



## Impact of Mango Peel Extract on the Physicochemical Properties, Microbiological Stability and Sensory Characteristics of Beef Burgers During Cold Storage



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THE impact of adding mango peel extract (MPE) on lipid oxidation, color deterioration, microbial stability and sensory properties of beef burgers stored at  $4 \pm 1$  °C for 12 days was investigated. The MPE was incorporated into beef burger mix at 0.1, 0.2 and 0.3%, and compared with 0.01% butylatedhydroxyanisole (BHA)/butylatedhydroxytoluene (BHT) (1:1; positive control) and control (without any antioxidants; negative control). The results showed that mango peel powder contained high total phenolic content (TPC) (45.17 mg/g GAE) and antioxidant activity (92.05%). Also, the results showed that pH and color ( $L^*$ ,  $a^*$  and  $b^*$ ) values of MPE-containing burgers were lower than those of both controls. By the end of storage time, the (0.3%) MPE-containing burgers showed the lowest pH (6.03) and color ( $L^*$ ,  $a^*$  and  $b^*$ ) values (49.95, 11.51 and 10.38, respectively). Also, the (0.3%) MPE-containing burgers had higher TPC (121.85) and lower TBARS values (0.18) compared to the controls (29.57-60.65 mg GAE/100g and 0.19-0.20 mg malondialdehyde/kg, respectively). Consequently, adding the MPE enhanced the antioxidant activity and resulted in a significant inhibition of total aerobic count in comparison to both controls. The results obtained from sensory analyses revealed that adding the MPE to beef burgers was effective with regard to retarding color and taste deterioration, and rancid odor formation. The (0.1%) MPE-containing burgers had the highest overall sensory scores. The results obtained from this study showed that MPE can be an effective additive with regard to retarding deterioration of quality characteristics during the cold storage of beef burgers.

**Keywords:** Mango peel extract, Beef burger, Antioxidant activity

### Introduction

In recent years, production and consumption of processed meat products such as burgers, patties and sausages notably increase in many countries worldwide. This may be due to the steady population increase and changes in consumer's attitude towards processed meats which contain appreciable amounts of proteins, vitamins and minerals (National Health and Medical Research Council 2006; Gahruie et al., 2017). Lipid oxidation is a major cause of quality deterioration and shelf-life reduction in the fat-containing foods such as meat and meat products. Rancid odor and off-flavor, discoloration, drip and nutrient losses,

formation of harmful compounds and decrease of shelf life can be a result of the lipid oxidation in foods (Falowo et al., 2014). As a consequence, sensory properties such as taste, odor, color and texture can be negatively impacted (Sebranek et al., 2005 and Falowo et al., 2014). The use of antioxidants is the most effective and commonly use approach for preventing, reducing or retarding lipid oxidation and harmful compounds formation, improving or maintaining the sensory properties and extending the shelf life of fat-containing foods (Pereira et al., 2011; Nor Adilah et al., 2018 and Amiri et al., 2019).

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Synthetic antioxidants such as butylated-hydroxyanisole (BHA), butylatedhydroxytoluene (BHT), tert-butylhydroquinone (TBHQ) and propyl gallate (PG) are widely and effectively used in the food industry for inhibiting lipid oxidation, preserving the degradation of sensory properties and extending the shelf life of processed meat products (Aziz and Karboune, 2018). Because of recent health concerns about using the synthetic antioxidants such as BHA and BHT, consumers have been tended more towards the natural antioxidants (Sebranek et al., 2005). Recently, use of natural antioxidants extracted from plant sources including spices, herbs, fruits and vegetables, and even agro-food by-products for preventing lipid oxidation occurred in meat products is steadily increasing (Falowo et al., 2014). Pomegranate peel, Shirazi thyme, cinnamon, rosemary, green tea and artichoke extracts are examples of natural sources of antioxidants incorporated in processed meat products (Özvural et al., 2016; Gahruie et al., 2017; Turgut et al., 2017 and Ergezer et al., 2018).

Mango (*Mangifera indica* L.), a member of the family Anacardiaceae, is one of the most popular, nutritious and tasty tropical fruits with different health promoting features (Ajila et al., 2007; Ajila et al., 2010; Kim et al., 2010 and Pereira et al., 2011). The world production of mangoes, mangosteens and guavas is about 50.6 million tonnes in 2017. The top ten mango-producing countries in 2017 were India, China, Thailand, Indonesia, Mexico, Pakistan, Brazil, Bangladesh, Egypt and Malawi, respectively. Egypt produced about 1.35 million tonnes in 2017 (FAOSTAT, 2017). Mango peels, resulting from the industrial processing of the mango fruit, can be a promising source of different bioactive compounds such as gallic, ellagic and ferulic acids, mangiferin, quercetin, catechin and ascorbic acid (Dorta et al., 2014 and Romainum et al., 2018). Mango peels and seeds resulted from the industrial production of mango pulp may represent up to 30% of the fruit weight (Larrauri et al., 1996). Therefore, mango peel can be considered as a valuable industrial agro-food by-product and recent studies reported the possibility of exploiting the mango peel or its extract as a source of natural antioxidants (Ajila et al., 2007; Ajila et al., 2010; Kim et al., 2010; Pereira et al., 2011; Kadakadiyavar et al., 2017 and Nor Adilah et al., 2018). This study aimed to evaluate the impact of adding different levels of mango peel extract on lipid oxidation and some quality characteristics of beef burgers stored under cooling at  $4 \pm 1$  °C.

## Materials and Methods

### Materials and chemicals

Fresh ripe mango (*Mangifera indica* L. cv. Zebda) fruits were collected from a farm located in Ismailia, Egypt. Fresh beef flank and brisket along with beef fat were purchased from a local meat processing factory (Ismailia, Egypt). Folin-Ciocalteu's phenol reagent, 2-Thiobarbituric acid and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (St. Louis, MO, USA). All other chemicals and solvents were of analytical grade and obtained from Fisher Scientific (Mumbai, India) and Merck (Darmstadt, Germany).

