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Effect of pistachio seed hull extracts on quality attributes of chicken burger

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ABSTRACT

The effect of pistachio hull water extracts (PHWE) at different levels on quality of chicken burger during storage at $4 \pm 1^\circ\text{C}$ was investigated. Differences between treatments parameters means were separated using analysis of variance (ANOVA). There was no significant difference in fat, protein, and ash contents of the burgers. The increase in PHWE levels increased the cooking yield and moisture retention (MR) in the treated burger from 59.82% to 66.99% and from 44.27% to 54.73%, respectively. The treated burgers had significantly ($p < 0.05$) higher phenolics than untreated. The pH of the burger was decreased with the increase of storage time. As the storage period increased, thiobarbituric acid reactive substance and plate count were increased in untreated burger. The sensory results showed no significant difference in overall acceptability of the burger. The addition of PHWE to chicken burgers improved its quality during storage for up to 10 days at $4 \pm 1^\circ\text{C}$.

Efecto de extractos de cáscara de pistacho en los atributos cualitativos de la hamburguesa de pollo

RESUMEN

Se investigó el efecto de los extractos de agua de cáscara de pistacho (PHWE) a diferentes niveles en la calidad de la hamburguesa de pollo durante almacenamiento a $4 \pm 1^\circ\text{C}$. Se separaron las diferencias entre los promedios de los parámetros de los tratamientos utilizando el análisis de varianza. No se observaron diferencias significativas en la grasa, las proteínas y los contenidos de cenizas de las hamburguesas. El aumento de los niveles de PHWE aumentó el rendimiento del cocinado y la retención de humedad de las hamburguesas tratadas de 59,82 a 66,99% y de 44,27 a 54,73%, respectivamente. Las hamburguesas tratadas tuvieron un mayor contenido de fenoles de forma significativa ($p < 0,05$) en comparación con aquellas que no fueron tratadas. El pH de las hamburguesas se redujo con el aumento del tiempo de almacenamiento. A medida que aumentaba el tiempo de almacenamiento, las sustancias reactivas al ácido tiobarbitúrico y el contenido de gérmenes aumentaron en la hamburguesa sin tratar. Los resultados sensoriales no mostraron diferencias significativas en el total de aceptación de la hamburguesa. La adición de PHWE a las hamburguesas de pollo mejoró su calidad durante almacenamiento hasta máximo 10 días a $4 \pm 1^\circ\text{C}$.

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1. Introduction

The growing interest of the public for ready-made, fast, and easy foods increased, which stemmed from the busy life of modern consumers (Lawrie & Ledward, 2006). The replacement of red meat with chicken in burger production is becoming more popular due to their high fat content and because of no cultural or religious constraints to the consumption of poultry (Mikhail et al., 2014). According to The World Cancer Research, the consumption of a large amount of red meat (more than 500 g/week) may be unhealthy (Bingham, 2006). However, during storage, the quality of chicken burger can deteriorate due to the growth of microorganisms and oxidation of lipids, thereby reducing the nutritional quality and affecting flavor (Bali et al., 2011). In addition, both local and imported chicken burgers had a high percentage of added water and hydroxyproline with respect to the standard, which gives clear indication of fraudulence, as these ingredients are used to increase the size and weight of the final products without any regard to the nutritional value (Al-Bahouh et al., 2012).

The addition of antioxidants has become popular as a means of increasing the shelf life of food products and reducing wastage and nutrient losses by inhibiting and delaying oxidation (Jadhav, Nimbalkar, Kulkarni, & Madhavi, 1996). Synthetic antioxidants such as butylated hydroxyanisole and butylated hydroxytoluene have been used as antioxidants in foods. However, toxicologists and nutritionists have long noted the noxiousness of these compounds which are used in food processing (Bali et al., 2011). There has been a constant search for alternative and efficient compounds for food conservation, aiming a partial or total replacement of antimicrobial chemical additives. Here lies the scope of natural antioxidants and antimicrobial agents.

Pistachio by-products are produced during de-hulling of pistachio nuts after harvesting and contain a high level of pistachio epicarp and to a lesser extent pedicules, leaves, mesocarp, and kernel of the pistachio plant (Bohluli, Naserian, & Valizadeh, 2008). Most of the pistachio by-products are considered as agricultural waste and often mixed with soil and to a lesser extent used as feedstuff by local livestock

farmer and a small portion is used in herbal medicine and human foods (pistachio hull jam) (Behgar, Ghasemi, Naserian, Borzoei, & Fatollahi, 2011).

