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Impact of Incorporating Mango Peels Powder on Beef Burger Quality Attributes

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ABSTRACT

This study was conducted to evaluate the bioactive properties of mango peels by studying its physiochemical properties such as pH, % acidity and chemical properties as phenolic, flavonoids content, phenolic compounds profile and their antioxidant activity. In addition to applying mango peel powder to the beef burger at (0, 3, 6, 9 and 12% concentrations) to improve the physiochemical properties and extend the shelf life during refrigerated storage at 4±1ºC. Approximate chemical composition of beef burger, physical properties (water holding capacity and pH), cooking properties (cooking loss and shrinkage), sensory evaluation, shelf life limiting parameters (TVN, TBA and microbiological tests) were all estimated. The total phenolic and flavonoids contents of El Gahrawy peels were 61.47 mg GAE/g extract and 28.08 mg QE/g extract, respectively. The Gallic acid, Coumaric acid, Catecin and methyl gallate were the most abundant polyphenols. Also, results showed that mango peels had high antioxidant activity 121.21 µg/ml as Inhibition concentration. The results showed that adding of mango peels powder up to 12% to beef burger resulted in improving the nutritional, physiochemical, cooking properties and microbiological of beef burger. Our findings elucidated that TVN, TBA and total bacterial count at 12% treatment were lower than control sample along storage time which reached to 19.06 mg N/ 100g, 0.056 mg MDA/Kg sample and 5.47 log CFU/ g sample, respectively at 21th day of storage period compared to control which were 26.65 mg N/100g, 1.02 mg MDA/Kg sample and 7.21 log CFU/g sample, respectively.

Keywords: Mango peels, Phenolic compounds, Beef burger, physiochemical properties, shelf life

INTRODUCTION

Mango (*Mangifera indica L.)* is one of the most famous tropical fruits that belongs to the *Anacardiaceae* family because of its distinctive color, taste and flavor and its high nutritional, medicinal and phytochemical benefits (Espinosa-Espinosa *et al.*, 2022). The edible part of mango is used industrially in juices and pulps, while the inedible part is discarded, even though it contains bioactive compounds that can be used in many food applications.

Mango waste represents 35-50% of the fruit total weight. Moreover, using of these materials reduces their negative impact on the environment (Oliver-Simancas *et al.*, 2020&García-Mahecha *et al.*, 2023). So, there is an urgent need to get rid of mango waste, prevent the resulting pollution, and produce high-value products.

Mango peels have even more distinctive bioactive components, like phenolic and flavonoid compounds, than the fruit's edible portion. The presence of phenolic compounds in mango peels will encourage its utilization for many purposes. In addition, there is much evidence that natural products and their derivatives have effective antioxidant properties that are associated with anti-cancer, hypolipidemic, and anti-inflammatory activity. Phenolic compounds are also more effective as antioxidants than vitamins (Vinson *et al.*, 2001).

The high value products that can be used mainly in the food, cosmetics and pharmaceutical industries can be obtained by extracting bioactive components from the inedible parts of fruits, especially the peels, considering the use of low temperature and not using of toxic solvents (Ray *et al.*, 2023 & Zhu *et al.*, 2023).

The microbiological quality and safety of refrigerated minced meat are the greatest concerns of consumers, retailers, and public health officials that are being sold at temperatures ranging from 2 to 5 ºC. Nonetheless, refrigerating minced meat inside this temperature reach can bring about unfavorable changes because of microbial development, prompting a decrease in quality, meat deterioration, and financial losses (Elabbasy *et al.*, 2014). Natural and synthetic antioxidant food additives are widely used in meat products to prevent oxidative reactions and prolong their shelf life (Cunha *et al.*, 2018). However, consumers prefer to replace synthetic preservatives with natural additives in various products to retard oxidative degeneration of lipids and enhance food quality and nutritional value (Aminzare *et al.*, 2019). As well as extension the shelf life of meat products by delaying microbial growth and lipid oxidation, fruit peels can be used as natural additives to produce low-cost, high-nutrition products with good sensory and physicochemical characteristics (Nieto *et al.*, 2021).

Accordingly, some bioactive compounds in mango peels and their antioxidant effects and the effectiveness of addition of mango peels powder (3.6.9 and 12%) on some physiochemical quality properties and shelf-life of beef burger during refrigerated storage at (4ºC±1) was investigated in the present experiment.

MATERIALS AND METHODS

Materials:

Mango peels:

Mango fruits (*Mangifera indica L.*) of Egyptian cultivar namely El-Gahrawy was obtained from a farm in

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Damietta city during 2021/2022 season were used in this study and were cleaned from foreign materials.

Other materials:

The other materials that were used in preparing burger product were meat, salt, sugar, spices and soybeans were obtained from the local market, Damietta City, Egypt.

Methods:

Preparation methods:

Preparation of mango peels powder:

The peels of mango fruits were manually separated. The mango peels were dried at 50 °C in air drier until constant weight. The dried mango peels were ground using electrical grinder (Lab Scale Mill) and sieved through 70 mesh sieve. The mango peels powder was packed in plastic bags and kept at 5±1°C until used.

