Antioxidant Effect of some Plant Extracts as Compared with BHA/BHT on Lipid Oxidation and some Quality Properties of Fresh Beef Burgers Stored at 4°C

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Received: *25/11/2014*

Abstract: The properties of plants with food preservation potential are well known since the antiquity. In recent years, the use of herbs and spices to improve the sensory characteristics and to extend the shelf-life of foods has been growing. Antioxidant effect of adding rosemary extract (RE), sage extract (SE), oregano extract (OE), ginger extract (GE), clove extract (CE), tea catechins (TC) compared to BHA/BHT, on lipid oxidation and beef burger quality were investigated. The proximate composition, TBARS values, antioxidant activity (AOA%), colour parameters (Hunter *L*, a*, b** values, redness index and total colour difference), and sensory attributes of the beef burgers contained RE, SE, OE, GE, CE, TC and BHR/BHT during refrigerated storage at 4±1°C for 15 days were determined and calculated. Significant reduction in TBARS values and colour changes for all treated beef burgers was observed during storage compared to control. TBARS values were significantly low in TC, followed by RE, CE, BHA/BHT, OE, SE and GE beef burgers. Antioxidant activity of the tested beef burgers was in the order TC > RE > CE > BHA/BHT > OE > SE > GE, sensory scores were in agreement with these results. So, TC, RE and CE prevent lipid oxidation in beef burgers, and could be used in place of synthetic antioxidants, which have proved for their negative health implications.

Keywords: Plant extracts, BHA/BHT, Lipid oxidation, Chilling storage, Antioxidant activity, Beef burger quality.

INTRODUCTION

Recently, antioxidant-supplemented foods have gained a great deal of interest from consumers because of the growing awareness of cancer prevention and the risk of free radicals in the diet. The aim of food producers, food processors and food scientists has been to increase nutritional value of food products supplemented with antioxidants while simultaneously improving formulas for consumer acceptability. Meat products, due to fat content are highly susceptible to lipid oxidation. Moisture, prooxidant pigments, storage, handling and display conditions contribute to lipid oxidation of meat products. Grinding of meat disrupts the integrity of muscle membranes and exposes lipid membranes to metal ions and facilitates the interaction of pro-oxidants with unsaturated fatty acids resulting in generation of free radicals and propagation of oxidative reaction (Ibrahim *et al.,* 2010 and Yogesh and Ali, 2014).

Lipid oxidation is a major cause of deterioration in the quality of meat products (Asghar *et al.,* 1988) because it has detrimental effects on the colour, flavour and texture of meat which render these foods less acceptable. Lipid oxidation can have negative effects on the quality of meat and meat products causing changes in sensory attributes (colour, texture and flavour) and nutritional quality (Fenaille *et al.,* 2003; Goodridge *et al.,* 2003; Ripoll *et al.,* 2011; Trefan *et al.,* 2011 and Vaithiyanathan *et al.,* 2011). One method to reduce lipid oxidation is the application of antioxidants.

The oxidation of lipids in foodstuffs results in the development of off-flavours, rendering the product unacceptable for human consumption and limiting the shelf-life of products. The structure of foods is changed during processing, and as a result, lipids may become more exposed to oxygen. In addition, naturally occurring antioxidant systems are impaired during processing, making processed food more susceptible to oxidation. Oxidative reactions can decrease the nutritional quality of food, and certain oxidation products are potentially toxic of meat and meat products which are reflected in economic losses and health disorders (Insani *et al.,* 2008). The physical and chemical changes alter meat quality during the conversion of muscle to meat, including discolouration, development of off flavours, odours and texture changes (McMillin, 1996). However, the oxidation of myoglobin and lipids during refrigerated storage reduces the colour and flavour acceptability of fresh meat (Trout, 2003).

Usually, antioxidants such as butylated hydroxytoluene (BHT) and butylaled hydroxyanisole (BHA), both powerful synthetic antioxidants, are used to reduce the rate of oxidation processes. However, these antioxidants suffer from the drawback that they are volatile and readily decompose at high temperatures (Martinez-Tome *et al.* 2001). Additionally, they are believed to possess carcinogenic activity. With increased consumer concerns about the amount of chemicals in their foods, processors are looking for more natural ways to protect their products. In the last few years, there has been an increasing interest in the use of natural additives in preference to synthetic substances for the stabilization of fat-containing foodstuffs. These observations have led to a demand for antioxidants derived from naturally occurring sources (Lindberg *et al.,* 1995). Many herbs and spices, usually added to season dishes, are an excellent source of phenolic compounds, which have been reported to show good antioxidant activity (Zheng and Wang, 2001). Antioxidants can prevent lipid peroxidation using the following mechanisms: preventing chain inhibition by scavenging initiating radicals, breaking chain reaction, decomposing peroxides, decreasing localized oxygen concentrations and binding chain initiating catalysts, such as metal ions (Dorman *et al.,* 2003).

Rosemary (*Rosmarinus officinalis* L.) and sage (*Salvia officinalis* L.) are popular *Labiatae* herbs with known potent antioxidant activity (Estévez *et al.,* 2006).

Carnosic acid, carnosol, rosmarinic acid, rosmanol, and phenolic acids are the major phenolic constituents of these plants (Karakaya *et al.,* 2011). Oregano (*Origanum vulgare* L.) also is *Labiatae* family and had a potent antioxidant activity. Derivatives of phenolic acids, flavonoids, tocopherols are the major constituents (Karakaya *et al.,* 2011). Clove (*Eugenia caryophyllus*) is a member of *Caryophyllaceae* family was the strongest antioxidant in retarding lipid oxidation (Shan *et al.,* 2009). The superior antioxidant activity of clove may arise from its high content of eugenol (3.0%) and gallic acid (1.3%) (Shahidi and Pegg, 1998). Ginger (*Zingiber officinale*) is a member of *Zingiberaceae* family and it is known to has antioxidant activity for long time. The antioxidant activity of ginger was attributable to gingerol-related compounds and diarylheptanoids (Karakaya *et al.,* 2011 and Ibrahim *et al.,* 2011) Tea catechins, the predominant group of polyphenols present in green tea leaves (*Camellia sinensis*) composed of four compounds epicatechin, epicatechin gallate, epigallocatechin and epigallocatechin gallate (Zhong *et al.,* 2009). The effectiveness of rosemary, sage, clove, oregano, ginger and tea catechins as antioxidants has been demonstrated in a large variety of foodstuffs including beef and pork (Fasseas *et al.,* 2008; Mitsumoto *et al.,* 2005; Nissen *et al.,* 2004 and Shahidi *et al.,* 1995), buffalo meat (Naveena *et al.,* 2006), pork sausages (Sebranek *et al.,* 2005) and beef, duck, ostrich, pork and chicken (McCarthy *et al.,* 2001; Mitsumoto *et al.,* 2005 and Tang *et al.,* 2001).