### Preparation of mango peel powder

The mango fruit's peels were manually separated by using a kitchen peeler, washed with tap water, and then cut using a sharp knife into small squares ( $\approx 1 \times 1$  cm). The mango peel cuts were placed in one layer on stainless steel trays and subjected to air drying using a connective dryer (WT-binder, type F115, Germany) at temperature (45 °C), air velocity (0.6 m/s) and ambient relative humidity for 24 hr reaching a moisture content of around 6 %. The dried mango peel cuts were ground using a blender (Waring Commercial, HGB2WTS3, Torrington, Connecticut, USA) and then sieved through a mesh 60 (0.25 mm) sieve shaker (Retsch, 5657 Haan, Germany). The obtained mango peel powder (MPP) [moisture (4.9%), crude protein (3.8%), crude fat (2.6%), ash (3.3%) and carbohydrate (85.4%)] was packaged under vacuum in sealed polyethylene bags and kept at  $4 \pm 1$  °C for 24 hr for both analyses and extraction.

### Preparation of mango peel extract

The MPP was extracted with an absolute ethanol (1:10 w/v). The extraction was carried out twice with a constant agitation of 100 rpm for 24 hr using a laboratory shaker (Decoloring Table, TY-B, China). Then the ethanolic extracts were filtered through filter paper (Whatman No. 4, 110 mm). The ethanol was evaporated from the combined filterates using a rotary evaporation (Strike 300, Steroglass, Italy) at 40 °C and under vacuum. The remixed extract was stored at -18 °C until use.

### Preparation of beef burgers

Fresh beef flank and brisket were trimmed of the separable fats and connective tissues to provide a very lean meat. The lean meat and beef fat were separately minced using a meat mincer

(SAP Meat Mincer TC22, Italy) through a 10 mm steel plate and then through a 4 mm steel plate. The minced meat (87.5%) was mixed with minced fat (12.5%) for 5 min using a meat mixer (Classic Chef-KM353, Kenwood Ltd., Havant, UK). Sodium chloride, seasoning and sodium tripolyphosphate were added in rations of 1.5, 0.65 and 0.015 g/100 g of meat mixture. After mixing well, the final meat mixture [moisture (59.87 %), crude protein (19.03 %), crude fat (19.79 %) and ash (1.29 %)] was divided into five equal portions. The first portion did not include any natural or synthetic antioxidant as a negative control (T1). The second portion included BHT/BHA (1:1, w/w) at a concentration of 0.01 % as a positive control (T2). Mango peel extract (MPE) was added to the last three portions at a concentration of 0.1% (T3), 0.2% (T4) and 0.3% (T5). All portions were formed into burgers (60±1 g) using a manual burger former (Italmans, Italy). The burgers were laid on Styrofoam trays, covered with polyethylene pouches and stored in a refrigerator at 4±1°C for 12 days. Burger samples were subjected to analyses before starting the cold storage (day 0) and then at intervals of three days during the cold storage.

#### *Proximate analysis of mango peel powder and beef burger mixture*

The moisture content was determined using a hot air oven at 100 °C (method No. 925.10). The crude protein content (N x 6.25) was determined by Kjeldahl's method (method No. 978.04). The crude fat content was determined by a Soxhlet extracting method using petroleum ether (60-80 °C) (method No. 930.09). The ash content was determined by dry ashing of the dried samples at 550°C in a muffle furnace (method No. 930.05). All of these determinations were carried out according to the guidelines of Association of Official Analytical Chemists (AOAC, 2005). Carbohydrate content was calculated by difference.

#### *Determination of pH*

The pH values were monitored by blending 10 g burger sample with 90 mL distilled water for 2 min. Values were taken with a Jenway pH meter (Jenway 3510, Bibby Scientific Ltd., Stone, Staffs, UK).

#### *Measurement of instrumental color*

Color parameters (CIE  $L^*$ ,  $a^*$ , and  $b^*$ ) of MPP and beef burger samples were taken by the color reader CR-10 (Konika Minolta, Inc., Osaka, Japan) according to the method of Özvural et al.

(2016). Five readings were taken and averaged for each replicate.

#### *Determination of ascorbic acid concentration*

The ascorbic acid content of MPP was determined by a titration method using 2,6-dichlorophenolindophenol dye solution (method No. 967.21) and according to AOAC (2005).

#### *Determination of total phenolic content*

The total phenolic content (TPC) of the methanolic extracts of MPP, MPE and beef burger samples was determined by the Folin-Ciocalteu colorimetric method as described by Osorio-Esquivel et al. (2011). The obtained phenolic contents were expressed as milligrams of gallic acid equivalents per gram MPP and MPE (mg GAE/g MPP or MPE) and as milligrams of gallic acid equivalents per 100 gram burger samples (mg GAE/100 g burger).

#### *Determination of antioxidant activity*

Antioxidant activity of the methanolic extracts of MPP and beef burger samples was determined on the basis of their scavenging activities against DPPH (2,2-diphenyl-1-picrylhydrazyl) according to the method described by Ravichandran et al. (2013). The mixture of MPP or burger extract and 0.1 mM DPPH in methanol was allowed to react for 30 min in a test tube at room temperature. The absorbance was measured spectrophotometrically at 517 nm.

#### *Determination of lipid oxidation*

The extent of lipid oxidation was assessed through the determination of the 2-thiobarbituric acid reactive substance (TBARS) using a distillation method described by Tarladgis et al. (1960) and modified by Shahidi et al. (1987). Five mL distillate of 10 g of the burger sample was reacted with TBA reagent (0.02 M of 2-thiobarbituric acid) in tightly tubes. Tubes were heated in a water bath at 100 °C for 35 min. The absorbance of the resultant color was measured at 532 nm using a spectrophotometer (T80 UV/VIS, PG Instruments Ltd, UK). TBARS values were expressed as mg malondialdehyde equivalent/kg burger sample (mg MDA/kg).