Preparation of mango peels methanolic extract:

The mango peels cultivars were dried at 50ºC in a single layer, and then they were powdered and combined with methyl alcohol in a closed flask. The mixture was left for 24 hours, with frequent shaking during the first 6 hours and then allowed to stand for 18 hours. Following this, the solution was quickly filtered, taking care to avoid losing the solvent. After that, a rotary evaporator was used at 40-50°C under low pressure to dry the extract, and finally it was stored at 4°C until used (Ali *et al.*, 2012).

Beef burger production:

The control beef burger formula included a mixture of 62% lean meat, 7% fresh eggs, 12% soy flower, 7% fresh onion paste, 1.5% salt, 10% iced water, 0.5% spices (including black pepper 15 g, white pepper 15 g, 10 g of each (nutmeg, coriander, garlic powder, onion powder, cumin and fennel), ginger 5 g and clove 5 g), 0.015% sodium nitrite, 0.03% sodium ascorbate and 0.3% sodium tripolyphosphate according to Dreeling *et al.* (2000) which modified by Oroszvari *et al.* (2006). To prepare beef burger treatments, the mango peels powder was added to the standard formula as 0% (control), 3% (B_1), 6% (B_2), 9% (B_3) and 12% mango peels powder (B_4). All components were mixed well, and then shaped into pieces weighing 50 g and packaging in polyethylene bags. Then, all treatments were preserved at refrigerated storage at 4±1ºC until analysis every 3 days up on 21 days.

Physiochemical properties:

Total acidity (Titratable method):

Five gram of peels powder was mixed with 45ml of distilled water, homogenized, and allowed to rest briefly. 10 mL of each supernatant were used. After that, a small amount of phenolphthalein indicator solution was added, and the contents were titrated with NaOH (0.1N) while stirring until the first clear change to pink color.

% Acidity= (V × N× Equiv. weight of the most common organic acids×R×100) / (Weight of sample taken × 1000)

where, V= volume of NaOH solution, N= Normality of NaOH solution R = inverted dilution.

pH value:

pH value of mango peels powder and burger samples was determined using a pH meter (3510 Jenway pH meter, England), mix 5 g of the sample with distilled water (50 ml) for 30 Sec. Values of pH measured at 20 °C according to Fernández-López *et al*, (2020).

Chemical analysis:

Gross chemical composition:

The gross chemical composition of mango peels powder and burger treatments were determined according to (AOAC, 2016). Moisture (dry oven method), crude protein (Kjeldal method), crude fat (Soxhlet method), crude fiber (gravimetric method) and crude ash (muffle furnace method) carbohydrate was calculated by differences.

Determination of total phenolic content (TPC) of El Gahrawy mango peels extract:

Total phenolic content in the mango peels extract was determined using Spectrophotometer (Pg-T60) and the absorbance was measured at 750 nm by Folin Ciocalteu reagent and external calibration with gallic acid. All determinations were performed in triplicate. The concentration of the total phenolic was calculated as mg of Gallic acid equivalent per 100 g of dry weight (GAE/100 g) using an equation obtained from curve of Li *et al*. (2008).

Determination of total flavonoid content of mango peels extract:

Total flavonoid content was determined colorimetric using Spectrophotometer (Pg-T60) and the absorbance was measured at 415 nm. as described by Chang *et al*. (2002). The concentration of flavonoids was determined from the standard curve and the result was expressed as mg of quercetin equivalent (mg QE)/g extract.

Fractionation and identification of phenolic compounds content by HPLC of mango peels extract:

HPLC analysis was carried out using method described by (Pérez-Ramírez *et al*., 2015).

Free radical scavenging activity using DPPH assay of mango peels extracts

Antioxidant activity was determined of mango peels extract by DPPH assay using Spectrophotometer (Pg-T60) at 517 nm according to (Gülçin, 2006). Radical scavenging activity was estimated as the inhibition percentage and was calculated using the following formula:

Percentage Inhibition = [(AC-AA)/AC] × 100.

Where: AC: absorbance value of control.
AA: absorption of the sample solution.

Determination of Total Volatile Nitrogen content:

Total volatile nitrogen (TVN) content of beef burger treatments was determined every 3 days of refrigerated storage (Pearson, 1976).

Determination of Thiobarbituric Acid (TBA):

The Thiobarbituric acid value (TBA) of burger treatments determined every 3 days of refrigerated storage using the distillation method outlined by Tarladgis *et al*., (1960).

Physical analysis:

Color analysis of burger treatments:

The color of burger samples were determined instrumentally, the (L*a*b*) by a colorimeter (Konica Minolta CM3600A, Osaka, Japan) (CIE, 2004). Color was expressed in units L* (Lightness/darkness), a* (redness/greenness), b* (yellowness/blueness).

Water holding capacity (WHC):

Water holding capacity was evaluated by the filter paper press method according to Volovinskaia and MerKoolova (1958). Then, the zones were measured by a planimeter (KOIZUMI Digital Planimeter PLACOM KP-92) in Cm^2. Results were presented in Cm^2 per 0.3 g sample.