The objective of this study was to determine whether natural antioxidants namely, [(rosemary extract (RE), sage extract (SE), oregano extract (OE), ginger extract (GE), clove extract (CE) and Tea catechins (TC) are sufficiently potent to replace the synthetic antioxidants namely BHA/BHT currently used in beef burgers.

MATERIALS AND METHODS

Materials

Fresh beef loin (*Longissimus dorsi*) muscles were obtained from local retail meat processing plants (Ismailia, Egypt). Fresh meat samples were obtained separately for each of the replications. 2-Thiobarbituric acid (TBA), butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) were obtained from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). All other chemicals used were of analytical grade or the highest grade available and were obtained either from Sigma-Aldrich, Merck (Darmstadt, Germany) or Lab-Scan Ltd., Dublin, Irland.

Plant Extracts Powder

Rosemary extract (Guardian ^{TM}) was purchased from Danisco, Denmark. Clove and ginger extracts, and tea catechins 98% were obtained from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Sage and oregano extracts were obtained from Kingherbs Ltd., Changsha, China.

Preparation of Beef Burgers

Fresh beef loin muscles were chopped into small pieces after removal of visible fat and connective tissues. Chopped meat samples were minced using a meat mincer (Bizerba, Wilhelm Kraut GmbH & Co KG, Germany) through a plate with 4- mm holes. Portions of uniform weight of the minced muscles were mixed in a Classic Chef-KM353 Kenwood meat mixer (Kenwood Ltd., Havant, UK) for 5 min with salt (2% w/w) and adding the tested extracts to minced meat and assigned as follows: (1) control (without adding any extracts) ; (2) 200 ppm RE; (3) 200 ppm SE; (4) 200 ppm OE; (5) 200 ppm GE; (6) 200 ppm CE; (7) 200 ppm TC; and (8) 200 ppm BHA/BHT in a 1:1 ratio. After mixing, beef burgers of 50±1 g were formed using a beef burger former (Italmans, Italy). The beef burgers were placed on Styrofoam trays, wrapped with polyethylene film and kept in refrigerator at 4±1 ºC for 15 days. All experiments were repeated thrice in order to remove effects deriving from the initial quality of raw material.

TBARS values were determined in the beef burger samples for 0,1, 3, 6, 9, 12 and 15 days of storage period and antioxidant activity (AOA %) was calculated. Also, pH and instrumental color attributes were analyzed in beef burger samples at 0, 1, 3, 6, 9, 12 and 15 days of storage period. Whereas, sensory attributes were performed on cooked samples after 0, 3, 6, 9, 12 and 15 days of cold storage.

Proximate Analysis

Moisture (hot air oven), protein (Kjeldahl, N × 6.25), fat (ether extractable), and ash were determined only in the initial meat mixture used for the preparation of the experimental beef burgers according to AOAC (2000).

pH Determination

A raw beef burger sample 10 g was homogenized in 90 ml distilled water for 1 min in a blender. The pH values were measured using a Jenway pH meter (Jenway 3010; Jenway Ltd., Essex, UK).

Thiobarbituric Acid Reactive Substances (TBARS) Measurement

Lipid oxidation of the beef burger samples from each treatment and storage day was determined using the distillation 2-thiobarbituric acid (TBA) procedure of Tarladgis *et al.* (1960) with modified by Shahidi *et al.* (1987). Distillates of 10 g samples were reacted with TBA reagent (0.02M aqueous solution of 2-thiobarbituric acid) and the absorbance of the resultant pink-coloured chromogen was measured at 532 nm using a spectrophotometer (6505 UV/Vis, Jenway Ltd., Felsted, Dunmow, UK). Values of absorbance at 532 nm were multiplied by 8.1 and expressed as TBARS numbers in mg malonaldehyde equivalents/kg of meat sample.

Instrumental Color Measurement

The measurement of (CIE) color values $L*$ (lightness), $a*$ (redness) and $b*$ (yellowness) was conducted on the surface of the beef burger samples from day zero to day 15 with a using a color reader CR-10 (Konica Minolta, Inc., Osaka, Japan). The redness index ($a*/ b*$) was determined as described by Chen *et al.* (1997). A numerical total color difference (ΔE) between beef burgers on 0 and 15 days of storage was calculated according to Vega-Gálvez *et al.* (2012) as follows:

$$\Delta E = [(L^*15 - L^*0)^2 + (a^*15 - a^*0)^2 + (b^*15 - b^*0)^2]^{1/2}$$

Sensory Evaluation

Samples of beef burgers were evaluated according to the method described by García *et al.* (2009), ten experienced panelists were chosen from the staff members of the Department of Food Technology at Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. Panelists were selected according to their habits, their familiarity with the burgers to be analyzed, their sensitivity and the ability to reproduce the evaluation made. Moreover, they received a preparatory session prior to testing so that each panelist could thoroughly discuss and clarify each attribute to be evaluated. Eight beef burgers were cooked on a preheated electric grill (WA-BBQ 01, White Whale, China) at approximately 180 ºC for 2 min, then turned over and cooked for another 2 min. The temperature of the centre of burgers reached approximately 80 ºC. A beef burger of each sample was served to the panelists. Beef burgers were pre warmed before serving and water was served for rinsing the mouth between samples (Kanatt *et al.,* 2010).

