.63
C16:1	0.36
C18:1	24.56
C18:2c	54.27
C18:2t	0.43
C18:3	0.48

The different tocopherol isomers, that is, alpha (α), beta (β), gamma (γ), and delta (δ), are distinguished by the locations of methyl groups on the chromanol ring. Tocopherol content of BCO is given in Table 3. The highest content was referred to γ -tocopherol with levels 241.72 ppm. However, β -tocopherol was the lowest tocopherol isomer found in BCO (6.29 ppm). This result was lower than those reported by another study earlier [31].

Table 3. Levels of Tocopherols (mg/kg) in BCO

α Tocopherol	16.4
β Tocopherol	6.29
γ Tocopherol	241.72
δ Tocopherol	9
Total Tocopherols	273.41

3.2 Physical and Chemical Properties of Samples

3.2.1 Refractive Index (RI)

Mean values of data demonstrated that the highest reduction in Refractive Index over time was occurred in the control sample (C) which reached from 1.479 in the first day to 1.473 in the

30th day. As can be seen in Fig. 1, when synthetic antioxidant was added in flaxseed oil, the change in refractive index was lesser than control sample. However, the minimum reduction in the refractive index was observed in the treatment containing 5% BCO during the storage period ($p < 0.01$).

3.2.2 Iodine value

Iodine values are often used to determine the amount of unsaturation in fatty acids. According to the results, along with the increase in the amount of BCO in flaxseed oil from 5 to 25%, iodine number decreased over time. However, the least reductions in iodine value occurred in sample containing 5% BCO on 30th day. Besides,

the highest reduction in iodine number was observed in the treatment contained 25% BCO.

3.2.3 Impact of extraction method and storage on Oxidative Stability (OS) of flaxseed oil containing BCO

According to the result, induction periods of different samples were in the range of 2.56 to 1.01 h. The results of induction period showed that sample containing 5% BCO was the highest (2.56 h) and control sample was the lowest (1.01 h). However, the use of 5 to 10% of BCO in flaxseed oil had a greater effect on the induction periods compared with treatment containing of synthetic antioxidant (BHA) (Fig. 2).

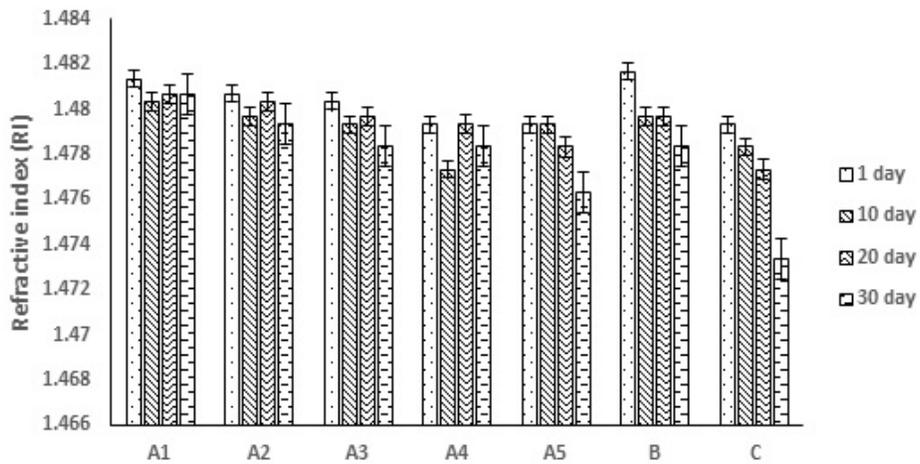


Fig. 1. Changes in refractive index (RI) of treated flaxseed oil samples at different storage time (1, 10, 20 and 30th days)