Cooking loss%:

To estimate the cooking loss in meat burger treatments, preheated electric grill was used at 148 ºC, where treatments were cooked for 6 minutes, then transferred and re-cooked for another 4 minutes. To calculate the cooking loss %, the samples were weighed before and after cooking as described by Ali *et al.*, (2011).

Determination of Shrinkage of beef burger samples:

Shrinkage was determined by calculating the difference between the diameters of the burger before and after cooking and dividing it by the diameter of the burger before cooking (Dreeling *et al*., (2000).

Microbiological studies:

Total plate count, Molds and yeast were conducted according to the protocol described by Mohsen *et al*. (2013). Coliform group and Pathogenic (*Salmonella* and *Shigella*) determined as recommended by Libby *et al.* (1994).

Sensory evaluation of cooked burger treatments:

A group of 10 panelists assessed appearance, taste, odor, texture and overall acceptability of beef burger samples. The panelists were asked to rank the sensory characteristics at 1 – 10 scale since, (1), very dislike, (2) dislike, (2- 4) fair, (5-6) like (7-8) very like, and (9 -10) highly like, the mean ratings for the assessments were determined. All sensory studies were carried out under the guidance of the Food Science Department, Damietta University, Egypt (Mahmoud *et al*., 2021).

Statistical analysis

The obtained results were analyzed using the analysis of variance (ANOVA) according to the statistical analysis system (Costa) version 6.303 and comparisons were done by Duncan's Multiple Range test (Steel *et al*., 1997) at $P<0.05$ level of significance.

RESULTS AND DISCUSSION

The physiochemical properties of El Gahrawy mango peels:

The results of current study showed that El Gahrawy variety peels contain 1.76% as acidity with the pH value of 4.33. These results were close to the results obtained by (Masoud and El-Hadidy, 2017) who found that the pH value of mango peels was 4.10. These differences in pH might be due to the mango cultivars, geographical location and date of harvest.

Approximate chemical composition of El Gahrawy mango peels:

Moisture, crude protein, fat, fiber, ash and carbohydrates were determined in dried mango peels of El Gahrawy variety which presented in Figure 1. From the obtained results, it could be noticed that the studied variety recorded 6.36, 1.94, 6.59, 2.10, 4.01 and 78.73% as moisture, protein, fat, fiber, ash and carbohydrates, respectively. These values of mango peels may vary as a result of the variety, harvest time, and storage conditions.

Phenolic compounds profile of El Gahrawy mango peels:

Phenolic compounds are among the most important active substances that scavenge free radicals, and their presence in plant is considered an important indicator of antioxidant components (Subramanian *et al.*, 2011). Nearly about 15 phenolic compounds of mango peels extract were fractioned in Table 1. The tabulated data indicated that the Gallic acid, Coumaric acid, Catechin and Methyl gallate were the most abundant, which were 7025.14, 5090.48, 3664.01 and 1845.69 µg/g extract, respectively. Other phenolic compounds were also found, but in varying quantities.

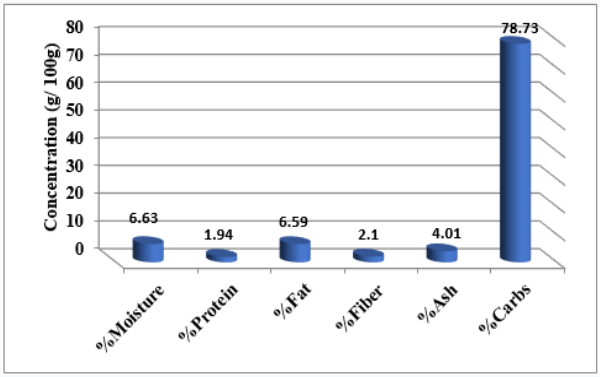

Figure 1. Chemical composition of El Gahrawy mango peels.

Table 1. Phenolic compounds profile of "El-Gahrawy" mango peels (µg/g extract):

Compound	Concentration (µg/g extract)
Gallic acid	7025.14
Chlorogenic acid	245.78
Catechin	3664.01
Methyl gallate	1845.69
Coffeic acid	2.18
Syringic acid	1165.24
Pyro catechol	ND
Rutin	55.70
Ellagic acid	979.84
Coumaric acid	5090.48
Vanillin	ND
Ferulic acid	2804.43
Naringenin	1274.82
Daidzein	6.87
Querectin	126.03
Cinnamic acid	ND
Apigenin	4319.05
Kaempferol	ND
Hesperetin	ND
Total phenolic content as (mg GAE/g extract)	61.47
Total flavonoid content as (mg QE/g extract)	28.08

ND= Not detected

These results were in agreement with Alañón *et al.* (2021) who found phenolic compounds in mango peels such as Gallic acid, Ellagic acid, Querectin, Coumaric acid, Methyl gallate and Ferulic acid. Gómez-Maldonado *et al.* (2020) found the same phenolic compounds as the previous ones, in addition to Syringic acid, Rutin and Coffeic acid. This variation in phenolic compounds is probably caused by variations in the solvent type, extraction technique and mango variety.