A hedonic test was carried out using non-structured 9 point scales (0 = dislike extremely and 9 = like extremely) in which the panelists evaluated different attributes: colour, texture, odour, taste and overall acceptability.

Statistical Analysis

The conventional statistical methods were used to calculate means and standard deviations, All the measurements were replicated three times and the data are presented as mean ± SD. The effects of natural antioxidant extracts addition and storage period were analyzed and the obtained data were subjected to analysis of variance (ANOVA) accompanied with Duncan test using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago) were conducted to identify the significance ($p < 0.05$) between means of treatments.

RESULTS AND DISCUSSION

Chemical Composition of Meat Mixture

Mean values of chemical composition of the meat mixture used for the preparation of the experimental beef burgers are presented in Table 1. The moisture of minced meat averaged 66.7%, total crude protein 18.6%, crude fat 13.2% and ash 096%.

pH Changes

The effect of natural and synthetic antioxidants on pH values of beef burgers stored at 4±1 ºC is presented in Table 2. At zero time the pH of the control and all tested samples had the values ranged (5.79-5.83). The pH values of all treatments were similar ($p > 0.05$); therefore, it was not affected by the antioxidants addition. These results are in agreement with the results obtained by Mohamed and Mansour (2012) who reported that the addition of natural herbal extracts to beef patties did not significantly change the pH values of all formulas after preparation and during storage. The pH values of all beef burger samples decreased slowly during the first 3 days of storage, whereas after day 3 there was a gradual increase. The increase in pH may be due the accumulation of metabolites by bacterial action in meat and deamination of proteins (Jay, 1996). Bacteria, upon exhaustion of stored glucose, utilize amino acids released during protein breakdown and as a product of amino acid degradation, ammonia accumulates and pH rises (Gill, 1983). During storage time (3-15 days) it was noticed that the pH value of the control was higher (6.01) than the other tested samples. At the 15th day beef burger containing RE and SE extracts had the highest pH value (5.96) and the beef burger containing BHA/BHT had the lowest value (5.91). Similar findings in pork patties containing natural food and plant extracts, and BHA/BHT antioxidants during refrigerated storage have been reported by (McCarthy et al., 2001).

Table (1): Proximate analysis of the meat mixture used for the preparation of beef burgers

Component (%)	Mean ± SD
Moisture	66.7 ± 0.53
Protein	18.6 ± 0.36
Fat	13.2 ± 0.44
Ash	0.96 ± 0.07

Data represent averages of three independent repeats ± standard deviation

TBARS Values and Antioxidant Activity (AOA %)

Effect of plant extracts: RE, SE, OE, GE, CE, TC as well as BHA/BHT on thiobarbituric acid reactive substances (TBARS) values in fresh beef burgers stored at 4±1 °C for 15 day are shown in Table 3. All antioxidant treatments significantly ($P < 0.05$) reduced the TBARS values throughout storage compared to the control sample. The effectiveness of the added antioxidants inhibiting lipid oxidation throughout storage time could be listed in the following order of decreasing TBARS values: TC > RE > CE > OE > BHA/BHT > SE > GE. Results also showed that the TC extract was the most effective antioxidant and GE had the lowest effect. This can indicate that natural extracts used as antioxidants was effective against TBARS formation at different way when incorporated into beef burgers. Chen *et al.* (1999); Formanek *et al.* (2001) and McCarthy *et al.* (2001) reported that dried herbs and their essential oils were successfully used to reduced lipid oxidation in meat products. The large amount of phenolic compounds may cause its strong antioxidant ability (Li *et al.,* 2006). Polyphenolic extracts are excellent electron and proton donors, and their intermediate radicals are quite stable due to electron delocalization phenomena and owning to the lack of positions attackable by O_2 (Djenane *et al.,* 2005). In the present study, since the natural extracts used in preparing beef burgers contain bioactive substances e.g. phenolic compounds which cause an inhibition of the chain reactions during lipid oxidiation. Again, these phenolic compounds might be involved in the inhibition of lipid oxidation, by inhibiting free radical formation, by preventing propagation of free radical chain reactions through the chelation of transition metal ions, particularly those of iron and copper (Brown *et al.,* 1998).

The total antioxidant activity or capacity has been generally recognized as a tool to test the antioxidant potential of a pure compound or a food extract (Aruoma, 1996). Antioxidant activity of a food could be a useful index to predict oxidative stability (Sacchetti *et al.*, 2008). Data on the antioxidant activity of beef burgers as affected by addition natural extracts as antioxidants stored at 4+1°C for 15 days are depicted in Table 3. Within the tested samples, a significant difference between the AOA% as a result of adding the natural extracts during storage for 15 days was observed. The order of antioxidant activity was TC > RE > CE > BHA/BHT > OE > SE > GE. It was also, noticed that TC exhibited a higher AOA% than other tested samples at storage periods. The data indicated that the marked antioxidant activity of TC, RE as well as CE seemed to be the result of their radical scavenging activity. The phenolics may act in a similar fashion as reductones by donating electrons and reacting with free radicals to convert them to more stable products and terminate free radical chain reactions (Negi and Jayaprakasha, 2003). This result was consistent with studies in precooked roast beef (Murphy *et al.,* 1998). Mitsumoto *et al.* (2005) reported that TC treatments greatly suppressed ($P < 0.01$) lipid oxidation in meat patties compared to controls and vitamin C treatments. Also, Trindade *et al.* (2007) concluded that rosemary extracts contain phenolic primary antioxidants which react with lipid or hydroxyl radicals and convert them into stable products. Also, Fang and Wada (1993) demonstrated that the rosemary extracts may chelate metal ions, such as Fe^{2+} resulting in a reduce rate of formation of activated oxygen.