#### *Determination of microbiological quality*

For determining the total aerobic count (TAC), 25 g of burger samples were aseptically taken and transferred into a sterile pestle contained 225 mL of sterile 0.1 % peptone water. Samples were homogenized with peptone water for 2 min at room temperature. The appropriate dilutions were prepared and plated on nutrient agar. The

inoculated plates were incubated at  $37 \pm 1$  °C for 48 hr, and the TAC were expressed as  $\log_{10}$  colony forming units (CFU)/g (Özvural et al., 2016).

#### *Sensory evaluation*

Burger samples were evaluated according to the method described by Rodríguez-Melcón et al. (2017). Panelists were chosen from the staff members of Food Technology Department, Suez Canal University, based on their previous experience and familiarity in sensory analysis of meat products. Preparatory training sessions were provided to the panelists before the sensory evaluation for ensuring that each panelist could completely identify and clarify each sensory attribute in cooked burgers. Ten selected trained panelists evaluated the cooked burgers on the days 0, 3, 6, 9 and 12 during the cold storage. The burger samples were grilled at around 180 °C for 3 min on each side using an electric grill (WA-BBQ 01, White Whale, China). The grilled burgers were kept warm and tested within 5-10 min after grilling. A structured nine-point hedonic scale for evaluating the color, odor, taste and overall acceptability (1 = extremely undesirable, 9 = extremely desirable) and the juiciness (1 = extremely dry, 9 = extremely juicy) of the burger samples was applied.

#### *Statistical analysis*

All measurements were done in triplicate and data are presented as mean values  $\pm$  SD. Analysis of variance (ANOVA) accompanied with Duncan's multiple range test for determining the significance at ( $p < 0.05$ ) level between treatment means, and further, Pearson's correlation between MPE concentration and each of pH, TPC, antioxidant activity and TBARS values were performed. Analysis were carried out using SPSS software (version 17.0 for Windows, SPSS Inc., Chicago, USA).

## **Results and Discussion**

#### *Physicochemical properties of mango peel powder*

Results presented in Table 1 showed that mango peel powder (MPP) has high contents of ascorbic acid (120.83 mg/100 g) and TPC (45.17 mg GAE/g). Total phenolic content in mango peels from different varieties ranged from 16.14 to 98 mg/g (Vergara-Valencia et al., 2007 and Dorta et al., 2012). As a consequence, mango peel powder (MPP) exhibited a high antioxidant activity, 92.05% of the DPPH scavenging activity was inhibited by the mango peel extract (MPE) after 30 min of starting the reaction (Table 1). The

results obtained either by the present study or by previous studies (Ajila et al., 2010; Dorta et al., 2012 and Kadakadiyavar et al., 2017) showed that mango peel may have higher TPC and antioxidant activity than those found in peels from other fruits such as orange, pomegranate and tomato (Nassar et al., 2016).

With regard to color values ( $L^*$ ,  $a^*$  and  $b^*$ ), the measurements using CIELAB color reader showed a lower  $a^*$  value in comparison to  $b^*$  value (Table 1). The  $a^*$  axis and  $b^*$  axis in the CIELAB system denote intensity in the green to red and blue to yellow spectrum, respectively. While positive and negative values of  $a^*$  value indicates redness and greenness, the positive and negative values of  $b^*$  indicates yellowness and blueness, respectively.  $L^*$  is a measure of lightness ranges from 0 for black to 100 for white. MPP exhibited a slight brightness, low redness and high yellowness values of 64.70, 2.53 and 26.55, respectively (Table 1).

#### *pH value and color parameters of beef burgers*

Changes in the pH and color ( $L^*$ ,  $a^*$  and  $b^*$ ) values of beef burger samples during the cold storage at  $4 \pm 1$  °C are illustrated in Fig. 1 and 2. The pH values of the freshly prepared burgers ranged between 5.86 for (T5) and 5.91 for (T1). Increasing the addition level of MPE caused a decrease in the pH values of the prepared beef burgers with a negative correlation ( $r = -0.289$ ). Similarly, Turgut et al. (2017) reported that adding pomegranate peel extract decreased the pH values of beef meatball samples. Results presented in Fig. 1 revealed that though pH values of all burger samples gradually increased during the cold storage, the MPE-containing burgers exhibited the lowest values (6.03-6.06) in comparison to negative control (6.08). This increase in pH values of all burger samples that occurred during the cold storage might result from the production of some alkaline by-products such as trimethylamine and ammonia as a result of a probable microbial growth and a deamination of proteins (Amiri et al., 2019). An increase in pH values during storage in ground beef patties was reported by Amiri et al. (2019).

Color is an important organoleptic quality characteristic which contributes in determining the overall acceptance of meat or processed meat products by consumers. Results presented in Fig. 2a-c showed that the negative control (T1) exhibited  $L^*$ ,  $a^*$  and  $b^*$  values of 51.72, 12.75 and 11.23, respectively. Adding the synthetic

antioxidants (T2) did not cause a significant change in the color ( $L^*$ ,  $a^*$  and  $b^*$ ) values, while all addition levels of MPE (T3-T5) significantly decreased all color values of the negative control (T1) (Fig. 2a-c).

The decrease steadily occurred in the  $L^*$  values by increasing the addition level of the MPE might be due to the dark green color of the MPE. With regard to impact of storage time on color values, results showed that all color values decreased significantly in all treatments by progress of storage time. A similar decrease in color values was observed by adding some plant extracts such as artichoke, cinnamon, rosemary, thyme, mango seed and pomegranate peel extracts to different meat products (Pereira et al., 2011; Gahruie et al., 2017; Turgut et al., 2017 and Ergezer et al.,

2018). However, this decrease might be a result of biochemical reactions (e.g. oxidation) occurred for components of beef burgers such as red meats' natural pigments. Gahruie et al. (2017) and Amiri et al. (2019) reported that the color of stored meat becomes dark red-brown as a result of metmyoglobin formation, surface drying and low light reflection.