The tabulated data in the same table showed the total phenolic and flavonoids content of El Gahrawy mango peels. Total phenolic content was 61.47 mg GAE /g extract. On the other hand, our finding results showed the total flavonoid content expressed as mg of quercetin equivalent per gram of dry peels extract, which was 28.08 mg QE/g extract in El-Gahrawy mango peels. The previous results were in agreement with (Bekheet, *et al.* 2024) who found that the total phenolic and flavonoids contents of mango peels in the same range which were 46.13 mg GAE / g and 5.38 QE /g extract. These differences may be due to the variety and the stage of maturity.

Antioxidant activity of El Gahrawy mango peels extract:

The DPPH method is commonly used to measure the radical scavenging activity of antioxidants. Figure 2 indicated that mango peels showed the highest value of antioxidant activity of methanolic extract. It was found that IC_{50} were 121.21 µg/ml in El-Gahrawy variety compared to ascorbic acid (V.C) which was 6.23 µg/ml. This is may be due to the peel's content of phenolic and flavonoids as shown in Table

1, which have an antioxidant effect. These results were in the same range of that obtained by El-Faham *et al.* (2016) who reported that mango peel extracts contained high antioxidant compounds, which give a lower IC_{50} value.

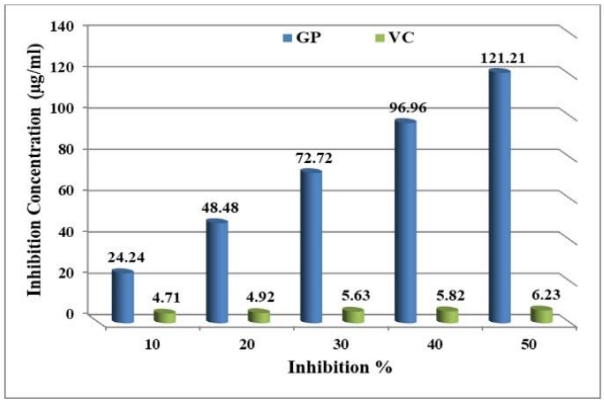

Figure 2. DPPH radical scavenging activity of El Gahrawy mango peels extract (µg/ml).

Organoleptic attributes of cooked beef burger treatments:

Avoiding undesired sensory alterations in food products is one of an ingredient's most important qualities. The cooked beef burger samples in this study were assessed for appearance, odor, taste, texture, and overall acceptability. From the results in Table 2, it could be noticed that the addition of mango peels did not significantly alter sensory qualities of burger and it was nearly satisfactory at all addition levels.

Table 2. Effect of mango peels addition on organoleptic attributes of cooked beef burger treatments.

Treatments	Attributes				
	Appearance (10)	Taste (10)	Odor (10)	Texture (10)	Overall Acceptability (10)
Control	9^{a}	9^{a}	9^{a}	9^{a}	9^{a}
CB_1	9^{a}	8.5^{a}	8.5^{a}	8.5^{ab}	9^{a}
CB_2	8^{a}	8^{a}	7.5^{a}	8^{ab}	8.5^{a}
CB_3	8^{a}	7.5^{a}	7.5^{a}	7^{b}	8^{a}
CB_4	7.5^{a}	7.25^{a}	7^{a}	6.5^{ab}	7^{a}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

From the same results, it was noticed that there was an increase in darkness with the increase in addition levels (3, 6, 9, and 12% level). The darkness might be due to the increase in pigments with an increase in the addition rate, as well as due to the transformation of the myoglobin into the dark meta-myoglobin. In addition, there was no significant difference in taste between samples at all addition levels as compared to control sample. As for odor, increasing of mango peel powder addition led to a decrease in odor values of burger samples, but it was acceptable in all treatments and there were no significant differences between them.

On the other hand, there was gradually decrease in the texture values from control sample up to CB_3 sample (9% mango peel powder), this is might be due to the increase of fiber content and decrease of moisture percentage. Regarding to overall acceptability, it could be observed that burger samples incorporated with mango peels powder from 3 to 12% were acceptable. These obtained results are agreed with those obtained by Abdeldaiem and Ali (2012).

The chemical composition of beef burger treatments

The approximate chemical composition of beef burger treatments formulated with different concentration of mango peel powder (3, 6, 9, and 12%) before and after cooking was shown in Table 3. The obtained results showed that adding mango peels powder to the burger product led to non-significant changes in the fat and ash content compared to the control sample. On the other hand, a significant increase in the protein and carbohydrates contents were noticed in all beef burger treatments with the increase of mango peels powder. Nonetheless, the moisture content decreased with the increment of addition mango peel powder in burgers formulations compared to control sample, which led to an increase in the percentages of solid matter percentage (protein, fat, ash, and carbohydrates).

On the other hand, as a result of cooking, there was a clear increase in fat, ash and carbohydrate contents. This increment is a result of cooking loss, which led to a decrease in moisture content and soluble protein which led to the decrease of total protein content and an increase in other dry matter. These results were agreement with Abdeldaiem and Ali (2012) who reported similar results for burger patties made with mango peel powder addition.