Colour Evaluation

Colour is one of the most important sensory qualities as it helps us to accept or reject particular food items. Colour is important in consumer perception of food and it is often associated with a specific flavour and intensity of flavour. The effect of natural and synthetic antioxidants on the colour parameters of beef burgers stored at 4±1 ºC is presented in Table 4. In general, as the storage days number increased, $L*$, $a*$ and $b*$ values decreased, the amount of discolouration increased, and the colour was darker. For $L*$ value, fresh beef burgers with TC had the highest value ($P<0.05$) compared to other treatments. Also, samples with TC and with RE had significantly ($P<0.05$) higher $a*$ values than those of the control and samples with any other antioxidants, throughout the whole period of storage. The CE, BHA/BHT, OE and SE also gave significantly higher $a*$ values ($P<0.05$) than those of the control over a 15-days storage period. At the end of the storage period, the control samples and those with GE had very low $a*$ values below 7. Therefore, according to our results, addition of TC and RE maintained the red colour of beef burgers better than control and other treatment samples. The decrease of $a*$ value during storage is probably due to oxymyoglobin oxidation to metmyoglobin. The iron in oxymyoglobin is in the reduced state (Fe^{2+}), but the iron in metmyoglobin is in the oxidised state (Fe^{3+}). The effectiveness of an antioxidant, in terms of colour stability, is determined by its ability to keep iron in the reduced state which results in a desirable colour. Once iron has been oxidised, it cannot be converted back to its reduced state, thus the shift from oxymyoglobin to metmyoglobin is permanent (Jenschke, 2004). The observed effect of TC and RE was in agreement with the results reported by Maher *et al.* (2002), who showed that addition of TC and rosemary to minced raw beef greatly improved colour compared to controls. Also, a reduction in metmyoglobin formation was noticed and intense red colour obtained in fresh beef steaks whose surface was sprayed with rosemary during refrigeration (Djenane *et al.,* 2005).

At day 0, the redness index ($a*/b*$ ratio) of tested samples was higher. The redness index of beef burger samples decreased when the storage time increased. This ratio was used as an index of apparent change in redness (Chen et *al.,* 1997), and used to evaluate the discolouration in tuna meat during storage (Lee *et al.,* 2003). Boulianne and King (1998) showed a strong positive correlation between total pigment concentration and $a*$ values. The decrease in the redness index was associated with the darkening of meats, resulting from the formation of metmyoglobin. Faustman *et al.* (1992) reported that the saturation of red color in meat was directly related to myoglobin concentration. Fleming *et al.* (1991) reported that dark colouration in meat was also associated with the total pigment concentration. Thus, the changes in the redness index can be used as the index of pigment changes of beef burgers.

The overall color change (ΔE) demonstrated that the addition of TC protect against discolouration of the beef burgers ($p<0.05$). The result of our study showed (Figure 1) a good correlation ($R^2 = 0.7442$) between AOA % and ΔE of beef burger samples. Many undesired chemical reactions can take place among which lipid oxidation is the most unfavourable and can negatively affect the colour of the meat product. Lipid oxidation reactions usually also interacts with haem pigments and so can turn their red colour brown. Kong *et al.* (2010) observed that clove, rosemary and cassia bark extracts to be highly effective antioxidants in cooked pork patties as they inhibited lipid oxidation and stabilized red colour (myoglobin) during refrigerated storage. Oxidation of lipids and muscle pigments is one of the main parameters of meat quality deterioration. Lipid oxidation causes development of off-odours and off flavours; muscle pigment oxidation negatively affects colour, appearance and acceptability (Kolakowska, 2003).

Sensory Evaluation

The effect of natural and synthetic antioxidants on the sensorial criteria of beef burgers stored at 4±1 ºC is presented in Table 5. Alterations in food quality as a result of lipid oxidation range from colour variations to changes in appearance, odour/aroma, texture and taste. Sensory evaluations are the most significant methods for predicting oxidative stability, product shelf life and consumer acceptability (Rajalakshmi and Narasimhan, 1996). Colour is an important factor for consumer acceptance of meat and its products. The shelf life and quality of meat products are strongly influenced by the initial meat quality, additives, packaging parameters, and storage conditions. In general, all beef burger samples treated with natural and synthetic antioxidants had significantly ($P<0.05$) higher colour, odour, taste and overall acceptability scores than the control. Results clearly demonstrated that beef burgers treated with TC and RE were given higher scores than any other beef burgers throughout the whole storage period, for colour, taste, odour and overall acceptability, followed by CE, BHA/BHT, SE, OE and GE, which also differed significantly from the control ($P<0.05$). This intensity order of the protective ability on beef burgers quality of the examined antioxidants, as measured by sensory evaluation, consistently agreed with their effectiveness in preventing both lipid and myoglobin oxidation. Also, the reduction of the rate of lipid oxidation by antioxidants during storage probably prevents the formation of secondary oxidation products and consequently decreases the rate of odour and taste deterioration. The results in Figure (2), showed a high correlation ($R^2 = 0.9026$) between TBARS values (mg malonaldehyde/kg meat sample) and odour sensory scores. As regards to texture, the texture scores of all treatments and control were similar ($p>0.05$) when different antioxidants were added; therefore, the texture of beef burgers was not affected by addition of different antioxidants. These data are in agreement with Mohamed and Mansour, (2012) who reported that beef patties prepared with addition of rosemary and marjoram essential oils had significantly ($P<0.05$)

Table (2): Effect of natural and synthetic antioxidants on pH values of beef burgers during storage at 4±1°C

Treatment	Storage time (days)						
	0	1	3	6	9	12	15
CON	5.83±0.035a	5.81±0.025a	5.78±0.046a	5.80±0.049a	5.83±0.068a	5.89±0.049a	6.01±0.056a
RE	5.79±0.030a	5.78±0.015a	5.75±0.032a	5.76±0.015a	5.82±0.059a	5.85±0.040a	5.96±0.042a
SE	5.83±0.055a	5.82±0.052a	5.78±0.055a	5.81±0.059a	5.84±0.076a	5.90±0.059a	5.96±0.040a
OE	5.82±0.050a	5.79±0.031a	5.76±0.038a	5.79±0.036a	5.83±0.075a	5.88±0.051a	5.93±0.053a
GE	5.79±0.029a	5.75±0.040a	5.73±0.025a	5.76±0.025a	5.79±0.061a	5.83±0.046a	5.90±0.070a
CE	5.82±0.017a	5.78±0.025a	5.73±0.020a	5.75±0.025a	5.77±0.035a	5.82±0.032a	5.92±0.049a
TC	5.81±0.025a	5.76±0.032a	5.74±0.025a	5.77±0.046a	5.82±0.061a	5.86±0.046a	5.92±0.053a
BHA/BHT	5.80±0.036a	5.76±0.042a	5.72±0.023a	5.75±0.036a	5.81±0.049a	5.85±0.040a	5.91±0.067a