Redness ( $a^*$ ) is important parameter for evaluating the extent of oxidation occurred in meat or meat products. Results presented in Fig 2b showed that adding synthetic antioxidants (BHA/BHT, T2) maintained the redness of prepared burgers in comparison to the negative control (T1) during the storage time. A similar impact was achieved by adding the MPE even at the lowest level of addition (T3). Similar results were recorded with regard to  $b^*$  values (Fig. 2c).

TABLE 1. Physicochemical properties of mango peel powder.

Constituents	Value <sup>a</sup>
Ascorbic acid (mg/100 g)	120.83 ± 0.265
Total phenolic content (mg/g)	45.17 ± 0.253
Antioxidant activity (%)	92.05 ± 0.229
Color parameters	
$L^*$	64.70 ± 0.570
$a^*$	2.53 ± 0.195
$b^*$	26.55 ± 0.499

<sup>a</sup> Data are averages of triplicate determinations ± standard deviation.

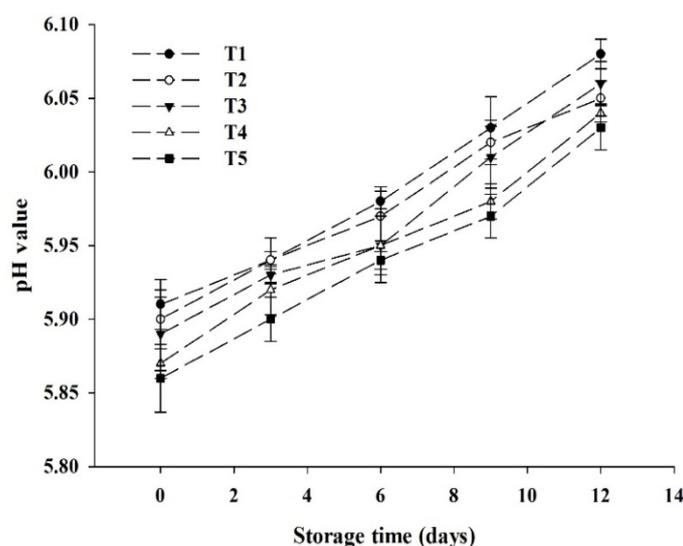


Fig. 1. Effect of mango peel extract and BHA/BHT on pH values of beef burger during 12 days storage at  $4 \pm 1$  °C. T1 (control), T2 (0.01% BHA/BHT; 1:1), T3 (0.1% MPE), T4 (0.2% MPE) and T5 (0.3% MPE). Results represent mean value of triplicate determinations ± SD.

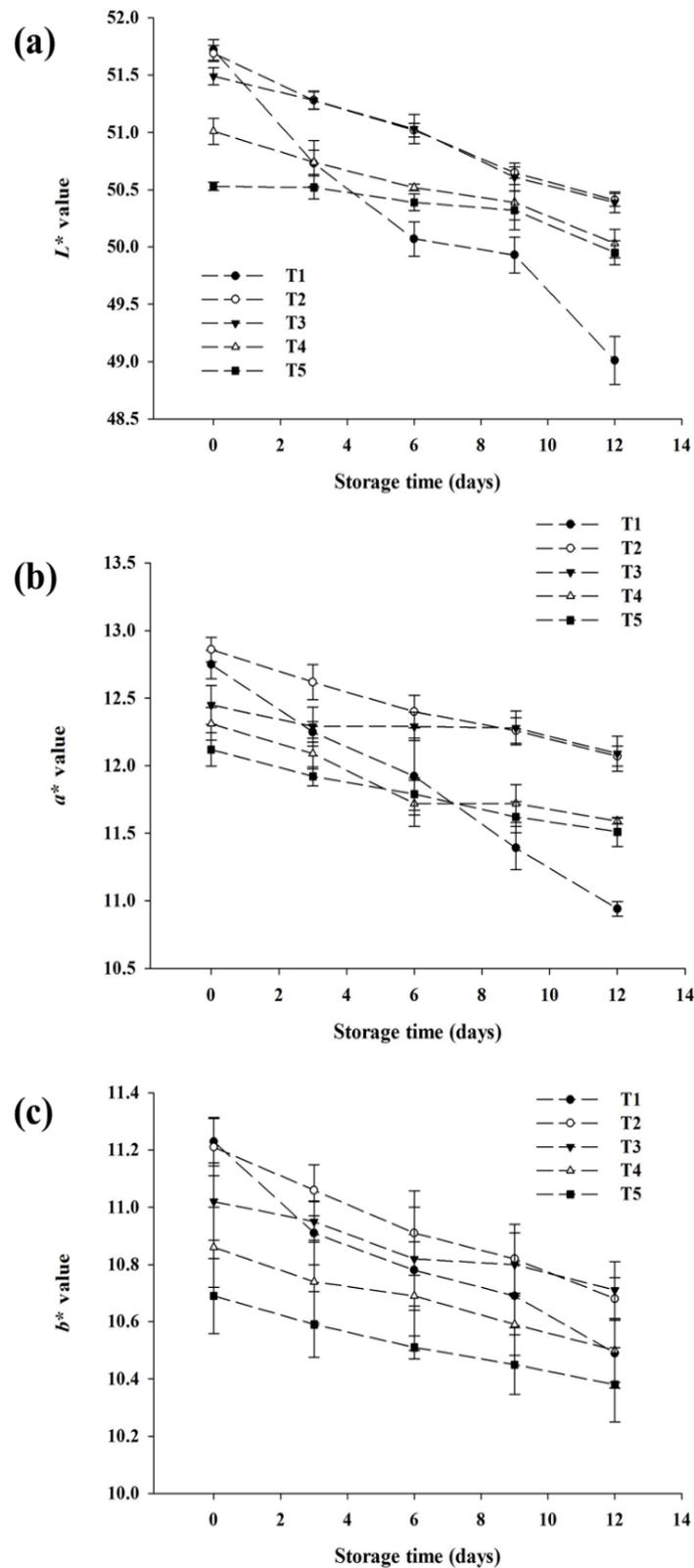


Fig. 2. Effect of mango peel extract and BHA/BHT on  $L^*$  (a),  $a^*$  (b) and  $b^*$  (c) values of beef burger during 12 days storage at  $4 \pm 1$  °C. T1 (control), T2 (0.01% BHA/BHT; 1:1), T3 (0.1% MPE), T4 (0.2% MPE) and T5 (0.3% MPE). Results represent mean value of five determinations  $\pm$  SD.

