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Effect of Addition Antioxidants to Beef Meatballs on Oil Oxidative Stability during Deep Fat Frying

M. S. Ammar[a], M. A. El-Waseif[b*], Samaa M. El-sayed[c]

[a]M.S. Ammar and [b]M. A. El-Waseif are with Food Science and Technology Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt.

[c]Samaa M. El-sayed is with Food Science and Technology Department, Faculty of Home Economic, AL-Azhar University, Tanta, Egypt.

[b]Email: m_elwaseif@yahoo.com, melwaseif@gmail.com

Abstract

This study was aimed to investigate the effect addition of antioxidants to meatballs formulation on frying oil oxidative stability during deep fat frying. 200 ppm butylated hydroxytoluene (BHT), 2500 ppm rosemary extract (ROS) and 500 ppm ascorbic acid (ASC) were added separately to palm olein to achieve the study. The results showed that the addition of antioxidants to meatballs reduce the increment in refractive index during frying process as compared to control, while the rosemary extract was have the lowest refractive index among the antioxidant containing treatments. In regard to relative viscosity the addition of antioxidants to meatballs results in lower relative viscosity values as compared to control treatment. Since, rosemary extract was exhibited superior ability in reducing the formulation of free fatty acids which increased during the frying process in all treatments with low rates for antioxidant containing treatments. In regard to peroxide value, rosemary extract has been kept peroxide value under the ESS limit for long period (120 min.) followed by BHT containing treatment (90 min.), while ascorbic acid was similar to control in keeping peroxide value under the Codex Stand (No. 210/1999) and ESS (1706/2005) limit (60 min.).

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*Corresponding author

Changes in TBA value were observed during the progressing in frying process, the rate of increasing TBA value was low in antioxidant containing treatments as compared to control, also rosemary extract showed the lowest TBA values among all treatments along the frying period. Polymerization of oil during the frying process was reduced by addition of antioxidants to meatballs as compared to control, while the lowest polymerization percent was observed in rosemary extract treatment. The results of iodine value exhibited decreasing in iodine value as the frying time increased. Finally the rosemary extract was exhibit superior ability in protection the oil from oxidation during frying process.

Keywords: Beef meatballs; Deep frying; Natural antioxidant; Rosemary extract.

1. Introduction

Vegetable oils are used daily in food preparations and play an important role in human nutrition by providing us with necessary vitamins, antioxidants and energy [1]. Fats and oils are largely responsible for the pleasant creamy taste of foods [2].

Palm olein, stearin, and intermediary fractions of the palm are excellent raw materials for formulas and food applications free of trans isomers [3,4]. Like palm oil, palm olein is widely used in industrial frying because it does not emit undesirable odors, is highly resistant to oxidation since it free from linolenic acid, and has a favourable nutritional composition for being free of trans fatty acids and contain tocopherols, also it facilitates production of fried foods with acceptable quality [5,6].

Deep fat frying is one of the most common cooking techniques used in domestic and industrial food preparation which achieved by immersing food in hot oil in the presence of air at a high temperature (150 to 190 °C), since oils and fats are exposed to high temperature, atmospheric oxygen and water content of food stuff which results in a series of reactions namely hydrolysis, oxidation and polymerization [7,8]. These reactions produce rancid odors, undesirable flavors and discoloration that considerably influence the functional, sensory and nutritional quality of oils. The rate, at which these degradation reactions occur, is affected by several factors such as time, temperature, food and oil composition, food to oil ratio, kind of fryer and presence of antioxidants [7].

In commercial deep fat frying, oil is continuously exposed to air and light for extended periods at high temperatures reach to 180°C [9]. Under such conditions, both thermal and oxidative decompositions of oil maybe occur [10]. Products from lipid oxidation not only influence the quality and safety of the oil but also affect the acceptability of the fried product [11,12].