Like pistachio nut and skin (Tomaino et al., 2010), pistachio hull (Goli, Barzegar, & Sahari, 2005) is an excellent source of natural phenolics and antioxidants. Phenolic contents and antioxidant activity of pistachio hull are more than those of the skin and nuts (Bohluli et al., 2008). The previous study showed that pistachio hull aqueous extracts present a potent antioxidant activity, inhibition of the growth of different pathogenic bacteria (Gram positive) and antimutagenicity that can cause health problems (Rajaei, Barzegar, Mobarez, Sahari, & Esfahani, 2010). Thus, incorporating the hull extracts into food products could make it a source of phytochemicals, offer utilization for the by-product, as well as improve the storage stability and health benefits of the food products. Therefore, the present study was carried out to investigate the effect of pistachio hull aqueous extracts level as a functional ingredient on stability and quality attributes of chicken burger during refrigerated storage.

2. Materials and methods

2.1. Materials

Frozen minced chicken breast, onion powder, sodium chloride, white pepper, black pepper, garlic powder, and pistachio nuts were purchased from a supermarket in Riyadh, Saudi Arabia. All chemicals used were of analytical grade and purchased from Sigma-Aldrich.

2.2. Preparation of pistachio hull extract

The hulls were obtained by shelling fresh pistachio nuts manually, oven-dried at 45°C for 6 h, ground, and sieved through a 1-mm sieve. The pistachio hull powder was extracted by mixing with distilled water (flour to water ratio of 1:8) and stirred overnight at room temperature using a magnetic stirrer (Fisher, 14-511-1A, USA). The slurry was centrifuged (Hermle 66110068, Darmstadt, Germany) at $4500 \times g$ for 30 min. The supernatant was freeze-dried (Virtis Unipot 600SL, New York, USA) and was stored in a freezer at -20°C for further application and analysis.

2.3. Preparation of chicken burger

Chicken burger samples were prepared by mixing 95%, 93%, 90%, and 88% minced chicken meat with 0%, 2%, 5%, and 7% pistachio hull water extract. Then, to each blend, 3.1% onion powder, 1% sodium chloride, 0.3% white pepper, 0.3% black pepper, and 0.3% garlic powder were added. The blends were mixed with ingredients and formed into burger using a burger forming machine (Expro. Co., Shanghai, China). The chicken burgers were separately placed in low-density polyethylene bags and stored at $4 \pm 1^{\circ}\text{C}$ for 2 weeks and analyzed on days 0, 5, 10, and 14 of the storage period. The control and treated samples were replicated three times.

2.4. Cooking

Three molded burgers (average weight of 100 kg) were cooked as described by Al-Juhaimi, Ghafoor, Hawashin, Alsawmahi & Babiker (2016), for 20 min in a preheated hot-air oven at

$180 \pm 1^{\circ}\text{C}$ to an internal temperature of 75°C measured at the geometric center using a digital probe thermometer (Oakton, Eutech Instruments, China). The burgers were turned over at 10-min intervals to ensure uniform cooking.

2.5. Chemical composition and pH determination

The chemical compositions (fat, protein, and ash) of freeze-dried raw and cooked burgers were determined according to AOAC (1995) methods. The pH was determined by blending 5 g sample in 45 ml of distilled water. The mixture was filtered, and a pH meter (Sargent-Welch, 3413037, USA) was used to measure the pH values of the filtrate.

2.6. Cooking properties

The cooking yield (CY) of the chicken burger was calculated as a percentage of the weight of cooked burgers to that of raw burgers as described by Naveena, Muthukumar, Sen, Babji, and Murthy (2006). MR was calculated as described by Murphy, Criner, and Gray (1975) as follows:

$$\text{Moisture retention} = \text{cooking yield} \times \frac{\% \text{ moisture in cooked burger}}{\% \text{ moisture in raw burger}}$$

2.7. Microbiological evaluation

The total plate count (TPC) of the raw burgers at 0, 5, 10, and 14 days of storage was determined according to the method described by Harrigan and McCance (1976) with slight modification. One gram of the sample was homogenized with 9 ml of 0.1% sterile peptone water. Serial 10-fold dilutions were prepared by diluting 1.0 ml of homogenate in 9.0 ml of 0.1 ml of 0.1% peptone water. Appropriate serial dilutions were duplicate plated (pour plate method) with nutrient agar and plates were incubated at 37°C for 48 h.