CON: control (without antioxidant); RE: 0.2 g rosemary extract/kg meat; SE: 0.2 g sage extract/kg meat; OE: 0.2 g oregano extract /kg meat; GE: 0.2 g ginger extract/kg meat; CE: 0.2 g clove extract/kg meat; TC: 0.2 g tea catechins/kg meat; BHA/BHT: 0.2 g BHA/BHT (1:1)/kg meat.
Means in the same column for the same storage day with a different letter (a-g) differ significantly ($p < 0.05$)

Table (3): Effect of natural and synthetic antioxidants on TBARS values and AOA% of beef burgers during storage at 4±1°C

Treatment	Storage time (days)						
	0	1	3	6	9	12	15
TBARS values							
CON	0.21±0.025a	0.32±0.035a	0.55±0.036a	0.78±0.035a	0.99±0.027a	1.18±0.042a	1.22±0.040a
RE	0.18±0.017ab	0.18±0.046c	0.28±0.023d	0.31±0.040d	0.38±0.015e	0.44±0.025c	0.49±0.023de
SE	0.17±0.025b	0.19±0.025c	0.30±0.055cd	0.36±0.035cd	0.43±0.015cde	0.51±0.030c	0.59±0.032c
OE	0.18±0.015ab	0.20±0.025bc	0.29±0.036cd	0.36±0.032cd	0.46±0.035c	0.50±0.042c	0.53±0.021d
GE	0.20±0.027ab	0.24±0.025b	0.38±0.052b	0.52±0.025b	0.68±0.045b	0.89±0.040b	0.96±0.032b
CE	0.19±0.032ab	0.20±0.015bc	0.28±0.027d	0.35±0.023cd	0.39±0.010de	0.48±0.055c	0.50±0.017de
TC	0.18±0.015ab	0.18±0.012c	0.27±0.021d	0.33±0.023cd	0.39±0.044de	0.44±0.032c	0.45±0.027e
BHA/BHT	0.21±0.021a	0.20±0.027bc	0.35±0.035bc	0.38±0.046c	0.44±0.051cd	0.50±0.040c	0.54±0.053cd
AOA %							
RE	16.97±1.063ab	43.39±1.894a	48.38±1.708a	59.76±1.544a	61.96±0.848a	62.55±0.856a	59.57±0.986b
SE	18.92±1.418a	41.16±0.442ab	45.11±3.219a	54.15±1.410bc	56.91±0.806bc	56.92±0.221b	51.38±0.540d
OE	13.83±1.684b	35.83±1.010c	47.41±1.132a	53.27±0.760bc	53.91±0.778c	57.51±0.715b	56.29±0.524c
GE	4.73±0.549d	23.10±1.010d	31.06±1.684b	32.62±0.639d	31.02±1.542d	25.09±0.888c	21.04±0.961e
CE	9.46±0.709c	37.74±1.263bc	49.12±1.745a	54.52±0.684bc	60.60±0.347ab	59.50±0.473ab	59.01±0.715b
TC	14.19±1.063b	44.35±0.631a	50.33±0.566a	57.10±0.849ab	60.66±0.454ab	62.57±0.163a	63.13±0.265a
BHA/BHT	0.00±0.00e	36.88±1.010c	35.84±0.173b	51.18±1.054c	55.29±1.867c	57.50±0.221b	55.80±0.177c

CON: control (without antioxidant); RE: 0.2 g rosemary extract/kg meat; SE: 0.2 g sage extract/kg meat; OE: 0.2 g oregano extract /kg meat; GE: 0.2 g ginger extract/kg meat; CE: 0.2 g clove extract/kg meat; TC: 0.2 g tea catechins/kg meat; BHA/BHT: 0.2 g BHA/BHT (1:1)/kg meat.
Means in the same column for the same storage day with a different letter (a-g) differ significantly ($p < 0.05$)

Table (4): Effect of natural and synthetic antioxidants on Hunter colour values (*L**, *a** and b*), redness index (*a*/b**) and the numerical total colour difference (Δ E) between day 0 and day 15 of beef burgers during storage at 4±1°C

