Original Article

Antimicrobial Edible Films from Walnut Shell Waste: Extraction, Application on Chicken Meat, and Shelf-Life Extension

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Abstract

A useful, abundant, and inexpensive byproduct, walnut shell waste has many benefits. It may be recycled into eco-friendly materials for numerous sectors. This study investigated the effects of fortifying edible films with 0.5, 1.0, and 1.5% aqueous and alcoholic extracts of walnut shell powder on the microbial and sensory quality of chicken thigh pieces after 12 days of cooled storage. Solutions to environmental problems come from reducing agricultural waste by transforming walnut shells into edible coatings. Results showed that extraction method and solvent type directly impact the extract's capacity to inhibit Gram-negative and Gram-positive bacteria. The proportion of extracts supplied also affected this factor. Alcoholic extract inhibited better than water extract. While the 100% concentration inhibited target bacteria by more than 50%, the clear zoon around the hole of the alcoholic extract was 16.4, 14.9, 18.9, and 19.5 mm in dishes cultured with *E. coli*, *P. aeruginosa*, *S. aureus*, and *B. subtilis*, respectively. Adding 1.5% walnut shell alcoholic extract to edible chicken-thigh cut films considerably reduced bacterial growth and activity. The logarithm of total, coliform, and psychrophilic bacteria in films containing 1.5% walnut shell alcoholic extract after 12 days of refrigerated storage was 6.22, 4.042, and 4.880 cfu/g^{-1}. Fortifying the films with 1.5% walnut shell alcoholic extract improved the sensory qualities and overall acceptability of chicken thigh pieces after storage, as color, flavor, texture, and juiciness reached 9.420, 8.980, 8.740, and 8.600, respectively. Total acceptance was 8,000.

Keywords: walnut shell remnants, edible shells, refrigerated storage, chicken thigh cuts, sensory evaluation

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Received: 2025-09-05 **Accepted**: 2025-12-23 **Published**: 2026-03-31

Introduction

Food production processes usually generate much natural or industrial waste, such as peels, stems, or uneaten parts of fruits and vegetables, in addition to the waste from meat slaughterhouses and dairy factories. Most of these remains are considered unfit for human consumption or handling, in addition to being a suitable environment for the breeding harmful microbes, which negatively impacts the ecosystem and human health. This has led to the recycling of some or all of such waste and its incorporation into new industrial baskets by focusing on some of its useful components and by extracting the functional compounds found within it (14). The growing global concern about environmental pollution caused by traditional plastic packaging has

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How to cite this article: Khaleel, N T., Yaseen, A A., and Al-Kaabi. H J. (2026) Antimicrobial Edible Films from Walnut Shell Waste: Extraction, Application on Chicken Meat, and Shelf-Life Extension, Anbar Journal of Agricultural Sciences, 24(1):256-267. DOI: 10.32649/ajas.2026.191240.

spurred research on developing sustainable solutions, particularly alternatives derived from food waste and its by-products (8).

Innovative methods utilize the bioactive compounds and structural polymers found in industrial waste, paving the way for the production of biodegradable plastic packaging, functional compounds, and efficient or smart packaging materials. Therefore, there has been an increasing focus on the exploitation and recycling of waste, especially hygienically safe waste, such as whey, fruit and vegetable peels, and nut shells, which has led to the creation or development of new, unconventional, and sustainable solutions for use in food packaging, such as edible films (32). These modern trends have begun to alleviate the concerns of those interested in the environment or to resolve some of the questions they raise and confront with industrialists by minimizing, or even stopping, the use of plastic or metal waste, which is the crux of the problem between the two parties at present (21). Moreover, these trends enhance food safety and quality by extending its shelf life as well as maintaining them during storage (2).

Unfortunately, this trend is still in its early stages due to the practical and scientific challenges faced, whether in research laboratories or on a commercial production scale. This trend has not yet taken its natural course, which is what those interested in the environment and sustainable development aspire to (22). Reducing this gap requires a comprehensive assessment of its technical and economic feasibility and a survey of consumer opinions on the acceptability of this approach to facilitate its widespread adoption, which will help reduce reliance on petroleum-based packaging materials (20).