Table 3. Effect of mango peels addition on the chemical composition of burger treatments.

Sample	Treatments	Moisture %	Protein %	Fat %	Fiber %	Ash %	Carbs. %
Uncooked burger	Control	49.35^{a}	22.75^{a}	2.53^{a}	2.30^{b}	3.32^{a}	19.75^{c}
	B_1	46.30^{b}	22.56^{a}	3.32^{a}	2.37^{b}	3.50^{a}	21.95^{ab}
	B_2	45.84^{bc}	23.88^{b}	3.38^{a}	2.41^{ab}	3.65^{a}	20.84^{ab}
	B_3	45.12^{c}	24.81^{ab}	3.40^{a}	2.53^{ab}	3.87^{a}	20.27^{b}
	B_4	35.01^{d}	25.75^{c}	3.42^{a}	2.64^{a}	3.96^{a}	29.25^{a}
Cooked burger	Control	38.25^{a}	30.25^{a}	2.66^{a}	2.16^{b}	3.70^{a}	22.98^{d}
	CB_1	37.40^{a}	28.56^{b}	3.56^{a}	2.23^{ab}	3.88^{a}	24.37^{c}
	CB_2	35.51^{b}	25.81^{c}	3.59^{a}	2.30^{ab}	4.25^{a}	28.54^{ab}
	CB_3	35.06^{b}	25.06^{c}	3.60^{a}	2.36^{ab}	4.68^{a}	29.24^{b}
	CB_4	26.18^{c}	24.50^{d}	3.62^{a}	2.42^{a}	4.71^{a}	38.57^{a}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Color attributes of beef burger treatments at zero time of refrigerated storage:

It is necessary to notice the change in the color of the burger product, as color is one of the most important characteristics of the product's consumer acceptance. The influence of adding mango peel powder on the color indices of uncooked and cooked burger samples, according to International Commission on Illumination CIE L* (lightness), a* (redness), and b* (yellowness), are shown in Table 4.

The L* parameter determining the color brightness was 53.67 in the control uncooked burger which gradually decreased to 38.34 in uncooked burger samples as a result of mango peels addition, while it ranged from 26.35 to 27.04 in cooked samples. The uncooked and cooked control had the highest L*value, whereas it decreased in the rest treatments. This can be attributed to the gradual increase in the amount of mango peels powder, which led to a gradual decrease in the L*value.

On the other hand, in the uncooked burger samples, the value of parameter a * gradually increased as a result of mango peels powder addition, compared to the control, which indicates a reduction in the proportion of the red/brown color. While in the cooked samples, adding of mango peels powder decreased the value of the a* parameter, compared to the control, it was decreased from 11.33 to 9.30.

The same table indicated that the b* value in the uncooked and cooked samples were in the range of 21.53 – 24.05 and 13.79 – 17.02; respectively. It was noticed that as mango peels addition increased, the value of b increased and

the degree of yellow color increased. These results might be due to mango pigments which responsible for the yellow-orange color. These results were taken the same trend of those obtained by Ashoush and Gadallah (2011).

Table 4. Effect of mango peels addition on color attributes of beef burger treatments at zero time of refrigerated storage.

Samples	Treatment	*L**	*a**	*b**
Uncooked burger	Control	53.67^{a}	8.73^{c}	21.53^{b}
	B_1	45.57^{b}	10.41^{bc}	21.75^{b}
	B_2	40.12^{c}	10.62^{b}	21.82^{b}
	B_3	40.76^{c}	11.34^{b}	24.05^{a}
	B_4	38.34^{d}	12.8^{a}	24.54^{a}
Cooked burger	Control	26.35^{c}	11.33^{a}	13.79^{b}
	CB_1	34.11^{a}	9.93^{ab}	16.23^{a}
	CB_2	29.94^{b}	9.71^{ab}	16.17^{a}
	CB_3	29.03^{b}	9.66^{ab}	16.25^{a}
	CB_4	27.04^{c}	9.30^{b}	17.02^{a}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Water holding capacity and cooking properties of beef burger treatments:

WHC and cooking properties of beef burger samples formulated with different concentrations of mango peel powder are given in Table 5. There were significant differences between all treatments. Increasing of mango peels had a significant effect on WHC value, as B4 sample (5.81 cm2/0.3 g) had higher value of WHC than other treated samples. The increase of WHC value in burger samples is probable due to the higher dietary fiber content of mango peels powder, as it is responsible for absorbing and retaining moisture. This result was agreed with Gadallah and Abdel Fattah (2011).

Also, it was noticed a decrease in the rate of cooking loss in the treated samples compared to the control which was 21.03%, these results are consistent with previous results on WHC values.

After cooking, the diameter of a beef burger is measured to see if any water and fat have been removed from the burger. This process is known as shrinkage. It may provide information about the protein's quality and the burger matrix's capacity to retain water and fat (Darwish *et al.*, 2012). The obtained results in Table 5 showed the Shrinkage percentage which was taken the same trend of cooking loss, as the shrinkage ratio decreased with more mango peels powder addition. The highest reduction in diameter was obtained from the control sample (18.02%). This is may be due to the denaturation of meat protein as heat effect, which leads to muscle shrinkage, water loss, and fat separation.