2.8. Determination of thiobarbituric acid reactive substances (TBARS)

TBARS values of raw chicken burgers at 0, 5, 10, and 14 days of storage were determined according to the method described by Strange, Benedict, Smith, and Swift (1977) and reported as milligrams of malonaldehyde/kg of the sample.

2.9. Preparation of chicken burgers extracts

The raw and cooked chicken burgers were lyophilized (12525, Virtis Company, Gardner, New York), ground, and sieved through a 1-mm sieve. Approximately 2.5 g of dried sample was weighed and extracted with 20 ml of distilled water in a conical flask by stirring overnight using a magnetic stirrer (Fisher, 14-511-1A, USA) at 4°C . Then the mixture was centrifuged (Hermle 66110068, Germany) at $4500 \times g$ for 30 min. The supernatant was collected in a volumetric flask and subsequently used for the determination of total phenolic content.

2.10. Analysis of total phenolic contents

The total phenolic contents were analyzed using the Folin-Ciocalteu method with some modifications (Singleton &

Rossi, 1965). A 200 µl appropriately diluted sample or a standard solution of varying concentrations was mixed with 400 µl of Folin–Ciocalteu reagent. Deionized water was used for dilution and control. The solution was diluted with deionized water to a total volume of 4.6 ml and then thoroughly mixed. After incubation for 10 min at room temperature, 1 ml of 10% Na₂CO₃ solution was added, then immediately mixed, and incubated for 2 h. The absorbance was read at 765 nm on a spectrophotometer (Apel, Saitama, PD-303UV, Japan). Measurements were recorded in triplicate. The gallic acid of 1 mg/ml was used as the standard, and the total phenolic compounds of the samples were expressed in milligram gallic acid equivalent (GAE) per 100 ml extracts (mg GAE/100 ml extracts).

2.11. Sensory evaluation

Cooked chicken burgers were evaluated by 20 semi-trained members selected from the staff of Food Science and Nutrition Department, College of Food and Agriculture, King Saud University, on the basis of interest and experience in sensory evaluation. Panelists were instructed to evaluate color, texture, taste, flavor, juiciness, and overall acceptability using 9-point scale for grading the quality of samples. The testing sessions were carried out two times to reduce the measurement error. The test was conducted early morning in a sensory evaluation room at 20 ± 2.0°C. Sensory attributes were scored for 'like extremely' = 9 to 'dislike extremely' = 1.

2.12. Statistical analysis

All experiments were carried out in triplicate, and data were assessed using ANOVA described by Snedecor and Cochran (1987). Differences between the treatment means were separated using Duncan's multiple range tests. Significance was accepted at $p < 0.05$.

3. Results and discussion

3.1. Effect of the PHWE levels on chemical compositions and total phenolic contents of raw and cooked chicken burgers

The chemical composition of freeze-dried raw and cooked chicken burgers with and without PHWE is shown in Table 1. The result revealed that all the raw samples contained high fat (30.39–31.60%) and protein (58.89–59.85%) contents, and there was no significant difference in fat and protein contents in control and treated burgers. The protein contents were within the range (42.14–68.56%) of chicken burgers reported by Mikhail et al. (2014). There was no significant difference in ash content between control and treated burgers which were found to be ranged from 6.14% to 6.25%. Ash content is an indication of the mineral contents of samples and the high value obtained for the burgers imply that burgers serve as a source of micro and macro elements. Cooking decreased the fat and ash contents of the burgers, but it increased their protein contents. During cooking, there is a loss of fat and water which may result in a decrease in fat contents of the cooked burger compared to the raw.

Figure 1 shows the effect of different levels of PHWE on the total phenolic content of raw and cooked chicken burgers. The total phenolic contents of raw burgers ranged from 27.93 to

Table 1. Chemical compositions (%) of the freeze-dried chicken burgers formulated with different level of pistachio hull water extracts (mean ± SD).

Tabla 1. Composición química (%) de las hamburguesas de pollo liofilizadas formuladas con diferentes niveles de *PHWE (Promedio ± SD).