The use of safe agricultural waste is one of the most important trends that is fully in line with the sustainable development goals, as it reduces heat emissions and contributes to reducing air, soil, and water pollution. This, in turn, promotes the health of the planet and provides health benefits to humans through the functional and nutritional values of the extracted biological materials (17). Supporting traditional packaging with food processing plant waste, which is usually rich in complex or degraded processed starches, proteins, and bioactive materials, will provide a safe and sustainable alternative to non-biodegradable plastics and polyethylene (19). This technology is fully in line with the increasing demand and modern trend towards packaging materials that are durable and reliable, and simultaneously, considered a sustainable alternative that reduces the waste of natural resources and environmental pollution (1). It also charts a new course for a modern economic approach centered on waste recycling and contributing towards sustainable development goals targets (18).

Many scientific studies have confirmed that edible films, especially those made from treated agricultural and food waste, do contribute to improving food value and increasing its shelf life through the integration of many factors that come together within the film matrix. This is achieved by creating protective barriers between the food and its surrounding environment. In addition, these membranes possess antimicrobial properties that protect against pathogens, food spoilage, and antioxidants there by improving food preservation and safety (12, 6). Walnut shells, which are often thrown away, are a clear example of food waste that is rich in many biologically active compounds such as cellulose, hemicellulose, and lignin, in addition to containing phenolic compounds with antioxidant and antimicrobial properties (26). This makes them an excellent natural alternative and an inexpensive option for developing edible packaging materials, which not only contributes to reducing environmental pollution but also achieves positive functional benefits for packaged foods (15).

Many recent studies on the use of this shell waste in supporting packaging materials has offered promising hope for improving the standards of manufacturing, processing, and transportation of processed meats (23). Its role has been prevention, improving color stability, inhibiting lipid oxidation, and suppressing microbial activity in canned food, thereby increasing consumer acceptance of the final product, reducing global food waste, and

reducing shrinking devastating economic losses (3). As such, innovative and sustainable packaging solutions, particularly those derived from waste recycling, have been considered of much importance, particularly in the meat industry, and are essential for maintaining meat quality and extending its shelf life (28).

This study aimed to evaluate walnut shell extracts as functional additives in edible coatings for chicken thigh fillets. It hypothesizes that a 1.5% alcoholic walnut shell extract incorporated into a glycerol methylcellulose base will significantly reduce total bacterial, coliform, and psychrophilic counts, and improve sensory acceptance during 12 days of refrigerated storage, compared with untreated controls**.**

Materials and Methods

Walnut shell samples were collected from a local market in Ramadi, Anbar Governorate. They were thoroughly washed under running water to remove physical, chemical, and biological residues, then dried in a 45 °C oven. The shells were then ground using a coffee grinder, and the powder stored in airtight glass bottles until use.

Aqueous extract of walnut shell

The method described by Ratheesh et al. (24) was applied to obtain the aqueous extract from the walnut shells, by adding 250 ml of distilled water to a beaker containing 50 g of the prepared walnut shell powder. The mixture was then incubated for 24 h at room temperature with continuous stirring. It was filtered using a Buchner funnel under vacuum pressure, and the filtrate was then concentrated at 40 °C using a rotary evaporator to remove the solvent. The concentrated filtrate was collected, placed in sterile, sealed bottles, and stored in a refrigerator until further use.

Alcoholic extraction preparation

Fifty grams of walnut shell powder were placed in a flask containing 250 ml of 70% ethanol. The mixture was incubated in a shaker incubator for 48 h at room temperature. It was filtered through Whatman No. 1 filter paper, and the filtrate was then concentrated using a rotary evaporator at 40 °C to remove the solvent. The powder was preserved in sterile, transparent containers until use.