Table 5. Effect of mango peels addition on the water holding capacity (WHC), cooking loss% and shrinkage % of beef burger treatments.

Treatments	WHC (Cm^2/0.3 g) (Uncooked product)	Cooking loss%	Shrinkage %
Control	6.82^{a}	21.03^{a}	18.02^{a}
B_1	5.47^{b}	15.36^{b}	12.01^{b}
B_2	5.62^{c}	14.21^{b}	11.61^{b}
B_3	5.67^{c}	13.20^{c}	11.04^{cb}
B_4	5.81^{d}	13.06^{c}	10.78^{c}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

pH value of beef burger treatments:

The pH values of treated beef burger samples were recorded in Table 6 during cold storage (4±1ºC) for 21 days. The results indicated that the inclusion of mango peels powder in the beef burger formula led to a slight decrease in pH values in all beef burger treatments compared to the control sample during the 21 day cold storage period at 4±1ºC. This decrease may be attributed to the breakdown of glycogen and the accumulation of lactic acid in the product during storage. Hammad *et al.* (2000) illustrated that the pH values decrease in the samples during storage could be due to the production of acidic compounds resulting from the activity of lactic acid bacteria.

Table 6. Effect of mango peels addition on pH value of beef burger treatments during refrigerated storage at (4±1ºC).

Storage period (days)	pH value				
	Control	B_1	B_2	B_3	B_4
0	6.94^{a}	6.86^{a}	6.85^{a}	6.73^{a}	6.62^{a}
3	6.54^{a}	6.84^{a}	6.83^{a}	6.71^{a}	6.60^{a}
6	6.21^{a}	6.83^{a}	6.81^{a}	6.67^{a}	6.59^{a}
9	6.03^{a}	6.79^{a}	6.78^{a}	6.67^{a}	6.57^{a}
12	5.82^{a}	6.67^{a}	6.74^{a}	6.65^{a}	6.54^{a}
15	5.66^{a}	6.52^{a}	6.71^{a}	6.61^{a}	6.50^{a}
18	5.60^{a}	5.80^{a}	6.66^{a}	6.55^{a}	6.43^{a}
21	5.44^{a}	5.74^{a}	5.93^{a}	6.50^{a}	6.38^{a}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Total volatile nitrogen of beef burger treatments:

Total volatile nitrogen is an important indicator for measuring the extent of protein degradation (Han *et al.*, 2001) and its increment is an indicator of microbial activity and proteolytic enzymes (Yassin-Nesserin, 2003).

The obtained data in Table 7 revealed the mean value of TVN of treated samples compared control which recorded 9.71 mg N/100 g sample at zero time and continued to increase until it reached to 26.65 mg N/100 g sample at the end of refrigerated storage, which is considered above the permissible limit according to EOS (2006_a) which reported that the TVN of frozen meat products should not exceed 20 mg N / 100 g sample.

Table 7. Effect of mango peels addition on total volatile nitrogen content of beef burger treatments during refrigerated storage at (4±1ºC).

Storage period (days)	TVN (mg N/ 100 g sample)				
	Control	B_1	B_2	B_3	B_4
0	9.71^{g}	7.67^{e}	6.97^{e}	6.95^{e}	6.89^{e}
3	12.73^{f}	7.81^{e}	7.22^{e}	7.16^{e}	6.95^{e}
6	16.04^{e}	8.64^{e}	8.09^{e}	8.02^{e}	7.50^{e}
9	19.91^{d}	12.33^{d}	11.62^{d}	11.43^{d}	9.98^{d}
12	22.8^{c}	14.21^{c}	14.09^{c}	13.66^{c}	13.20^{c}
15	24.01^{b}	17.88^{b}	17.00^{b}	16.93^{b}	16.54^{b}
18	25.83^{a}	18.16^{b}	18.05^{b}	18.00^{b}	17.99^{a}
21	26.65^{a}	20.43^{a}	20.03^{a}	19.18^{a}	19.06^{a}

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

In the present study, it could be noticed that there were a significant difference statistically recorded between the control sample and treated ones. The results showed that the TVN values were at the permissible limit where slightly increased through the storage time in the treated beef burger samples with 3%, 6%, 9% and 12% of mango peels powder which reached to 20.43, 20.03, 19.18 and 19.06 mg N/ 100 g sample, respectively at 21 days of refrigerated storage period at 4±1ºC. This is might be due to the mango peels powder were able to reduce the TVN increment during storage of beef burger samples, antimicrobial and antifungal activity of mango peel powder as (*E coli, Enterobacter, Shigella and Aspergillus niger*) according to Thambi *et al.* (2016). The findings were consistent with those of Abdel-Naeem *et al.* (2022), who demonstrated that fruit peel powders led to a slower increase in TVN levels following

treatment. The bioactive compounds in the fruit peels were responsible for inhibiting microbial growth and internal enzyme activities, leading to this effect.