By end of storage time, both the 0.1% MPE-containing burgers (T3) and BHA/BHT-containing burgers (T2) exhibited similar higher  $L^*$ ,  $a^*$  and  $b^*$  values in comparison to the negative control (T1) which exhibited the lowest values at all. However, the lowest rate of decrease in the color values was achieved by 0.3% addition of MPE (T5) in comparison to negative control at the end of storage time (Fig. 2a-c).

#### *Total phenolic content, antioxidant activity and TBARS of beef burgers*

The phenolic compounds can be considered as predominant primary antioxidants in mango peels (Ajila et al., 2007). Results presented in Table 1 showed that MPP had a high TPC (45.17 mg GAE/g). As a consequence, the extract produced from MPP had a high TPC (206.33±0.577 mg GAE/g). The impact of adding mango peel extract (MPE) on the TPC, antioxidant activity and TBARS values of the prepared beef burger samples (T3 – T5) in comparison to either negative or positive controls (T1 and T2) during the cold storage at 4 ± 1 °C is illustrated in Fig. 3. The phenolic compounds are widely distributed in fruits and contribute to the overall antioxidant activities of these fruits (Aziz & Karboune, 2018). Some polyphenolic compounds such as flavonols accumulate in the peels of different fruits and boost their antioxidant properties (Ajila et al., 2007 and Sivankalyani et al., 2016). Gallic acid, mangiferin, ellagic acid, quercetin, ferulic acid and catechin are examples of the predominant phenolic compounds found in mango peels (Ajila et al., 2007; Dorta et al., 2014 and Sivankalyani et al., 2016). The results presented in Fig 3a-b showed significant differences ( $p < 0.05$ ) in TPC and antioxidant activity between the investigated beef burger samples.

The MPE-containing burgers (T3-T5) exhibited higher levels of TPC and antioxidant activity than the BHA/BHT positive controls (T2) and the negative controls (T1). At starting of storage time, 0.3% MPE-containing burgers (T5) exhibited the highest TPC (121.85 mg GAE/100g) and DPPH scavenging activity (62.85%) in comparison to the negative control which exhibited the lowest values, 29.57 mg GAE/100g and 32.21%, respectively. Ajila et al. (2007) reported a superior antioxidant activity of mango peel extract in comparison to the synthetic phenolic antioxidant BHA. Results showed that 0.1% MPE-containing burgers (T3) had TPC and antioxidant activity similar to that found in the

positive control (T2). As a consequence, the 0.1% addition level of MPE functioned in retarding the oxidation occurred in beef burgers as well as the addition level of BHA/BHT with regard to TBARS values (Fig. 3c). However, the results showed a high positive correlation between the addition level of MPE and both of TPC ( $r = 0.961$ ) and antioxidant activity ( $r = 0.924$ ) of stored beef burgers. These results agree with those reported in beef burgers and patties (Abdeldaiem and Ali, 2012; Nassar et al., 2016 and Ergezer et al., 2018). Further, Nor Adilah et al. (2018) observed an increase in TPC and free radicals scavenging activities of fish gelatin films at (3-5%) addition level of mango peel extract.

By progress of storage time at 4 ± 1 °C, both of TPC and antioxidant activity significantly decreased in all samples from the five treatments (T1–T5). These results agreed with those obtained by Ergezer et al. (2018) who reported a significant decrease in TPC and antioxidant activity during the cold storage of artichoke extract containing beef patties. Also, Nassar et al. (2016) reported a similar decrease in beef burgers incorporated with orange peel powder, pomegranate peel powder or tomato pomace powder by progress of the storage time. But results presented in Fig. 3a-b showed a better retention of TPC and antioxidant activity in all MPE-containing burgers (T3–T5) and positive control (T2) in comparison to the negative control (T1). By the end of storage time, the highest decrease in TPC (48.12%) and antioxidant activity (52.34%) was occurred in the negative control (T1). In contrast, only a decrease of 25.93 and 13.06% in TPC and antioxidant activity, respectively, occurred by adding 0.3% MPE (T5). This resulted in retarding lipid oxidation occurred in burgers produced from these four treatments (T2–T5) in comparison to negative control (T1).

Determination of TBARS values is one of the main measurements of inspecting the lipid oxidation. The TBARS values of all burger samples were very low at the start of storage time and ranged between 0.18 and 0.20 mg malondialdehyde/kg. Hasty et al. (2002) reported that TBARS value ranging between 0.202 and 0.664 mg malondialdehyde/kg is an indicator of the freshness of meats. Opposite to TPC and antioxidant activity, the TBARS values (Fig. 3c) increased in all burger samples by progress of storage time. The highest increase of TBARS values from 0.20 to 0.95 mg malondialdehyde/kg was recorded for the negative control (T1).