Antioxidant is a molecule that inhibits the oxidation of other molecules, which can be used to avoid or delay frying oil deterioration. Antioxidants act by inhibiting formation of free radicals or by interrupting propagation of the free radicals [7]. Nowadays using of synthetic antioxidants such as butylated hydroxytoluene (BHT), Butylated hydroxyanisole (BHA), TBHQ in food processing has raised questions regarding toxicity and health risks [13,14]. Elsewhere synthetic antioxidants provide poor protection, especially under frying conditions which may be attributed to their loss by thermal degradation, steam distillation, evaporation and adsorption by the fried food [7]. Consequently, to overcome these shortcomings, food researchers and processors have been conducted, in order to find natural antioxidants as natural alternatives to synthetic antioxidants.

Several spices and herbs containing antioxidant compounds have been concentrated as extracts, essential oils, or resins. Among them, rosemary (*Rosmarinus officinalis* L.) extract has gained considerable attention as a spice with one of the most powerful antioxidant potential [13,14]. The antioxidant properties of rosemary extract has contributed to the presence of phenolic diterpene compounds, such as carnosic acid, carnosol and rosmanol, rosmariquinone and rosmaridiphenol, which break free radical chain reactions by hydrogen atom donation and chelating metal ions [15].

This research was aimed to investigate the effect of adding antioxidants (BHT as commercially used antioxidant, rosemary extract (ROS) and ascorbic acid (ASC) as natural antioxidants) to beef meatballs on the oil (palm olein) oxidative stability during deep fat frying of beef meatballs.

2. Materials and methods

2.1 Materials

1. Oil samples used:

Refined, bleached, deodorized and antioxidant free palm olein was obtained from the Savola Group, Afia International Company, Suez, Egypt. The freshly refined oil samples packed in dark brown glass bottles were stored under frozen storage conditions (at -18°C) till further analysis and using. All chemicals and reagents used in the analytical methods (Analytical grade) were obtained from either Sigma Chemical Co. (St. Louis, MO, U.S.A.) or El- Gamhouria Trading Chemicals and Drugs Co., Egypt.

Frozen beef meat was purchased from local market at the day of processing.

Rosemary leaves and spices were purchased from Harraz market (dealer in plant seeds), Cairo, Egypt.

2. Other Ingredients:

Fresh eggs, onion, garlic, sugar and salt (sodium chloride) were obtained from the local market. While, sodium tripolyphosphate, ascorbic acid and sodium nitrite were obtained from Adwic Laboratory Chemicals Co., Cairo, Egypt.

3. Preparation of rosemary extract:

Rosemary extract was prepared by using ethanol according to the method described by [16].

4. Preparation of Meatballs:

Four meatball batches (5 kg / batch) were prepared in Laboratory of Food Science and Technology Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt. Meatballs were formulated to contain 75% minced beef meat, 10% (w/w) water (ice water), 1.6% (w/w) sodium chloride, 1.8 % spices, 0.3% sugar, 2.4 onion, 0.6% garlic, 3% wheat flour, 5% whole liquid egg, 0.3% Sodium tripolyphosphate, and 150 ppm Sodium nitrite according to [17]. Antioxidants were added separately to three batches as followed 200 ppm butylated hydroxytoluene (BHT), 2500 ppm rosemary extract (ROS), 500 ppm ascorbic acid (ASC) while the fourth batch was used as control (antioxidant free meatballs) then each batch was shaped into meatballs weighing 55 gm.

5. Frying process:

Deep frying was carried out in palm olein using fryer (SASHO Deep Fryer- SH 308). Since 2 kg of palm olein was placed in the fryer and heated to 180 °C for each treatment individually, since meatballs were consecutively introduced into hot oil and fried for 8 min. along the frying period, which reach to180 min. Sample of fresh oil (zero time) was stored at −18 °C. While samples of frying oils (100 g) were taken each thirty minutes, cooled to room temperature and frozen at −18 °C for further analyses [18].

2.2 *Methods*

1. Physical and chemical properties of oil samples :

Refractive index of different oil samples was measured using Carl Zeiss Refractometer at 40 °C, Viscosity (CPs) was determined at 40°C using Brookfield Viscometer, Free fatty acid (FFA) (as % Oleic acid), Peroxide value (meq. active O_2/kg) and Iodine Value (gI_2 / 100g) were determined according to the [19], while TBA was determined according to [20].