Thiobarbituric acid of beef burger treatments:

Increasing trend of TBA value during chilling is an indicator for the continuous lipid oxidation and oxidative by - product formation (Abdou *et al.*, 2018). Concerning the TBA results in Table 8, it was 0.08 mg MDA/kg for control sample at zero time and increased to 1.02 mg MDA/kg at the end of refrigerated storage. The same table showed slightly increased of the TBA values of treated samples, where TBA values were recorded 0.062, 0.054, 0.039 and 0.031 mg MDA/kg in the B_1, B_2, B_3 and B_4 samples, respectively at zero time until reached to 0.075, 0.068, 0.057 and 0.056 mg MDA/kg in the B_1, B_2, B_3 and B_4 treatments, respectively at 21th day of refrigerated storage period, which were below the permissible limit (0.9 mg MDA/kg) of burger according to EOS (2006_b). From this study, it is noted that the current results are consistent with the results of Table 1 and Figure 2, confirming the high content of phenolic compounds in mango peels. These results came in accordance with Bhat *et al.* (2017) who showed that mango peel powder reduced the thiobarbituric acid reacting substances of stored chicken cutlets up to 10 days due to their antioxidant properties and phenolic compounds content which decreases oxidative rancidity and oxidative by-product during refrigerator.

Table 8. Effect of mango peels addition on the Thiobarbituric acid content (TBA) of beef burger treatments during refrigerated storage at (4±1ºC).

Storage period (days)	TBA (mg MDA/ kg sample)				
	Control	B_1	B_2	B_3	B_4
0	0.08^a	0.062^a	0.054^a	0.039^a	0.031^a
3	0.10^a	0.064^a	0.056^a	0.04^a	0.033^a
6	0.34^a	0.065^a	0.056^a	0.042^a	0.038^a
9	0.62^a	0.068^a	0.058^a	0.045^a	0.04^a
12	0.78^a	0.069^a	0.06^a	0.047^a	0.045^a
15	0.91^a	0.071^a	0.062^a	0.05^a	0.048^a
18	0.96^a	0.073^a	0.064^a	0.052^a	0.052^a
21	1.02^a	0.075^a	0.068^a	0.057^a	0.056^a

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Total bacterial count as (log CFU/g) of beef burger treatments:

The effect of mango peels addition on the total bacterial count of beef burgers during cold storage was observed in Table 9. The initial bacterial count for control treatment at time zero was 5.42 log CFU/g, which continued to increase until it reached to 7.21 log CFU/g at the end of refrigerated storage and considered higher than the permissible limit (7 log CFU/g) set by ICMSF (1986) for TPC in processed meat.

Table 9. Total bacterial count as (log CFU/g) of beef burger treatments during refrigerated storage at (4±1ºC).

Storage period (days)	Total bacterial count (log CFU/g)				
	Control	B_1	B_2	B_3	B_4
0	5.42^a	5.37^a	5.32^a	5.28^a	5.26^a
3	5.46^a	5.31^a	5.27^a	5.24^a	5.21^a
6	5.48^a	5.35^a	5.33^a	5.28^a	5.23^a
9	5.60^a	5.39^a	5.36^a	5.31^a	5.29^a
12	6.12^a	5.42^a	5.40^a	5.38^a	5.34^a
15	6.26^a	5.45^a	5.41^a	5.39^a	5.36^a
18	6.34^a	5.49^a	5.46^a	5.44^a	5.43^a
21	7.21^a	5.55^{ab}	5.51^{ab}	5.49^{ab}	5.47^b

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Furthermore, mango peels powder addition enhanced the shelf life of beef burgers as illustrated in the Table 9. This treatment led to an obvious decrease in the total viable bacterial count of beef burger samples with the increase in the mango peel powder concentration during the refrigerated storage period. It is noticed that the current results are in the same trend of the results shown in Table 1 which showed phenolic and flavonoids content of mango peels. These results were in agreement with Kučuk *et al.* (2024) who represented that mango peels extract had a potential natural antimicrobial agent against *Bacillus cereus* and *E. Coli* as an alternative to conventional antimicrobial agents.

Total Mold and yeasts count as (log CFU/g) of beef burger treatments:

The effect of adding different concentrations of mango peels on the total mold and yeasts count of burger samples during refrigerated storage was observed in Table 10. There was a clear increase in the amount of mold and yeasts in the control sample and B_1 sample, but the control samples always contained a higher amount of mold and yeasts compared to sample B_1. On the other hand, mold and yeasts were not detected on B_2; B_3 and B_4 treatments from 6th day until the end of storage period, these results were due to the increased concentration of mango peels, which had an antifungal activity.

Table 10. Total Mold and yeasts count as (log CFU/g) of beef burger treatments during refrigerated storage at (4±1ºC).