Chemical composition	Extract concentration (%)			
	0	2	5	7
<i>Raw</i>				
Fat ^{ns}	31.60 ± 1.71	31.47 ± 0.14	30.39 ± 4.16	31.37 ± 2.77
Protein ^{ns}	59.41 ± 0.62	59.85 ± 0.49	59.32 ± 0.74	58.89 ± 1.11
Ash ^{ns}	6.18 ± 0.07	6.25 ± 0.19	6.14 ± 0.08	6.22 ± 0.03
<i>Cooked</i>				
Fat ^{ns}	30.39 ± 0.00	27.45 ± 2.77	29.00 ± 0.00	26.87 ± 3.60
Protein	63.53 ^a ± 2.23	62.65 ^a ± 0.74	60.11 ^b ± 0.62	59.06 ^b ± 1.11
Ash ^{ns}	6.01 ± 0.03	6.01 ± 0.01	5.82 ± 0.22	5.90 ± 0.15

Mean values with different superscripts within the same row are significantly ($p < 0.05$) different and without superscript indicates no significance differences among means.

Los valores promedio con superíndice diferente en una misma fila son significativamente ($p < 0.05$) distintos y sin superíndice indican que no hay diferencias significativas entre los promedios. *PHWE: Extractos de agua con cáscara de pistacho.

34.57 mg GAE/100 ml with the control burgers having significantly ($p < 0.05$) lower value than the treated ones. Also, there was a decrease in the total phenolic content of chicken burgers after cooking to the range of 20.79–28.02 mg GAE/100 ml. The reduction in the total phenolic content after cooking may be due to the high temperature used in cooking which may have destroyed the phenolic compounds. Furthermore, the loss in water during cooking may leach the phenolics of the PHWE extract and consequently resulted in a reduction in total phenolic of the cooked burgers. Although there is a decrease in total phenolics after cooking, still the content was significantly ($p < 0.05$) higher in treated burgers than the untreated one. The high phenolic content exhibited by the treated burgers may be due to the high phenolic content of the PHWE (65.94 mg GAE/100 ml extract) used in the treatment of the burgers. Previous studies have reported that pistachio hull extracts have high phenolic contents (Bohluli et al., 2008). Therefore, the PHWE was effective in increasing the total phenolic contents of chicken burgers and hence improve its antioxidant activity as compared to the control chicken burgers.

3.2. Effect of the PHWE levels on cooking properties of chicken burgers during storage

The cooking properties of the control and treated chicken burgers are shown in Table 2. At day 0, there was a significant ($p < 0.05$) difference in the CY of chicken burgers treated with 2% PHWE and that of control burger. As the storage period increased, the values of CY were significantly ($p < 0.05$) decreased for both control and treated burgers, and the reduction was found to be significant ($p < 0.05$) at days 0–14 for control and 2% treated burgers. The addition of PHWE to chicken burgers improved the CY probably due to the water retention capacity and capability of PHWE to keep moisture in the patty matrix as reported by Naveena et al. (2006) for chicken burgers formulated with finger millet flour. Alakali, Irtwange, and Mzer (2010) reported similar results for the CY in beef burgers formulated with Bambara groundnut seed flour. Also, the lower decreasing rate in CY of the treated burgers could be attributed to the high MR exhibited in the treated burgers compared to the control.

The MR of the control and treated chicken burgers showed no significant difference at day 0. As the storage period was

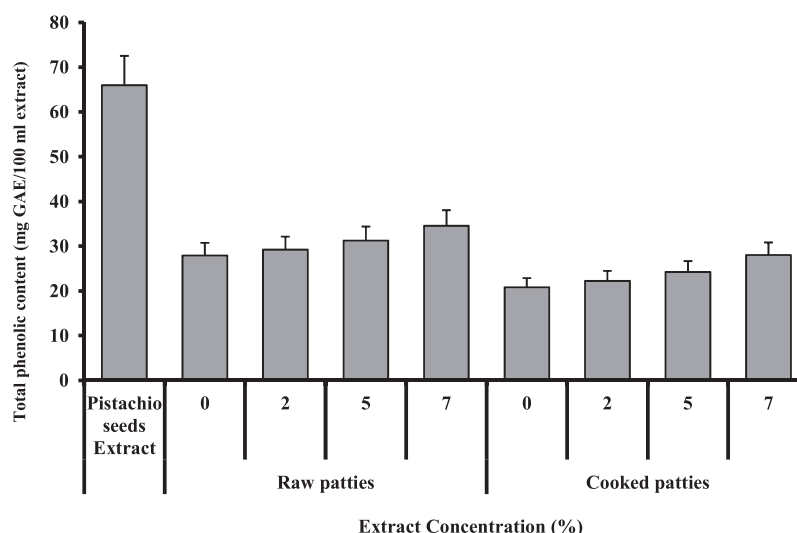


Figure 1. Total phenolic content of pistachio seeds hull extracts, raw, and cooked chicken burgers treated with different levels of pistachio hull extract.