Preparation of biofilms

Edible coatings were formulated according to the methodology described by Bashir (7), with modifications including the combination of 1 ml of glycerol, 0.5 g methyl cellulose, and 30 ml ethyl alcohol incorporated with 0.5, 1, and 1.5 g dry walnut shell extract to enhance antimicrobial and antioxidant efficacy. The mixture's total volume was calibrated to 100 ml by adding distilled water. It was heated and thoroughly agitated using a magnetic stirrer on a hot plate for one hour at 70 °C, and then used to coat the chicken meat samples.

Meat piece packaging

Chicken meat was obtained by slaughtering 10 hens from the same farm. The chicken thighs were removed and coated by submerging them in the coating solution for 2–3 min. The coated pieces were extracted and dried. The samples were then kept at 4 °C for 1, 4, 8, and 12 min, followed by qualitative testing.

Experimental samples

The experimental samples were as follows:

T1: control treatment

T2, T3, and T4: thigh meat coated with 0.5 g, 1 g, and 1.5 g dried walnut shell extract/coating mix^{-1}, respectively.

Bacterial isolates

The bacterial isolates for the study were procured from the Central Laboratory of the College of Agriculture at the University of Anbar. They included *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Bacillus subtilis*. Their purity was verified, and they were activated through two sequential transfers every 24 h in a culture medium at 37 °C.

Culture media preparation

The culture media were prepared according to the manufacturer's instructions. The

medium was thoroughly dissolved in water after heating to a boil, then transferred to an autoclave and sterilized at 121 °C and 1.5 psi for 15 min.

Antagonistic evaluation

The well diffusion assay was used to test the antibacterial activity of both alcoholic and aqueous extracts of walnut shells according to (11) with slight modifications. Petri dishes were inoculated with bacterial isolates, and the previously prepared medium was poured over them and allowed to solidify. Each dish was divided into four regions, three of which were perforated with a diameter of 5 mm using a cork piercer, and the fourth was left without perforation to place the antibiotic disc (amikacin). Two wells were filled with 50 µL aqueous and alcoholic extracts at 100% and 50% concentrations. The third well was filled with sterile distilled water as the control. Amikacin was placed in the fourth zone of the dish, and the dishes were incubated overnight at 37 °C. The effectiveness of the aqueous and alcoholic extracts was determined by measuring the length of the clear zone around the holes using an electronic Vernier caliper.

Bacteria counts

One gram of peptone was dissolved in 1 liter of distilled water and then sterilized at 121 °C for 15 min. The total number of microorganisms was estimated by weighing 11 g of each thigh meat sample. A sterile stomacher bag was placed in 99 ml of sterile dilution solution (0.1% peptone). The sample was then mixed for 2 min in a stomacher at a dilution of 10-1. One milliliter of the first dilution was transferred to 9 ml of the dilution solution to formulate a 10-2 dilution and mixed well using a vortex mixer. Subsequent dilutions were performed in the same manner. One milliliter of each dilution was transported to Petri dishes, nutrient agar was added for total bacterial counts, and MacConkey agar for coliform counts. After the medium solidified, the plates were transferred to an incubator at 37 °C for 48 h. For psychrophilic bacteria, the plates were incubated at 7 °C for 5-7 days. The number of colonies growing on the plate was counted and multiplied by the reciprocal of the dilution (5).

Sensory evaluation

Sensory evaluation was done by taking cubes of thigh meat, and salting and grilling them in an oven at 180 °C for 15 min. The samples were distributed and evaluated within a range of 1-7 in the evaluation form according to the method described by (16).

Statistical analysis

The data were statistically analyzed using two-way analysis system with the SAS program (27). The first direction included the effect of storage periods, while the second involved the effect of additives and the interaction between the two directions on the studied traits by following the General Linear Model and using the statistical program above. Significant differences between the averages were tested according to the Duncan multi-nominal test (9) at the $P \leq 0.01$ significance level.