Storage period (days)	Total Mold and yeasts count (log CFU/g)				
	Control	B_1	B_2	B_3	B_4
0	1.95^a	1.86^a	1.82^a	1.72^a	1.63^a
3	2.01^a	1.83^a	1.76^a	1.65^a	ND
6	2.30^a	1.84^a	ND	ND	ND
9	2.33^a	1.85^a	ND	ND	ND
12	2.42^a	1.87^a	ND	ND	ND
15	2.45^a	1.92^a	ND	ND	ND
18	2.47^a	1.93^a	ND	ND	ND
21	2.50^a	1.97^a	ND	ND	ND

Mean values in the same column with the same letter are not significantly different at $P < 0.05$.

Also, B_2 and B_3 samples had mold and yeasts only on zero time and three days of storage. As for B_4 sample, mold and yeasts were detected only on zero time, yet their values were significantly lower than the control sample. These results are consistent with Abdeldaiem and Hoda (2012), who observed that mango peel powder addition to beef burgers had a significant effect in reducing the numbers of mold and yeast.

On the other hand, *E. coli* is the most crucial organism among coliform bacteria and is primarily associated with symptoms of gastroenteritis, particularly diarrhea. Additionally, it plays a significant role in impacting the hygiene standards of minced meat, whether it is in its raw or frozen state (Cruickshamk *et al.*, 1975). Coliform bacteria are not detected in beef burger treatments during storage period.

Also, Salmonellosis is one of the main bacterial food-borne illnesses worldwide (PHAC, 2014). Meat in general is the most common source of food-borne illness by *Salmonella* (Mead, 2004). *Salmonella sp*. is not detected in beef burger treatments during chilled storage period. These results were in agreement with (Thambi *et al.*, 2016) who illustrated that mango peels extract had an antibacterial activity against *salmonella*, *shigella*, *E. coli* and *Enterobacter*.

CONCLUSION

The organoleptic attributes of treated beef burger samples were enhanced by mango peels powder, leading to a decline in TVN, TBA and pH values. Our results presented

that the concentration of mango peels had a significant impact on the sensory, chemical, and bacteriological characteristics, with the effects becoming more noticeable as the concentration increased up to 12%.

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تأثير إضافة مسحوق قشور المانجو علي صفات جودة برجر اللحم

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الملخص

أجريت هذه الدراسة لتقييم الخواص النشطة بيولوجيا لقشور المانجو من خلال دراسة خواصها الفيزيوكيميائية مثل الرقم الهيدروجيني ونسبة الحموضة والخواص الكيميائية مثل المحتوي الفينولي والفلافونويدات والمركبات الفينولية والنشاط المضاد للأكسدة. كما تم إضافة مسحوق قشور المانجو إلى برجر اللحم بتركيزات (صفر، ٣، ٦، ٩ و ١٢%) لتحسين الخواص الفيزيوكيميائية وإطالة مدة الصلاحية أثناء التخزين المبرد عند درجة حرارة ٤±١ درجة مئوية. حيث تم تقدير التركيب الكيميائي، الخواص الفيزيائية (القدرة علي مسك الماء و رقم الحموضة)، وخصائص الطبخ (فقد الطبخ و الانكماش)، والتقييم الحسي، والمقاييس المحددة لصلاحية منتج برجر اللحم (النيتروجين الكلي المتطاير، حمض الثيوباربتيوريك والاختبارات الميكروبيولوجية). أظهرت النتائج أن محتوى الفينولات الكلية والفلافونويدات في قشور المانجو الجحراوي كان ٦١,٤٧ مليجرام حمض جاليك /جم مستخلص و٢٨,٠٨ مليجرام كواريسيتين /جم مستخلص، على التوالي. وكانت مركبات حمض الجاليك، حمض الكوماريك، الكاتيكين والميثيل جالات هي الأكثر وفرة. كما أوضحت النتائج ارتفاع النشاط المضاد للأكسدة لقشور المانجو ١٢١,٢١ ميكروجرام / الملليلتر كنسبة تثبيط (IC_{50}). أوضحت النتائج أن إضافة قشور المانجو لمنتج برجر اللحم حتي تركيز ١٢%، نتج عنها تحسين الخصائص التغذوية، الفيزيوكيميائية، خصائص الطبخ والخصائص الميكروبيولوجية لمنتج البرجر حيث أظهرت النتائج التي توصلنا إليها إلي أن النيتروجين الكلي المتطاير، حمض الثيوباربتيوريك والعدد الكلي للبكتريا عند معاملة ١٢٪ كانت أقل من عينة الكنترول طوال فترة التخزين والتي وصلت إلى ١٩,٠٦ ملجم نيتروجين/ ١٠٠ جرام عينة، ٠,٠٥٦ ملجم مالونالدهيد/ كجم عينة و ٥,٤٧ CFU / جم عينة، على التوالي في اليوم الحادي والعشرين من فترة التخزين مقارنة بعينة الكنترول التي وصلت إلي ٢٦,٦٥ ملجم نيتروجين/ ١٠٠ جرام عينة ، و ١,٠٢ ملجم مالونالدهيد/ كجم عينة و ٧,٢١ CFU / جم عينة ، على التوالي.

الكلمات المفتاحية: قشور المانجو، المركبات الفينولية، برجر اللحم، الصفات الفيزيوكيميائية و فترة الصلاحية.