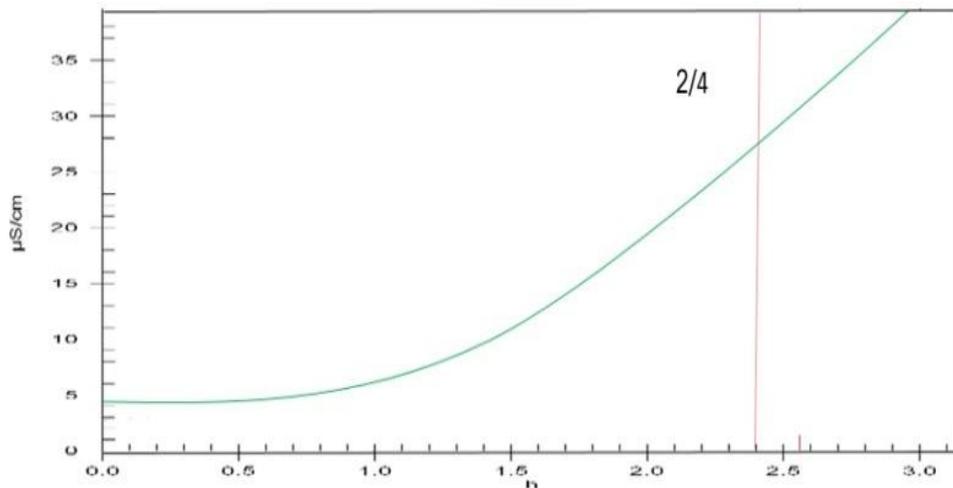


Fig. 2. Rancimat test for treatment contained 5% of BCO

3.2.4 Peroxide Value (PV)

According to the hypothesis of this study, BCO was considered as a natural antioxidant to slow down the lipid oxidation. Hydroperoxide is the primary product of lipid oxidation; therefore, determination of PV can be used as oxidative index during the early stage of lipid oxidation [32,33]. The PV calculated for samples are shown in Fig. 3. All samples showed more antioxidant activity in comparison with control sample after 1, 10, 20 and 30th days ($p < 0.01$). However, the peroxide value of the treatment contained BCO (5 %) in the whole of storage time was lesser than other samples ($p < 0.01$). The results also revealed that, with increase of amount of BCO in flaxseed oil from 5 to 25 %, the total amount of peroxide value was regularly expanded. This can be attributed to the amount of unsaturated fatty acids in BCO. The total increase in PV was followed in descending order by Control sample $> A5 > A4 > A3 > B > A2 > A1$ with maximum 4.38, 3.79, 2.43, 2.14, 1.99, 1.34 and 0.6 meq O₂ / kg of oil respectively in 30th day ($p < 0.01$). However, the treatment contained 5% of BCO has had a superior activity in terms of delaying the hydroperoxides formation comparing to the sample contained BHA (Fig. 3). As it could be seen results show a considerable effect made by BCO, approving the hypothesis of this research.

3.2.5 P-Anisidine Values (AV)

Generally, The AV of all the samples increased in a regular pattern over the storage time (Fig. 4).

Under accelerated storage for 30th days, the total increased of AVs were in the following sequence: A3>A4>A5>C>B>A2>A1 with maximum values of 3.73, 3.72, 3.56, 3.49, 3.22, 2.98 and 2.64 respectively in 30th day. This could be explained that A1 and A2 treatments were more effective than B sample in retarding the formation of secondary oxidation products compared to primary oxidation products. The AV of all the samples raised in a regular pattern over the storage time (Fig. 4).

3.2.6 Total Oxidation (TOTOX) values

As can be seen in Fig. 5, the TOTOX values of all the samples increased in a regular pattern over the storage time. On the first day, the least TOTOX values was related to sample containing 5% BCO with a value of 2.48 and the highest was referred to treatment contained 25% BCO with a value of 6.72%. Over the time, the TOTOX value increased in all treatments. Under accelerated storage for 30th days, the total increased of TOTOX values were in the following sequence: Control sample $> A5 > A4 > A3 > B > A2 > A1$ with maximum 12.26, 11.13, 8.58, 8.01, 7.21, 5.66, and 3.84 respectively in 30th day. The results showed that, in samples with lower levels of BCO (samples A1, A2), the TOTOX value was increased slower than the other treatments. However, optimum concentration of BCO (sample contained 5% BCO) had better preventing effects on retarding oil degradation compared with synthetic antioxidant ($p < 0.01$).

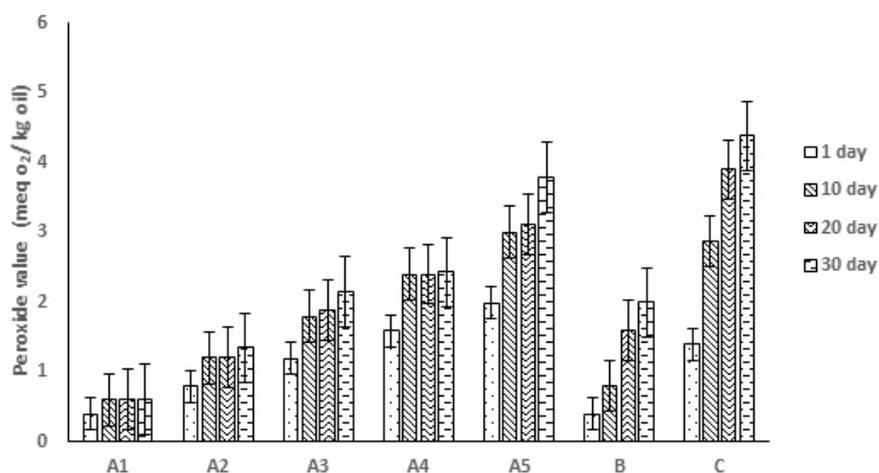


Fig. 3. Changes in Peroxide Value (PV) of treated flaxseed oil samples at different storage time (1, 10, 20 and 30th days)