Storage time (days)	Treatment	*L**	*a**	*b**	*a*/b**	Δ E
0	**CON**	45.87±0.072e	12.58±0.093c	11.89±0.056c	1.06±0.013b	-
	RE	47.58±0.055a	12.85±0.041b	12.22±0.098a	1.05±0.011b	-
	SE	45.98±0.067e	12.30±0.128d	12.04±0.086b	1.02±0.010d	-
	OE	46.89±0.087c	12.32±0.084d	11.78±0.104d	1.05±0.016bc	-
	GE	46.72±0.066d	12.05±0.148e	11.66±0.088e	1.03±0.009cd	-
	CE	47.64±0.118a	12.60±0.037c	11.89±0.093c	1.06±0.011b	-
	TC	47.22±0.158b	13.09±0.134a	11.82±0.079cd	1.11±0.017a	-
	BHA/BHT	46.78±0.067cd	12.62±0.074c	12.29±0.037a	1.03±0.004d	-
1	**CON**	45.58±0.164g	11.80±0.131d	11.41±0.070ef	1.03±0.008de	-
	RE	47.98±0.059a	12.90±0.106a	12.08±0.086a	1.07±0.001b	-
	SE	46.13±0.052f	12.12±0.040c	11.85±0.074c	1.02±0.008e	-
	OE	46.70±0.082e	12.02±0.074c	11.44±0.091e	1.05±0.012c	-
	GE	46.97±0.130d	11.09±0.113e	11.32±0.125f	0.98±0.018f	-
	CE	47.55±0.076c	12.42±0.069b	11.96±0.088bc	1.04±0.010cd	-
	TC	47.86±0.035b	13.66±0.070a	11.59±0.102d	1.12±0.009a	-
	BHA/BHT	47.06±0.038d	12.40±0.063b	11.98±0.044ab	1.04±0.007de	-
3	**CON**	46.98±0.087e	9.67±0.143f	10.87±0.058f	0.89±0.013f	-
	RE	48.07±0.052b	11.98±0.099ab	11.59±0.096a	1.03±0.014b	-
	SE	47.02±0.093e	11.29±0.081d	11.14±0.105d	1.01±0.016c	-
	OE	47.36±0.042d	11.33±0.076d	11.50±0.112ab	0.99±0.010d	-
	GE	47.70±0.080c	10.18±0.067e	11.01±0.084e	0.92±0.001e	-
	CE	47.71±0.084c	11.70±0.057c	11.49±0.103ab	1.02±0.007c	-
	TC	48.49±0.068a	12.07±0.138a	11.43±0.073b	1.06±0.008a	-
	BHA/BHT	47.40±0.112d	11.90±0.079b	11.29±0.024c	1.05±0.009a	-
6	**CON**	47.27±0.067f	8.24±0.076f	10.05±0.065e	0.82±0.009e	-
	RE	48.81±0.143ab	11.03±0.072a	11.08±0.098a	1.00±0.003ab	-
	SE	48.64±0.084c	10.76±0.050c	10.69±0.089c	1.01±0.011a	-
	OE	48.67±0.059c	10.64±0.131d	10.89±0.084b	0.98±0.017c	-
	GE	48.05±0.139d	9.06±0.065e	10.42±0.124d	0.87±0.008d	-
	CE	48.75±0.047bc	10.89±0.054b	11.01±0.066a	0.99±0.010bc	-
	TC	48.92±0.057a	10.98±0.104ab	10.99±0.074ab	1.00±0.012ab	-
	BHA/BHT	47.85±0.103e	10.70±0.077cd	10.76±0.109c	0.99±0.009ab	-
9	**CON**	47.90±0.086h	7.62±0.086g	9.44±0.052g	0.81±0.012e	-
	RE	49.83±0.062b	10.34±0.128b	10.79±0.146ab	0.96±0.010b	-
	SE	49.18±0.116d	9.36±0.042e	10.30±0.084e	0.91±0.010d	-
	OE	49.59±0.067c	9.49±0.153d	10.51±0.119d	0.90±0.015d	-
	GE	48.69±0.091g	8.19±0.029f	10.09±0.150f	0.81±0.014e	-
	CE	48.90±0.080e	10.52±0.081a	10.68±0.088bc	0.98±0.012a	-
	TC	49.96±0.035a	10.42±0.101ab	10.86±0.068a	0.96±0.011b	-
	BHA/BHT	48.79±0.068f	9.89±0.087c	10.62±0.125cd	0.93±0.007c	-
12	**CON**	48.47±0.096e	7.14±0.079e	9.52±0.153f	0.75±0.012e	-
	RE	50.95±0.162a	9.96±0.132a	10.36±0.051b	0.96±0.013bc	-
	SE	49.93±0.069b	8.95±0.058c	9.98±0.120de	0.90±0.005d	-
	OE	50.04±0.102b	8.90±0.084c	10.06±0.122d	0.88±0.017d	-
	GE	49.32±0.068d	7.36±0.067d	9.89±0.130e	0.74±0.011e	-
	CE	49.69±0.125c	10.02±0.073a	10.21±0.072c	0.98±0.008a	-
	TC	51.07±0.048a	10.05±0.076a	10.51±0.084a	0.96±0.014c	-
	BHA/BHT	49.22±0.085d	9.80±0.036b	10.09±0.089cd	0.97±0.008ab	-
15	**CON**	48.37±0.112e	6.81±0.084d	9.64±0.137c	0.71±0.012c	6.68±0.124b
	RE	50.80±0.079a	9.53±0.147a	10.09±0.076ab	0.94±0.012a	6.08±0.185c
	SE	50.42±0.155b	8.37±0.086c	9.71±0.103c	0.86±0.014b	6.58±0.160b
	OE	49.94±0.165c	8.44±0.044c	9.73±0.159c	0.87±0.011b	6.20±0.151c
	GE	49.52±0.149d	6.92±0.128d	9.65±0.096c	0.72±0.017c	7.10±0.206a
	CE	49.92±0.107c	9.30±0.101b	10.03±0.056b	0.93±0.010a	5.54±0.129d
	TC	50.93±0.066a	9.56±0.069a	10.21±0.065a	0.94±0.007a	6.13±0.093c
	BHA/BHT	49.65±0.098d	9.27±0.183b	9.98±0.071b	0.93±0.020a	5.38±0.155d

CON: control (without antioxidant); RE: 0.2 g rosemary extract/kg meat; SE: 0.2 g sage extract/kg meat; OE: 0.2 g oregano extract /kg meat; GE: 0.2 g ginger extract/kg meat; CE: 0.2 g clove extract/kg meat; TC: 0.2 g tea catechins/kg meat; BHA/BHT: 0.2 g BHA/BHT (1:1)/kg meat. *L** = lightness; *a** = redness; *b** = yellowness

Means in the same column for the same storage day with a different letter (a-g) differ significantly ($p < 0.05$)

Table (5): Effect of natural and synthetic antioxidants on sensory attributes of beef burgers during storage at 4±1°C