Figura 1. Contenido fenólico total de los extractos de cáscara de pistachio, hamburguesas de pollo crudas y cocinadas tratados con diferentes niveles de extracto de cáscara de pistachio.

Table 2. Effect of different levels of pistachio hull water extracts on the cooking properties (cooking yield and moisture retention) of chicken burger (mean \pm SD).

Tabla 2. Efecto de diferentes niveles de PHWE en las propiedades de cocinado (rendimiento del cocinado y retención de humedad) de la hamburguesa de pollo (Promedio \pm SD).

Extract concentration (%)	Storage period (days)			
	0	5	10	14
Cooking yield (%)				
0	81.70 ^{aw} \pm 3.21	67.17 ^{bx} \pm 3.26	64.04 ^{cy} \pm 1.07	59.82 ^{dz} \pm 1.42
2	80.16 ^{aw} \pm 2.72	67.21 ^{bx} \pm 3.29	63.43 ^{cwy} \pm 0.61	61.99 ^{dy} \pm 0.83
5	77.98 ^{ay} \pm 0.91	69.29 ^{bw} \pm 0.27	68.34 ^{bw} \pm 1.36	63.20 ^{cx} \pm 1.48
7	78.62 ^{ax} \pm 1.69	71.73 ^{bw} \pm 1.28	67.39 ^{cx} \pm 2.24	66.99 ^{cw} \pm 1.67
Moisture retention (%)				
0	71.98 ^{aw} \pm 2.83	53.91 ^{by} \pm 2.62	50.34 ^{cy} \pm 0.84	44.27 ^{dz} \pm 1.05
2	72.02 ^{aw} \pm 2.45	54.16 ^{by} \pm 2.65	48.57 ^{cz} \pm 0.47	46.86 ^{dwy} \pm 1.10
5	69.96 ^{aw} \pm 0.86	58.74 ^{bx} \pm 0.23	58.49 ^{bw} \pm 1.17	47.73 ^{cx} \pm 0.64
7	72.10 ^{aw} \pm 1.55	62.77 ^{bw} \pm 1.12	55.86 ^{cx} \pm 1.39	54.95 ^{cw} \pm 1.82

Mean values with different superscripts (a, b, c, d) within the same row and that with superscript (w, x, y, z) within the same column are significantly ($p < 0.05$) different.

Los valores promedio con superíndices diferentes (a, b, c, d) en la misma fila y con superíndice (w, x, y, z) en la misma columna son significativamente ($p < 0.05$) distintos.

increased from 5 to 14 days, there was a significant ($p < 0.05$) decrease in MR for all samples. After 14 days of storage, the values of MR for the burgers treated with 2%, 5%, and 7% PHWE were 46.86%, 47.73%, and 54.95%, respectively, and were higher ($p < 0.05$) than that of the control (44.27%). This could be attributed to the high water absorption capacity of the extracts used in the preparation of the burger. The increase in water absorption capacity of heated protein flours, the heated dissociation of proteins, and the gelatinization of starch in the flour may improve MR of burger (Modi, Mahendrakar, Narasimha Rao, & Sachindra, 2004).

3.3 Effect of the PHWE levels on microbiological properties, pH, and TBARS of raw chicken burgers during storage

The TPC of control and treated chicken burgers ranged between 2.81 and 2.97 log cfu/g on day 0, and there was no significant difference between them (Table 3). As the storage period increased from 0 to 14 days, there was a linear increase in the TPC of burgers. The increase in TPC with the

advancement of storage period might be due to the multiplication of microorganisms during storage (Al-Juhaimi et al. 2016). Bali et al. (2011) reported similar results for the TPC of chicken sausage formulated with garlic and coriander flour. After 10 days of storage, the TPC of the control burgers increased to 7.34 log cfu/g, which was significantly ($p < 0.05$) higher than that of the burgers treated with 2%, 5%, and 7% PHWE. Also, an increase in the levels of extracts has no significant effect on the TPC of the treated burgers after storage for 10 days. At the end of the storage period (14 days), the TPC of all burgers was high and can be considered unsafe for human consumption. Studies have shown that polyphenol-rich foods correlate with a broad range of physiological properties such as antimicrobial characteristic (Sousa et al., 2006). Rajaei et al. (2010) reported the inhibitory effect of crude and purified extracts of pistachio hull against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella thuyphi*, *Candida albicans*, and *Navia intermedia*, and the effect increased with increase in the concentration of the extracts. It can be deduced that the high phenolic contents of the PHWE (65.95 mg GAE/100 ml extract) used in