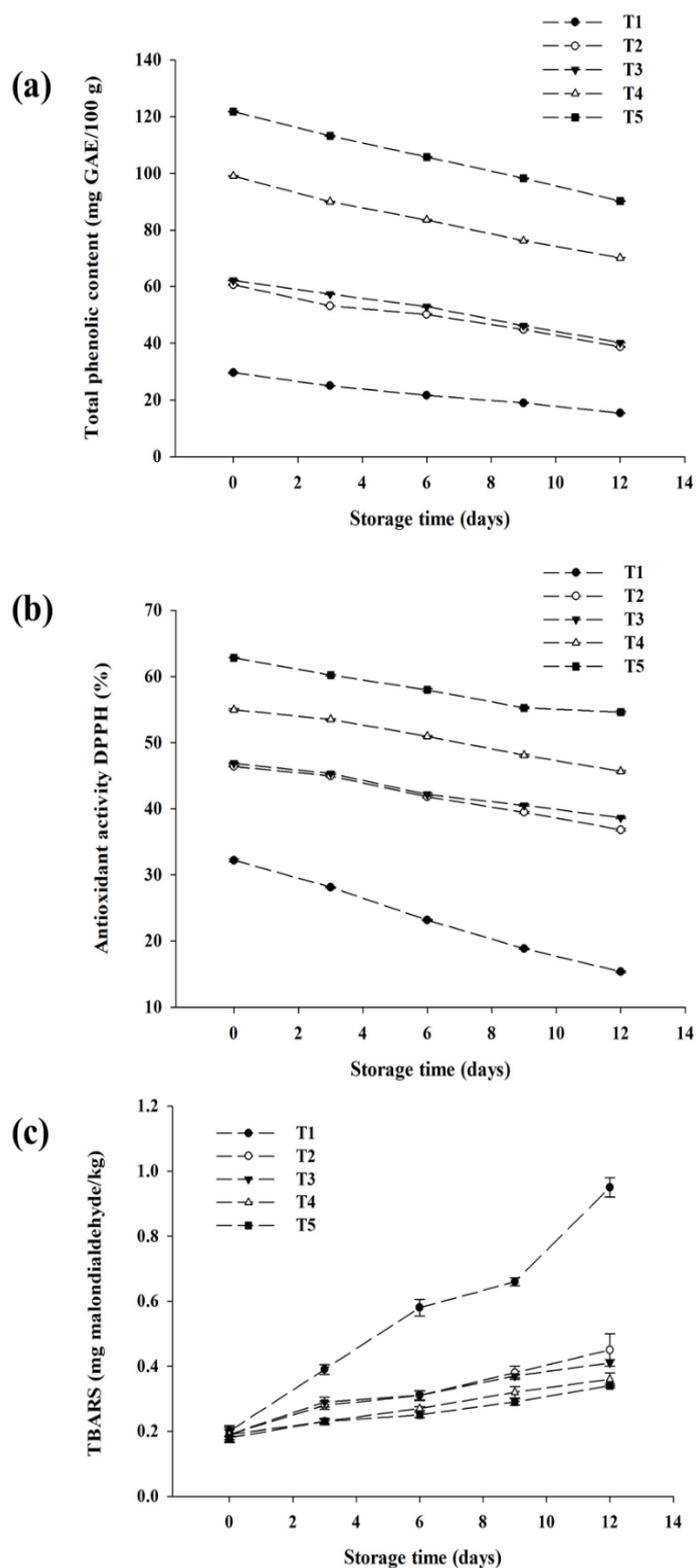


Fig. 3. Effect of mango peel extract and BHA/BHT on total phenolic content (a), antioxidant activity (b) and TBARS values (c) of beef burger during 12 days storage at  $4 \pm 1$  °C. T1 (control), T2 (0.01% BHA/BHT; 1:1), T3 (0.1% MPE), T4 (0.2% MPE) and T5 (0.3% MPE). Results represent mean value of triplicate determinations  $\pm$  SD.

In contrast, the lowest increase from 0.18 to 0.34 mg malondialdehyde/kg was recorded for the 0.3% MPE-containing burgers (T5). However, all MPE-containing burgers (T3 – T5) exhibited lowest TBARS values during storage time in comparison to either BHA/BHT-containing burgers (positive control, T2) or negative control (T1). Increasing the addition level of MPE caused a suppression of the development of lipid oxidation by progress of storage time whereas the TBARS values recorded for beef burgers from T4 and T5 were below 40% of that recorded for the negative control (T1) at end of storage time (Fig. 3c). A negative correlation ( $r = -0.570$ ) was found between the concentration of MPE and TBARS values in the produced beef burgers. As mentioned above the antioxidant properties of bioactive compounds such as phenolic compounds accumulated in the mango peel may contribute in retarding the oxidation of lipids and other sensitive substances susceptible to oxidation occurred in meat products. A similar positive impact of mango seed extract on retarding the lipid oxidation in mortadella was reported by Pereira et al. (2011). Also, Wang et al. (2019) observed that lipid oxidation of Cantonese sausages was effectively inhibited by the addition of fresh or dried mushroom rich in phenolic content, whereas lower TBARS values were obtained by increasing the addition level of this fungus. 4 °C is a temperature recommended by Forsythe (2020) and different food safety authorities for cold storage of ground beef meats. Changing this storage temperature may produce results differ from those obtained by this recent study. However frozen storage is expected to decrease the rate of lipid oxidation and microbial growth in comparison to the cold storage. The results illustrated by Turgut et al. (2017) showed

that frozen storage decreased the formation rate of oxidation products in the beef meatballs.