2. Polymer Compounds (%):

The insoluble polymers were determined according to the method described by [21].

3. Fatty acids profile:

Fatty acid composition of studied oil samples were determined using gas liquid chromatography technique. Methylation process was carried out using BF3 in methanol (20%) [19].

4. Determination of oxidative stability by Rancimat:

The oxidative stability (as induction period, IP) in hours of oil samples was evaluated by the Rancimat method (Mod 679 MetrohmUd. CH-9100, Herisau, Switzerland) [22]. The assays were carried out using 5 g of oil sample at 120 ± 0.5°C with an air flow of 20 L/h. Oil stability was expressed in terms of induction period (IP), expired and shelf life in months according to the method described by [23].

5. Statistical analysis:

Obtained results were statistically analyzed by one-way analysis of variance using SPSS 16.0 for windows performed on all experimental data sets. Post-hoc multiple comparisons were carried out by Duncan analysis to determine significant differences between sample means at 5% level [24].

3. Results and discussion

1. Fatty acids profile and oxidative stability:

The induction period (IP) is taken as an indicator for the oxidative stability of oils and fats, consequently as an indicator for the shelf-life of pure oils and fat.

Table (1) shows that RBD palm olein has markedly high oxidative stability (IP 11.7 hrs.) due to its high saturated fatty acids content (43.84%). Also, data in table 1 indicates that fresh palm olein had the following fatty acid composition: 38.50% of palmitic acid (C16:0), 3.80% of stearic acid (C18:0), 41.13% of oleic acid (C18:1) and 11.33% of linoleic acid (C18:2) which in agreement with the foundation of [25,26].

Table 1: Fatty acids profile and oxidative stability of antioxidant free Palm olein oil.

	Fatty acids profile %						IP
	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	Saturated	Unsaturated	(hrs.)
Palm olein	38.50	3.80	41.13	11.33	43.84	53.34	11.7

2. Changes in Refractive index:

Refractive index of the edible oils and fats is an important quality assurance characteristic because it is useful for identification purity, processing purposes and following the reactions which occurred in lipids and their containing fatty acids such as isomerization, hydrolysis, polymerization and oxidation throughout thermal processing. It is also characteristic for each kind of oil linked to its saturation degree and varies according to its free fatty acids content, and its oxidative state [27,28].

Table (2) shows that there is gradual increase in refractive index of all tested frying oil samples used in frying meatballs. The slight increase in that index at the beginning of frying period may be mainly due to the oxidation and polymerization occurred in the oil throughout storage, leading to the formation of high molecular weight compounds. Table (2) shows that addition of antioxidants to meatballs caused reduction in the refractive index of frying oil used in frying meatballs which contain antioxidants when compared with those used in frying of control sample (antioxidant free meat balls), which reached a maximum value 1.4678, when compared with 1.4662, 1.4654 and 1.4670, for BHT, ROS and ASC treatments respectively. The highest inhibitory effect on the propagation stage of oxidation was observed for the rosemary extract treatment which exhibit highest ability to retard oil degradation during the frying process, which agree with Alizadeh and his colleagues [18] since they reported that rosemary extract protect oil from degradation because its higher content of antioxidants, which reduce oxidation and polymerization.

These results indicate the general trend that the refractive index increased as oil degradation increased, but the rate of degradation clearly depend on the food fried in the oil [29,30].

Table 2: Changes in Refractive index (at 40 °C) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	1.4596	1.4596	1.4596	1.4596	0.188
After 30	1.4599	1.4598	1.4597	1.4599	0.0026
After 60	1.4605	1.4502	1.4600	1.4603	0.188
After 90	1.4621	1.4617	1.4618	1.4618	0.188
After 120	1.4653	1.4623	1.4626	1.4629	0.188
After 150	1.4657	1.4645	1.4641	1.4649	0.188
After 180	1.4678	1.4662	1.4654	1.4670	0.188

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different ($P<0.05$).

3. Changes in viscosity:

The flow time reflects the magnitude of oil viscosity and is generally considered as an adequate indicator of the alteration in the resistance of frying oils to flow as the result of changes occur in their chemical constituents during frying process[31].