Table 3. The aerobic plate count, pH, and thiobarbituric acid reactive substances (TBARS) of chicken burger formulated with various levels of pistachio hull water extracts during cold storage (mean \pm SD).

Tabla 3. El contenido de gérmenes aeróbicos, el pH y las sustancias reactivas al ácido tiobarbitúrico (TBARS) de la hamburguesa de pollo formulada con varios niveles de PHWE durante almacenamiento en frío (Promedio \pm SD).

Extract concentration (%)	Storage period (days)			
	0	5	10	14
<i>Total plate count (log cfu/g)</i>				
0	2.81 ^c \pm 0.05	4.44 ^b \pm 0.11	7.34 ^a \pm 0.03	8.27 ^a \pm 0.00
2	2.83 ^d \pm 0.10	4.26 ^c \pm 0.09	6.52 ^b \pm 0.04	7.85 ^a \pm 0.04
5	2.90 ^d \pm 0.03	4.01 ^c \pm 0.04	6.39 ^b \pm 0.06	7.64 ^a \pm 0.03
7	2.97 ^d \pm 0.04	4.03 ^c \pm 0.10	6.29 ^b \pm 0.03	7.60 ^a \pm 0.00
<i>pH</i>				
0	6.76 ^a \pm 0.01	6.26 ^a \pm 0.01	5.73 ^b \pm 0.01	5.59 ^b \pm 0.02
2	6.42 ^a \pm 0.05	5.81 ^a \pm 0.03	5.68 ^a \pm 0.02	5.56 ^a \pm 0.05
5	6.42 ^a \pm 0.03	6.04 ^a \pm 0.06	5.81 ^a \pm 0.02	5.75 ^a \pm 0.01
7	6.33 ^a \pm 0.04	6.07 ^a \pm 0.07	5.83 ^a \pm 0.05	5.80 ^a \pm 0.01
<i>TBARS (mg malonaldehyde/kg sample)</i>				
0	5.28 ^d \pm 0.11	8.94 ^{cw} \pm 0.35	11.03 ^{bw} \pm 0.64	13.90 ^{aw} \pm 0.33
2	4.88 ^c \pm 0.28	8.03 ^{bw} \pm 0.46	8.58 ^{bx} \pm 0.21	10.28 ^{ax} \pm 0.85
5	4.86 ^c \pm 0.27	7.05 ^{bx} \pm 0.47	7.88 ^{by} \pm 0.23	9.49 ^{ay} \pm 0.41
7	4.75 ^d \pm 0.17	6.53 ^{cx} \pm 0.04	7.62 ^{by} \pm 0.46	9.10 ^{ay} \pm 0.21

Mean values with different superscripts (a, b, c, d) within the same row and that with superscript (w, x, y, z) within the same column are significantly ($p < 0.05$) different.

Los valores promedio con superíndices diferentes (a, b, c, d) en la misma fila y con superíndice (w, x, y, z) en la misma columna son significativamente ($p < 0.05$) distintos.

the preparation of the treated chicken burgers were responsible for its strong antimicrobial effect and hence low TPC as compared to the control chicken burgers.

At day 0, the pH of control chicken burgers (6.76) was higher ($p < 0.05$) than burgers treated with 2%, 5%, and 7% PHWE, which was 6.42, 6.42, and 6.33, respectively (Table 3). The PHWE has an acidic pH of 5.8, and this reduced the pH of the treated burgers. There was a decrease ($p < 0.05$) in the pH values of control burgers with the advancement of storage period from days 5–10, while no significance differences were observed in the pH of the treated burgers. The pH of control burgers became more acidic as compared to the treated burgers after 14 days of storage. This could be due to the microbial growth and production of acids, thereby reducing the pH in foods during storage.