Storage time (days)	Treatment	Colour	Texture	Odour	Taste	Overall acceptability
0	CON	8.55±0.284ab	8.10±0.516a	8.25±0.264a	8.80±0.350a	7.95±0.798a
	RE	8.60±0.211ab	7.80±1.006a	8.30±0.258a	8.70±0.258ab	8.10±0.615a
	SE	8.65±0.338ab	7.75±0.979a	8.05±0.643a	8.70±0.422ab	8.00±0.624a
	OE	8.45±0.284b	7.99±0.410a	8.10±0.460a	8.85±0.242a	7.80±0.823a
	GE	8.70±0.422ab	8.15±0.580a	7.95±0.438a	8.50±0.408b	7.73±0.901a
	CE	8.75±0.354a	8.25±0.540a	7.96±0.427a	8.60±0.394ab	8.13±0.637a
	TC	8.60±0.211ab	8.05±0.599a	8.20±0.350a	8.65±0.242ab	8.33±0.501a
	BHA/BHT	8.80±0.258a	7.98±0.650a	8.25±0.354a	8.50±0.333b	8.23±0.448a
3	CON	7.70±0.350d	7.85±0.412a	7.45±0.369d	7.30±0.715c	6.40±0.699b
	RE	8.30±0.350abc	7.50±0.882a	8.35±0.338a	8.15±0.530ab	7.60±0.966a
	SE	8.60±0.394a	7.90±0.516a	8.05±0.550abc	7.95±0.685ab	7.40±0.775a
	OE	8.20±0.789abc	7.65±0.747a	7.90±0.394bc	7.90±0.738ab	7.40±0.843a
	GE	7.85±0.580cd	7.90±0.658a	7.80±0.350c	7.60±0.709bc	7.30±0.856a
	CE	8.30±0.350abc	8.00±0.624a	7.98±0.381bc	8.05±0.685ab	7.62±0.977a
	TC	8.45±0.497ab	8.05±0.550a	8.15±0.242ab	8.20±0.483a	7.55±0.956a
	BHA/BHT	8.10±0.394bcd	7.80±0.675a	8.05±0.438abc	7.95±0.497ab	7.50±0.913a
6	CON	7.15±0.669b	7.90±0.615a	6.00±0.333d	6.93±1.000b	5.80±0.747b
	RE	8.05±0.497a	7.65±0.626a	7.05±0.550a	7.73±0.506ab	7.05±0.985a
	SE	8.03±0.478a	7.75±0.589a	6.80±0.483ab	7.40±0.568ab	6.90±0.937a
	OE	7.80±0.587a	7.50±0.882a	6.55±0.369bc	7.50±1.054ab	6.90±1.174a
	GE	7.70±0.538ab	7.85±0.580a	6.40±0.460c	7.05±0.896ab	6.70±1.135ab
	CE	7.95±0.497a	7.80±0.675a	6.90±0.394ab	7.80±0.856a	7.04±0.980a
	TC	8.03±0.786a	7.90±0.843a	7.00±0.408a	7.65±1.001ab	7.15±0.973a
	BHA/BHT	7.80±0.919a	7.80±0.978a	6.80±0.483ab	7.50±1.155ab	7.00±0.624a
9	CON	6.25±0.589d	7.20±0.789a	5.30±0.633d	6.05±0.956b	5.75±0.755b
	RE	7.70±0.350a	7.35±0.626a	6.90±0.658a	7.30±0.888a	6.70±0.978a
	SE	7.75±0.486a	7.50±0.577a	6.10±0.516bc	6.95±1.066a	6.40±1.287ab
	OE	7.10±0.615bc	7.30±0.823a	6.25±0.354bc	6.90±1.075ab	6.55±1.166ab
	GE	6.78±0.721cd	7.45±0.864a	6.00±0.408c	6.50±0.667ab	5.90±0.843ab
	CE	7.50±0.527ab	7.13±0.616a	6.75±0.635a	7.25±0.890	6.63±1.029ab
	TC	7.60±0.699ab	7.40±0.843a	6.95±0.497a	7.35±1.029a	6.78±1.088a
	BHA/BHT	7.50±0.707ab	7.45±0.956a	6.50±0.408ab	7.25±1.184a	6.60±1.049ab
12	CON	6.00±0.667b	7.00±1.054a	4.10±0.460d	5.13±0.907c	4.75±0.950c
	RE	7.20±0.538a	6.95±0.643a	6.45±0.599a	6.95±0.927a	6.25±0.890a
	SE	7.13±0.615a	6.90±0.810a	5.75±0.540b	6.70±1.160ab	5.90±1.022ab
	OE	7.03±0.606a	6.80±0.753a	5.65±0.412b	6.63±0.680ab	5.80±0.919ab
	GE	6.20±0.789b	6.75±0.589a	5.10±0.394c	5.95±0.685bc	5.20±0.823bc
	CE	7.05±0.762a	6.90±0.810a	6.30±0.538a	6.88±0.775a	6.30±0.978a
	TC	7.10±0.658a	7.02±0.297a	6.60±0.316a	7.00±0.943a	6.40±0.876a
	BHA/BHT	7.00±0.817a	7.00±1.202a	6.40±0.738a	6.80±1.358ab	6.25±0.825a
15	CON	5.20±0.633c	6.55±1.117a	3.75±0.717e	4.80±1.033c	3.80±0.633c
	RE	7.05±0.438a	6.65±1.029a	5.95±0.643ab	6.65±1.180a	6.10±1.287a
	SE	6.95±0.550a	6.50±0.850a	5.40±0.394c	6.30±1.059a	5.85±1.668ab
	OE	6.90±0.568a	6.40±1.075a	5.45±0.369bc	6.20±1.135ab	5.75±1.275ab
	GE	6.00±0.408b	6.45±0.762a	4.30±0.587d	5.30±1.006bc	4.90±0.516b
	CE	6.80±0.856a	6.65±0.818a	5.90±0.394abc	6.60±1.174a	5.95±1.383ab
	TC	6.95±0.685a	6.70±0.949a	6.10±0.810a	6.65±0.973a	6.15±1.107a
	BHA/BHT	6.80±1.085a	6.55±1.166a	5.85±0.669abc	6.50±1.247a	5.90±0.810ab