Table (3) illustrates that there was a successive increase in the relative viscosity values of the all investigated oil samples during frying of meatballs.

The results in table 3 show that addition of antioxidants to meatballs reduced the viscosity of frying oil samples as compared to the control sample. At the end of frying periods, the viscosity of control sample reached a maximum value 68.5 CPs as compared to 67.5, 67.0 and 68.5 CPs for BHT, ROS and ASC treatments respectively. The lowest change was observed for rosemary treatment, which is in agreement with foundation of Jaswir and his colleagues [32].

The increment alteration in the relative viscosity of all frying oil samples during the frying process may be due mainly to effect of thermal oxidation and polymerization of the unsaturated fatty acids, which result in formation of viscous high molecular weight compounds. These results are similar to those explained by [32,33,34].

4. Changes in Free fatty acids:

The Free fatty acids (FFA) content of oil is an important method for measuring the suitability of oils for human consumption and frying purposes. Free fatty acids are primarily a result of hydrolysis, although small amounts may be produced by oxidative reactions [35]. Table (4) shows that addition of antioxidants to meatballs caused a significant reduction in FFA content of frying oils used in frying meatballs containing antioxidants as compared to the control treatment [32]. At the end of frying operation, FFA content of oils treated with BHT, ROS and ASC reached maximum values of 0.512, 0.483, and 0.566 %, respectively, which were significantly lower than that of control sample (0.604%), which confirmed that adding antioxidants reduce free fatty acids formation. It is evident from the results that addition of rosemary extract to meatballs showed significantly the lowest increment in FFA content which in agreement with the results obtained by Zhang and his colleagues [13].

Table 3: Changes in viscosity of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	60.5 ^{a}	60.5 ^{a}	60.5 ^{a}	60.5 ^{a}	0.188
After 30	62.5 ^{a}	62.0 ^{b}	62.0 ^{b}	62.5 ^{a}	0.188
After 60	64.0 ^{a}	63.5 ^{b}	63.5 ^{b}	63.5 ^{b}	0.188
After 90	65.0 ^{a}	64.0 ^{c}	64.0 ^{c}	64.5 ^{b}	0.188
After 120	65.5 ^{a}	64.5 ^{c}	64.0 ^{d}	65.0 ^{b}	0.188
After 150	67.0 ^{a}	66.0 ^{c}	66.0 ^{c}	66.5 ^{b}	0.188
After 180	68.5 ^{a}	67.5 ^{b}	67.0 ^{c}	68.5 ^{a}	0.188

*Control, antioxidant free; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different (P<0.05).

Table 4: Changes in Free fatty acids (as oleic acid %) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	0.015 ^{a}	0.015 ^{a}	0.015 ^{a}	0.015 ^{a}	0.0018
After 30	0.187 ^{a}	0.189 ^{c}	0.199 ^{d}	0.196 ^{b}	0.0018
After 60	0.240 ^{a}	0.236 ^{b}	0.228 ^{c}	0.236 ^{b}	0.0018
After 90	0.362 ^{b}	0.265 ^{c}	0.252 ^{d}	0.364 ^{a}	0.0018
After 120	0.443 ^{a}	0.368 ^{c}	0.353 ^{d}	0.431 ^{b}	0.0018
After 150	0.489 ^{a}	0.425 ^{c}	0.397 ^{d}	0.480 ^{b}	0.0018
After 180	0.604 ^{a}	0.512 ^{c}	0.483 ^{d}	0.566 ^{b}	0.0018

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different (P<0.05).

Table (4) illustrates that all the treatments showed PV increased gradually and significantly as frying period increased, then began to decrease which in agreement with the findings of Guillén and his colleagues [36].

Peroxide value reduction can be explained by the decomposition of unstable hydroperoxides to secondary oxidation products such as: hydrocarbons, alcohols, ketones and aldehydes.

5. Changes in peroxide value:

Peroxide value (PV) is one of the most widely used methods in monitoring the initial stage of lipid oxidation and reflects the concentration of peroxides and hydroperoxides.