#### *Microbiological analysis of beef burgers*

Changes in the total aerobic count (TAC) of beef burger samples during cold storage at  $4 \pm 1^\circ\text{C}$  are presented in Table 2. The results showed that the initial TAC of all beef burger samples ranged between 3.85 and 3.94 log cfu/g with no significant differences ( $p > 0.05$ ) between the negative control (T1) and all other treatments (T2 – T5). Similarly, Özvural et al. (2016) reported that there was no significant difference at the beginning of storage time between green tea extract-containing hamburger patties and control. In the present study, during the storage period, there were no significant differences between MPE-containing burgers, with the lowest TAC, and BHA/BHT-containing burgers. By the end of storage time, an increase of about 3 log cycles was detected in the samples of the negative control, while about 2 log cycles increase was detected in the samples of all other treatments. Adding MPE at 0.3% level (T5) resulted in the lowest TAC detected in burgers even after 12 days of storage time. It might be due to the antimicrobial properties arising from occurring of phenolic compounds in MPE. Also, Tseng & Tseng (1995) reported that both synthetic phenolic antioxidants BHA and BHT have also an antimicrobial effect against *Penicillium islandicum*. Several studies reported antimicrobial properties of natural extracts from some plants such as artichoke, *Callistemon* leaves, thyme, cinnamon, rosemary and green tea (Özvural et al., 2016; Gahruiet et al., 2017; Fayemi et al., 2017 and Ergezer et al., 2018). These evidences may explain the positive impact of BHA, BHT and MPE on suppression the developing of the microbial growth by progress of storage time in comparison to burgers of negative control (T1).

**TABLE 2.** Effect of mango peel extract and BHA/BHT on total aerobic count (log cfu/g) of beef burger during 12 days storage at  $4 \pm 1^\circ\text{C}$ .

Treatment	Storage time (days)				
	0	3	6	9	12
T1	3.92±0.145Ae	4.72±0.120Ad	5.45±0.085Ac	6.02±0.072Ab	6.79±0.233Aa
T2	3.87±0.170Ae	4.56±0.050Bd	5.08±0.095Bc	5.58±0.026Bb	5.99±0.035Ba
T3	3.94±0.130Ae	4.42±0.045Bd	4.92±0.040Cc	5.47±0.064BCb	5.94±0.087Ba
T4	3.85±0.240Ae	4.45±0.053Bd	4.88±0.067Cc	5.39±0.085CDb	5.85±0.081Ba
T5	3.91±0.185Ae	4.44±0.060Bd	4.81±0.090Cc	5.28±0.040Db	5.82±0.066Ba

Mean values with different capital letters (A, B, C, D) in the same column are significantly different ( $p < 0.05$ ) between burger treatments at the same storage day. Mean values with different small letters (a, b, c, d, e) in the same row are significantly different ( $p < 0.05$ ) between storage days. T1 (control), T2 (0.01% BHA/BHT; 1:1), T3 (0.1% MPE), T4 (0.2% MPE) and T5 (0.3% MPE).

*Sensory properties of beef burgers*

Organoleptic quality characteristics of color, taste, odor, juiciness and overall acceptability were evaluated in cooked burger samples from all treatments (T1 – T5) during the cold storage period (Table 3). The results showed that all burger samples exhibited a high overall acceptability ranging between 8.7 and 8.8 with no significant difference between all treatments at starting of the storage time (Table 3). Similar results for overall palatability in chicken nuggets incorporated with 0.25 and 0.75 mg MPE/kg were reported by Kadakadiyavar et al. (2017). Also Price et al. (2013) mentioned that grape seed and green tea extracts did not modify the sensory characteristics except for the color of meatballs. In the present

study, similar scores were attributed to all samples after three days of storage except for the taste of negative control (T1) which significantly decreased. Sensory evaluation from the 6<sup>th</sup> day of storage time showed that scores of the organoleptic characteristics, except juiciness, of all samples from all treatments significantly decreased. However, the burger samples of treatments (T2–T5) exhibited high scores of sensory attributes in comparison to the negative control (T1). Furthermore, no significant differences ( $p > 0.05$ ) were found between the samples from either BHA/BHT-containing burgers (T2) and MPE-containing burgers (T3–T5). Also, MPE-containing burgers had higher taste (7.89–8.00) and odor (8.00–8.10) scores compared to BHA/BHT-

**TABLE 3.** Effect of mango peel extract and BHA/BHT on sensory characteristics of beef burger during 12 days storage at  $4 \pm 1$  °C.

Parameter	Treatment	Storage time (days)				
		0	3	6	9	12
Color	T1	8.78±0.441Aa	8.30±0.483Aab	7.90±0.316Bb	7.00±0.667Bc	6.70±0.675Bc
	T2	8.89±0.333Aa	8.60±0.516Aab	8.44±0.527Abc	8.20±0.422Abc	8.10±0.316Ac
	T3	8.90±0.316Aa	8.70±0.483Aab	8.56±0.527Aabc	8.30±0.483Abc	8.11±0.601Ac
	T4	8.80±0.422Aa	8.56±0.527Aab	8.30±0.483ABbc	8.10±0.316Ac	8.00±0.471Ac
	T5	8.70±0.483Aa	8.44±0.527Aab	8.20±0.422ABabc	8.00±0.667Abc	7.90±0.568Ac
Taste	T1	8.80±0.422Aa	8.20±0.632Bb	7.30±0.483Bc	6.50±0.527Bd	5.80±0.422Be
	T2	8.78±0.441Aa	8.60±0.516ABab	8.20±0.632Aabc	8.10±0.738Abc	7.80±0.789Ac
	T3	8.89±0.333Aa	8.70±0.483ABab	8.20±0.789Abc	8.11±0.782Abc	8.00±0.667Ac
	T4	8.80±0.422Aa	8.78±0.441Aa	8.30±0.483Aab	8.20±0.632Ab	7.89±0.782Ab
	T5	8.70±0.483Aa	8.67±0.500ABa	8.22±0.667Aab	8.10±0.738Aab	7.90±0.738Ab
Odor	T1	8.80±0.422Aa	8.60±0.516Aa	7.80±0.422Bb	7.20±0.632Bc	6.20±0.422Bd
	T2	8.90±0.316Aa	8.70±0.483Aab	8.50±0.527Aab	8.20±0.632Abc	7.90±0.738Ac
	T3	8.78±0.441Aa	8.80±0.422Aa	8.60±0.516Aa	8.30±0.483Aab	8.00±0.667Ab
	T4	8.89±0.333Aa	8.89±0.333Aa	8.56±0.527Aab	8.30±0.675Ab	8.10±0.738Ab
	T5	8.80±0.422Aa	8.67±0.500Aab	8.44±0.726Aabc	8.20±0.789Abc	8.00±0.471Ac
Juiciness	T1	8.80±0.422Aa	8.40±0.516Aab	8.10±0.738Abc	7.80±0.789Acd	7.50±0.527Ad
	T2	8.90±0.316Aa	8.44±0.527Aab	8.11±0.782Abc	7.90±0.876Abc	7.60±0.516Ac
	T3	8.78±0.441Aa	8.40±0.699Aab	8.20±0.422Aab	7.90±0.738Abc	7.60±0.699Ac
	T4	8.80±0.632Aa	8.30±0.675Aab	8.10±0.876Aabc	8.00±0.816Abc	7.50±0.707Ac
	T5	8.78±0.667Aa	8.30±0.823Aab	8.10±0.738Aabc	7.90±0.738Abc	7.50±0.850Ac
Overall Acceptability	T1	8.70±0.483Aa	7.90±0.568Ab	7.50±0.527Bb	6.60±0.516Bc	6.00±0.471Bd
	T2	8.80±0.422Aa	8.40±0.516Aab	8.20±0.422Ab	7.90±0.738Abc	7.50±0.527Ac
	T3	8.80±0.632Aa	8.50±0.527Aab	8.20±0.632Ab	8.00±0.471Abc	7.60±0.516Ac
	T4	8.70±0.675Aa	8.50±0.707Aab	8.10±0.568Abc	8.10±0.316Abc	7.56±0.527Ac
	T5	8.70±0.483Aa	8.33±0.866Aab	8.00±0.471Ab	7.90±0.316Abc	7.40±0.516Ac