CON: control (without antioxidant); RE: 0.2 g rosemary extract/kg meat; SE: 0.2 g sage extract/kg meat; OE: 0.2 g oregano extract /kg meat; GE: 0.2 g ginger extract/kg meat; CE: 0.2 g clove extract/kg meat; TC: 0.2 g tea catechins/kg meat; BHA/BHT: 0.2 g BHA/BHT (1:1)/kg meat.
Means in the same column for the same storage day with a different letter (a-g) differ significantly ($p < 0.05$)

higher flavour scores than those of other formulas during storage. Tang *et al.* (2006) reported that addition of TC at a level of 200 mg/kg meat improved colour stability in beef patties and prolonged the colour shelf life by 2 days, the colour stabilizing effect of TC in beef may be due delaying oxidation of oxymyoglobin in muscle via inhibition of lipid oxidation. Furthermore, a high positive correlation between TBARS values and trained panel scores for cooked beef was noted when stored at 4 °C for 1–3 days (Younathan *et al.,* 1980). Sánchez-Escalante *et al.* (2001) also reported that the presence of rosemary, both alone and with ascorbic acid, extended the fresh meat colour and odour storage time. Sebrank et al., (2005) mentioned that frozen sausage treated with 2500 ppm rosemary extract was significantly less brown than sausage treated with BHA/BHT during the entire 16-week testing period.

CONCLUSIONS

From the obtained results, it can be concluded that the use of natural and synthetic antioxidants can reduce lipid oxidation, enhance colour stability and improve the sensory characteristics of beef burgers. Thus, addition of natural antioxidants is one of the ways to extend the durability of meat and meat products. The TC and RE provided the best antioxidant protection against beef burgers deterioration during 15 days of storage. Moreover, TC and RE are superior to BHA/BHT in inhibiting the lipid oxidation and improving the colour and sensory attributes of beef burgers during refrigerated storage. The CE, BHA/BHT, SE and OE extracts proved to be effective antioxidants in beef burgers, while GE showed a small antioxidant effect. Because of the well-known health benefits of these highly effective extracts of natural antioxidant, their application in the meat industry may be very valuable and desirable.

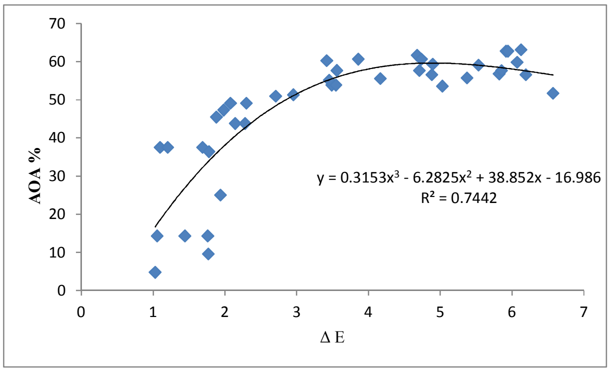

Figure 1. Correlation between antioxidant activity (AOA%) and A numerical total colour difference (Δ E) in beef burgers treated with natural and synthetic antioxidants and stored at 4±1 °C for 15 days.

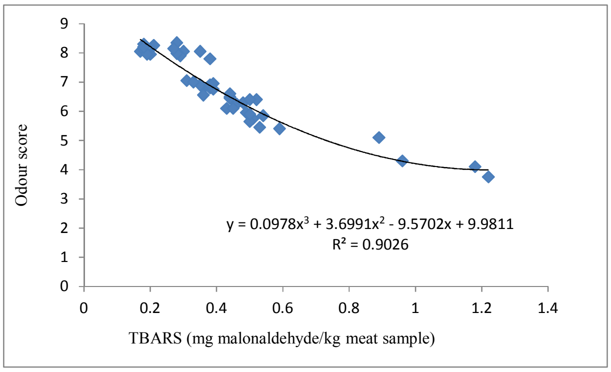

Figure 2. Correlation between lipid oxidation (TBARS values) and odour (sensorial scores) in beef burgers treated with natural and synthetic antioxidants and stored at 4±1 °C for 15 days.

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التأثير المضاد للأكسدة لبعض المستخلصات النباتية بالمقارنة بالـ BHA/BHT على أكسدة الدهون وبعض خصائص الجودة لبرجر اللحم البقري المخزن على ٤°م

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من المعروف منذ القدم فعالية بعض النباتات في حفظ الأغذية. ولقد تزايد في السنوات الأخيرة استخدام الأعشاب والتوابل لتحسين الخصائص الحسية وإطالة فترة الصلاحية للأغذية. تم دراسة التأثير المضاد للأكسدة لمستخلصات الحصالبان, الميرمية, البردقوش البرى, الزنجبيل, والقرنفل وكاتشينات الشاي بالمقارنة بالـ BHA/BHT على أكسدة الدهون وجودة برجر اللحم البقري المخزن على ٤ °م. تم تقدير وحساب التركيب الكيماوى, قيم الـ TBARS, النشاط المضاد للأكسدة AOA%, اللون (قيم *L*, *a*, *b*, مؤشر الاحمرار والاختلاف الكلى في اللون) والخواص الحسية لعينات برجر اللحم البقري خلال التخزين المبرد على ٤°م لمدة ١٥ يوم. تم ملاحظة أن هناك انخفاض معنوي في قيم الـ TBARS والتغير في اللون عينات البرجر المعاملة بالمقارنة بالكنترول خلال التخزين. حيث كانت قيم الـ TBARS أكثر انخفاضا بمعنوية في عينات البرجر المعاملة بكاتشينات الشاي يليها مستخلصي الحصالبان والقرنفل والـ BHA/BHT ومستخلصات البردقوش البرى, الميرمية والزنجبيل. ولقد كان ترتيب النشاط المضاد للأكسدة لعينات البرجر المختبرة كالتالي كاتشينات الشاي > مستخلص الحصالبان > مستخلص القرنفل > BHA/BHT > مستخلص البردقوش البرى > مستخلص الميرمية > مستخلص الزنجبيل وكانت قيم التقييم الحسى متوافقة مع هذه النتائج. لذلك فإن كاتشينات الشاي ومستخلصي الحصالبان والقرنفل تمنع أكسدة الدهون في عينات البرجر, وبالتالي يمكن أن تستخدم كبديل لمضادات الأكسدة الصناعية التي ثبت أن لها تأثيرات سلبية على الصحة.