Table (5) shows that during frying process, PV of oil sample used in frying meatballs contain ROS reached to 10.540 meq O_2/kg oil after 120 min of frying process followed by oil sample used in frying meatballs contain BHT which reached to 10.092 meq O_2/kg oil after 90 min., while peroxide values of oil sample used in frying meatballs contain ASC and control oil sample were 10.254 and 10.855 meq O_2/kg oil respectively after 60 min. These results showed that addition of ROS to meatballs significantly retarded the formation of hydroperoxides in frying oil since peroxide value was under the Egyptian standard specifications limit after 120 min. of frying process [37,38], which are in agreement with results obtained by [14,32].

Table 5: Changes in peroxide value (meq O_2/kg oil) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	0.844 ^{a}	0.844 ^{a}	0.844 ^{a}	0.844 ^{a}	0.0018
After 30	5.144 ^{a}	3.288 ^{d}	3.834 ^{c}	4.724 ^{b}	0.0018
After 60	10.855	6.916 ^{d}	5.532 ^{c}	10.254	0.0018
After 90	6.216 ^{d}	10.092	8.700 ^{c}	12.724	0.0095
After 120	5.110 ^{d}	7.569 ^{c}	10.540	8.362 ^{b}	0.0133
After 150	4.365 ^{d}	6.425 ^{b}	6.180 ^{c}	6.561 ^{a}	0.0095
After 180	3.210 ^{d}	4.322 ^{b}	4.267 ^{c}	4.943 ^{a}	0.0095

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different ($P<0.05$).

6. Changes in TBA:

Thiobarbituric acid (TBA) test is a condensation reaction between TBA and malonaldehyde, the most predominate product of the secondary oxidation of oil and measure aldehyde contents in oil, which produced from decomposition of hydroperoxides formed during food lipids oxidation. Therefore, the TBA value considered a good chemical quality criterion to identify the oxidative state of edible oils and fats, since it reflects the extent of occurred oxidation [28].

Table (6) shows that TBA values of all analyzed oil samples increased significantly with increase frying time. The addition of antioxidants to meatballs results significant reduction in the TBA values as compared to control sample. At the end of frying periods, the TBA of control sample reached maximum value 2.353 mg malonaldehyde/kg oil, which was higher than that of samples containing BHT, ROS and ASC 1.952, 1.257 and 1.420 mg malonaldehyde/kg oil respectively. The highest inhibitory effect on the propagation stage of oxidation was observed for the oil sample which used in frying meatballs containing ROS, which in agreement with the results of Zhang and his colleagues [13] and Alizadeh and his colleagues [18], who found that the inhibitory effect of ROS were higher than that of BHA and ASC. This fact might be contributed to the presence of compounds that donate hydrogen to peroxides in ROS, which change it to stable hydroperoxides, which reduce decomposition of hydroperoxides and secondary products formation [39].

Table 6: Changes in TBA value (malonaldehyde/kg oil) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	0.167 ^{a}	0.167 ^{a}	0.167 ^{a}	0.167 ^{a}	0.0018
After 30	0.415 ^{a}	0.258 ^{b}	0.195 ^{d}	0.210 ^{c}	0.0095
After 60	0.915 ^{a}	0.462 ^{b}	0.388 ^{d}	0.443 ^{c}	0.0018
After 90	1.410 ^{a}	0.716 ^{b}	0.623 ^{d}	0.678 ^{c}	0.0095
After 120	1.716 ^{a}	1.325 ^{b}	0.819 ^{d}	0.961 ^{c}	0.0018
After 150	1.924 ^{a}	1.669 ^{b}	1.141 ^{d}	1.150 ^{c}	0.0095
After 180	2.353 ^{a}	1.952 ^{b}	1.257 ^{d}	1.420 ^{c}	0.0095

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different (P<0.05).

7. Changes in Polymer compound (%):

Polymerization of frying oil results in formation of compounds with high molecular weight, which can formed from free radicals or triglycerides by the Diels-Alder reaction. Oxidized polymer compounds accelerate the oxidation and further degradation of the oil, which cause increased oil viscosity [40], reduce heat transfer, produce foam during deep fat frying, develop undesirable color in the food and cause high oil absorption by foods [41]. Oil quality control regulations [42] indicate that the polymer levels must not exceed 1.5%.