Mean values with different capital letters (A, B, C, D) in the same column are significantly different ( $p < 0.05$ ) between burger treatments at the same storage day. Mean values with different small letters (a, b, c, d, e) in the same row are significantly different ( $p < 0.05$ ) between storage days. T1 (control), T2 (0.01% BHA/BHT; 1:1), T3 (0.1% MPE), T4 (0.2% MPE) and T5 (0.3% MPE).

containing burgers (7.80 and 7.90, respectively) and this might be due to the impact of MPE on lipid oxidation and formation of rancid flavor. Similar results were obtained by Kadakadiyavar et al. (2017) who reported that adding 0.5% MPE improved significantly the flavor of chicken nuggets.

With regard to color, taste, odor and overall acceptability, the obtained results agree with those reported by Amiri et al. (2019) in beef patties incorporating *Zataria multiflora* essential oil fortified with cinnamaldehyde and Gahruie et al. (2017) in frozen beef burgers incorporated with Shirazi thyme, cinnamon and rosemary extracts. By progress of the storage time, the scores of the color attribute of all burger samples decreased (Table 3). This might be due to the oxidation of lipids and myoglobin. Amiri et al. (2019) reported that oxidation of lipids and myoglobin may lead to the formation of products such as aldehydes, ketones, alcohols, hydrocarbons, esters and metmyoglobin which negatively impact color, taste, odor, and overall acceptability. Juiciness was not impacted significantly by adding either the synthetic or natural phenolic antioxidants in the present study. Also, Kadakadiyavar et al. (2017) reported that addition of mango peel extract did not impact significantly the juiciness of chicken nuggets.

### Conclusion

Mango peel extract (MPE) exhibited a high content of phenolic compounds which contribute to its functional properties (*i.e.* antioxidant activity). Retarding the development of lipid oxidation and consequently the deterioration of quality (*i.e.* color parameters and microbial stability) occurred in beef burgers stored at  $4 \pm 1$  °C can be successfully achieved by using MPE. Whereas TBARS values showed that the lowest addition level of MPE (0.1%) functioned as well as the recommended addition level of the synthetic antioxidants (BHT/BHA).

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The authors hereby declare no funding or conflict of interests

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تم دراسة تأثير اضافة مستخلص قشور المانجو (0، 0.1، 0.2، 0.3٪) بالمقارنة بـ (0.01٪) BHA/BHT (1:1) - كمنترول موجب) على اكسدة الدهون، تدهور اللون، الثبات الميكروبي والخواص الحسية لبرجر اللحم البقري المخزن على  $4 \pm 1^\circ \text{C}$  / 12 يوم. أظهرت النتائج انخفاض قيم الـ pH واللون لعينات البرجر المحتوية على مستخلص قشور المانجو بالمقارنة بالكنترول. في نهاية فترة التخزين احتوت عينات البرجر المحتوية على 0.3٪ مستخلص قشور المانجو على القيم الأقل لك الـ pH واللون ( $L^*$ ,  $a^*$ ,  $b^*$ ) بمستويات 11.51، 49.95، 1.03 و 10.38 على التوالي. كما احتوت نفس العينة على المستويات الأعلى من الفينولات الكلية (121.85) والأقل من الـ TBARS (0.18) بالمقارنة بعينات الكمنترول (29.75-10.15 ملجم /GAE/100جم) و (0.19-0.20 ملجم مالونالدهيد/كجم) على التوالي. أدى اضافة مستخلص قشور المانجو إلى تحسين النشاط المضاد للأكسدة وخفض العدد الكلي للميكروبات الهوائية بمعنوية بالمقارنة بعينات الكمنترول. وأوضحت نتائج التقييم الحسي أن إضافة مستخلص قشور المانجو لبرجر اللحم البقري كان فعال في فيما يخص كلا من تدهور اللون والطعم وتكوين النكهة الزنخة، وسجلت العينة المحتوية على 0.1٪ القيم الأعلى للخصائص الحسية. من النتائج المتحصل عليها يمكن استخدام مستخلص قشور المانجو كمادة مضافة فعالة في خفض تدهور خصائص الجودة لبرجر اللحم البقري خلال التخزين المبرد.