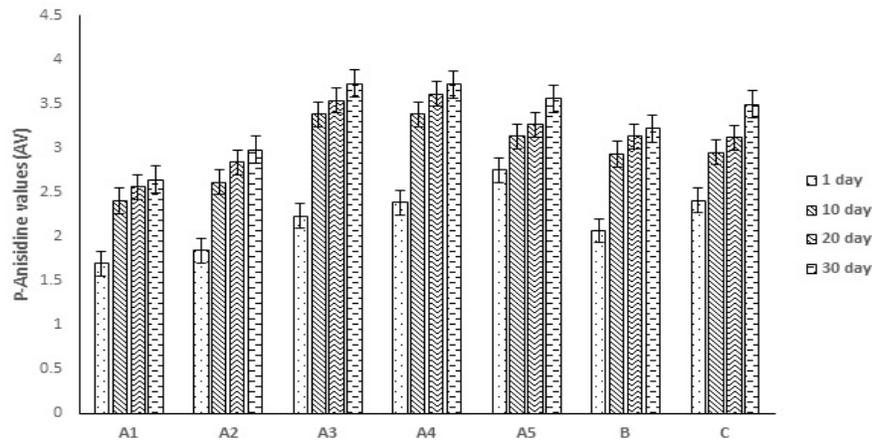


Fig. 4. Changes in p-Anisidine values (AV) of treated flaxseed oil samples at different storage time (1, 10, 20 and 30th days)

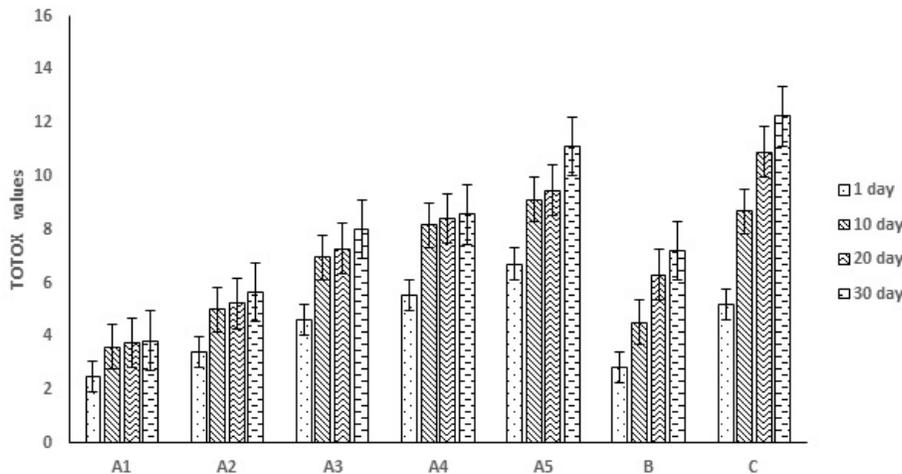


Fig. 5. Changes in Total Oxidation (TOTOX) values of treated flaxseed oil samples at different storage time (1, 10, 20 and 30th days)

3.2.7 Thiobarbituric acid

The consequences showed that the amount of Thiobarbituric acid in all treatments increased over time. The control sample, which did not contain any antioxidants, had the highest escalation in the value of Thiobarbituric acid. Among the different concentrations of BCO, the sample containing 5% (A1) exhibited the highest reduction in oxidation rate which was followed by sample containing 200 ppm BHA (B). As a result of the decomposition of the hydroperoxides formed in the early days and converting them into aldehydes and ketones, the value of Thiobarbituric acid increased over time. The results also showed that the effect of treatment, time and interactions of treatment and

time on the value of Thiobarbituric acid was significant ($p < 0.01$). These results were accordance with another study [34].

4. CONCLUSION

The results of our study showed that the treatment function containing 5% BCO in terms of oxidation prevention was equal with the sample containing synthetic antioxidant (BHA). However, the sample which contained 5% BCO had a better antioxidant performance over time. According to the outcomes attained from this study, higher concentrations of BCO not only decrease the antioxidant activity but also have a Pro-oxidants effect. Therefore, A1 (5% BCO) treatment is considered as the superior treatment

in this study. As a final point, BCO as a source of natural antioxidants has ability to react with free radicals resulting from lipid oxidation and it can discontinue chain reactions, oxidation and finally slow down the autoxidation rate rather than synthetic antioxidant (BHA). Consequently this oil could be introduced as an alternative to synthetic antioxidants which are commonly used in food.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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