Table (7) shows that polymer compounds percent in all analyzed oil samples increased during frying period which increased in acceleration at the end of the third frying period. Addition of antioxidants to meatballs caused a significant reduction in formation of polymer compounds (%) in oil samples as compared to control sample. At the end of frying periods, the polymer compound (%) of control sample reached to maximum level of 5.73%, as compared to 4.32, 3.15 and 5.94% for BHT, ROS and ASC respectively, which in agreement with the results of Tabee and his colleagues [43] and Farhoosh and Tavassoli-Kafrani [44]. The lowest polymer compounds (%) was dedicated to the oil sample used in frying meatballs containing ROS as compared to other antioxidant containing treatments, which in agreement with the foundation of Jaswir and his colleagues [32].

8. Changes in Iodine Value:

The alteration in the iodine value of frying media is considered one of the most chemical constants for oils quality assurance and as a good successful measure for changes occur in the unsaturated fatty acids of the frying oil.

Table 7: Changes in Polymer compound (%) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	0.00	0.00	0.00	0.00	
After 30	0.92^{a}	0.34^{c}	0.32^{d}	0.73^{b}	0.0018
After 60	1.53^{a}	0.87^{c}	0.71^{d}	1.30^{b}	0.0018
After 90	2.56^{a}	1.55^{c}	0.95^{d}	2.20^{b}	0.0018
After 120	3.17^{b}	2.14^{c}	1.62^{d}	3.32^{a}	0.0018
After 150	4.68^{a}	3.10^{c}	2.23^{d}	4.10^{b}	0.1333
After 180	5.73^{b}	4.32^{b}	3.15^{c}	5.94^{a}	0.0018

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different ($P<0.05$).

Table 8: Changes in Iodine Value (gI2/100g oil) of oil samples during frying of meatballs containing different antioxidants at 180 °C.

Time of frying	Treatments*				LSD
	Contro	BHT	ROS	ASC	
Zero	56.4^{b}	56.4^{a}	56.4^{b}	56.4^{b}	0.188
After 30	55.6^{b}	55.1^{d}	56.3^{a}	55.3^{c}	0.188
After 60	54.8^{a}	54.5^{b}	54.5^{b}	54.7^{a}	0.188
After 90	52.4^{c}	52.1^{d}	53.8^{a}	52.9^{b}	0.188
After 120	50.7^{c}	50.3^{d}	52.1^{a}	51.2^{b}	0.188
After 150	48.9^{c}	49.5^{b}	51.7^{a}	48.8^{c}	0.188
After 180	45.6^{d}	47.1^{c}	50.2^{a}	47.7^{b}	0.188

*Control , antioxidant free ; BHT, 200 ppm butylated hydroxytoluene; ROS, 2500 ppm rosemary extract; ASC, 500 ppm ascorbic acid.

** In the same row values with different superscript are significantly different ($P<0.05$).

Table (8) indicates that the iodine value of the tested frying oils was decreased from 56.4 g I2/100g oil at the initial zero time of frying to 45.6, 47.1, 50.2 and 47.7 g I2/100g oil for control, BHT, ROS and ASC treatments respectively after 180 min. of the frying process for meatballs at 180 ºC. The reduction in the iodine value of the tested frying oils could be attributed to the thermal oxidative degradation of the unsaturated fatty acids throughout frying process. Also, the results indicate that addition of ROS to meatballs was the super antioxidant in protection frying oil from oxidation, these results were in close agreement with those reported by Tsaknis and his colleagues [45,32,34,46].

4. Conclusion

We can be concluded that addition of rosemary extract to meatballs inhibits both primary and secondary oxidation changes in frying oil and protect it from detrimental changes, which make rosemary extract a good alternative to synthetic antioxidants in oil protection during frying process of foods but more studies are needed to discover excess natural antioxidant which can be used in protection of oil from oxidative changes.

Finally we recommend food processor by using rosemary extract as alternative of synthetic antioxidants to protect oil from oxidative changes at commercial level.

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