As shown in Table 3, there was no significant difference in TBARS values of the chicken burgers at day 0 and after that the values increased ($p < 0.05$) with the storage period irrespective of the treatments. This might be due to the increased lipid oxidation and production of volatile metabolites in the presence of oxygen during preparation and storage as well as during aerobic packaging (Goli et al., 2005). This observation supports the previous study reported by Soltanizadeh and Ghiasi-Esfahani (2015) on beef burger formulated with *Aloe vera*. The control chicken burgers had higher TBARS value throughout the storage periods, and TBARS value of 11.03 mg malonaldehyde/kg sample was observed after 10 days of storage. The addition of the PHWE to chicken burgers reduced ($p < 0.05$) the TBARS values to 8.58, 7.88, and 7.62 mg malonaldehyde/kg sample for 2%, 5%, and 7% PHWE, respectively, after 10 days of storage and the rate of increase decreased with the level of PHWE. The TBARS values of the treated burgers after 10 days of storage were slightly higher than the value reported by Bali et al. (2011) and lower than that reported by Rababah et al. (2006) on breast meat infused with plant extracts. The lower values of TBARS in the treated burger compared to the control one may be attributed to the

antioxidative effect of the pistachio hull extracts due to its high phenolic contents which have the ability to scavenge free radicals, thereby reducing the rate of lipid oxidation. The antioxidant activity of pistachio hull extracts had been strongly supported by Goli et al. (2005) who tested pistachio hull extracts on soybean oil for its reduction in TBARS value and the antioxidant effect increased with increase in the concentration of the extracts.

3.4 Effect of the PHWE levels on the sensory properties of chicken burgers

The effect of different levels of PHWE on the sensory evaluation of fresh chicken burger is shown in Table 4. Sensory evaluation of chicken burger revealed no significant difference in all sensory attributes between control and treated burgers except color. The overall mean value for color for the control burger was found to be higher ($p < 0.05$) than that of chicken burger treated with 5% and 7% PHWE. This difference might be due to the color of the pistachio hull extracts used in the preparation of the burger. Although a higher overall acceptability score was attributed for control chicken burgers, this score was not significantly different from the treated burgers.

4. Conclusion

The results of this study indicated that the use of water extracts prepared from pistachio hull in the treatment of chicken burgers increased the antioxidant activity of the burgers. Also at high levels (7%) of PHWE, there was an improvement in burger properties such as better cooking properties, lower lipid oxidation, and lower TPCs of the burgers. There was no significant difference in the overall acceptability of chicken burgers. It can be concluded that addition of PHWE at 7% level in the treatment of chicken burgers can improve the quality of the burgers even after storage for 10 days at $4 \pm 1^\circ\text{C}$.

Table 4. Sensory evaluation of fresh chicken burger formulated with pistachio hull water extracts (mean \pm SD).**Tabla 4.** Evaluación sensorial de la hamburguesa de pollo fresca formulada con PHWE (Promedio \pm SD).

Sensory attribute	Extract concentration (%)			
	0	2	5	7
Colour	8.14 ^a \pm 0.69	7.57 ^{ab} \pm 0.79	7.14 ^b \pm 0.90	7.00 ^b \pm
Texture ^{ns}	7.86 \pm 0.69	7.43 \pm 0.53	7.43 \pm 0.53	7.50 \pm 0.76
Taste ^{ns}	7.86 \pm 0.69	7.71 \pm 0.76	7.29 \pm 0.49	7.29 \pm 0.76
Flavour ^{ns}	7.57 \pm 0.79	7.57 \pm 0.79	7.14 \pm 1.07	6.71 \pm 1.70
Juiciness ^{ns}	7.29 \pm 1.11	6.86 \pm 0.38	6.57 \pm 1.13	6.57 \pm 1.72
Overall acceptability ^{ns}	7.43 \pm 1.13	7.14 \pm 1.07	6.93 \pm 0.73	6.86 \pm 1.07

Mean values with different superscripts within the same row are significantly ($p < 0.05$) different and without superscript indicates no significance differences among means. Sensory attributes were scored for 'like extremely' = 9 to 'dislike extremely' = 1.

Los valores promedio con superíndices diferentes en la misma fila son significativamente ($p < 0,05$) distintos y sin superíndice indican que no hay diferencias significativas entre los promedios. Los atributos sensoriales se valoraron entre 'gusta mucho' = 9 'no gusta nada' = 1.

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