Results and Discussion

Table 1 shows that both alcoholic and aqueous extracts of walnut shell powder at 50% and 100% concentrations produced inhibitory effects against the four bacterial strains, with the alcoholic extract demonstrating greater efficacy than the aqueous extract. The diameters of the inhibition zones for the 50% and 100% concentrations of the alcoholic walnut shell extract were 11.1 and 16.4 mm, 9.8 and 14.9 mm, 12.6 and 18.9 mm, and 13.6 and 19.5 mm against *E. coli, P. aeruginosa, S. aureus, and B. subtilis*, respectively. The clear zones of the aqueous extract against the same bacteria measured 8.3 and 11.2, 7.6 and 12.1, 9.7 and 14.6, and 10.4 and 13.8 mm, respectively. The inhibitory effect of walnut shells is due to the active compounds they contain, such as tannins, flavonoids, and phenolic acids such as calcineic and chlorogenic acids.

These compounds exhibit antibacterial activity against both gram-positive and gram-negative bacteria. They disrupt the formation and function of the bacterial cell membrane, inhibit nucleic acid formation, and cause oxidative damage within bacteria, as well as disrupt the enzymes responsible for vital cellular activities. The effect of walnut shells on Gram-positive bacteria was more pronounced than that on Gram-negative bacteria, which is attributed to the difference in cell wall structure between the two bacteria types (30). The results showed that the alcoholic extract of walnut shells was superior in terms of inhibition compared with the aqueous extract. Furthermore, the available results indicate that although walnut shells possess an inhibitory effect against the target bacteria, this effect is not comparable to the inhibitory efficacy of the antibiotic amikacin. This is consistent with the growing trend towards using natural sources as antimicrobial agents and promoting sustainability in food manufacturing.

Table 1. Inhibitory activity of alcoholic and aqueous extracts of walnut shells against different types of Gram-positive and negative bacteria compared to antibiotics

Bacteria	Extract	Inhibition zone diameter (mm)			
Escherichia coli	**Alcoholic**	11.1	16.4	22.2	——
	Aqueous	8.3	11.2		
Pseudomonas aeruginosa	**Alcoholic**	9.8	14.9	20.5	——
	Aqueous	7.6	12.1		
Staphylococcus aureus	**Alcoholic**	12.6	18.9	24.2	——
	Aqueous	9.7	14.6		
Bacillus subtilis	**Alcoholic**	13.6	19.5	22.9	——
	Aqueous	10.4	13.8		

Storage period duration had a positive effect on total bacterial count (Table 2). Although no significant differences ($p \leq 0.05$) were noted on the first day of cold storage, it recorded the lowest bacterial counts in the chicken thigh, with logarithms of 3.343, 3.336, 3.336, and 3.350 cfu/g-1 for the control, T2, T3, and T4 treatments, respectively. A significant increase ($p \leq 0.05$) in bacterial count was observed after 12 storage days compared to other durations, at 8.516, 7.480, 6.848, and 6.622 cfu/g-1 for the same treatments. In addition, the type of packing treatment significantly influenced total bacterial count, irrespective of storage duration, with a significant increase at $p \leq 0.005$ in total bacterial count in the control. However, T4 (chicken thigh with 1.5g-1 coating mixture) showed the lowest significant total bacterial count.

The table also shows that the length of the storage period positively affected total bacterial count for all treatments. A significant increase ($p \leq 0.05$) in counts was observed after 12 days of storage of chicken thigh samples compared to other storage periods. The lowest significant value appeared after one day of packaging for all treatments. Also, the type of packaging treatment had a significant effect on the total bacterial count, regardless of the storage period. A significant increase ($p \leq 0.05$) in total bacterial count was observed in the control group, while T4 (chicken thigh coated with dried walnut shell extract at 1.5 g/packaging mixture-1) recorded the lowest count. For the interaction between storage factors and the packaging treatments, no significant differences occurred in the first storage period for all treatments, while the highest significant superiority ($p \leq 0.05$) was for the control at 12th day of storage.

The results showed that the best interaction occurred between the fourth and third treatments during the four storage periods. The longer the storage period, the more significantly the fourth and third treatments improved total bacterial count compared to the other treatments. Both treatments registered a decrease in total bacterial count even after 12 days of storage. From the above, it is clear that the total number of bacteria in the control treatment increased during refrigerated storage, more than the other treatments involving the walnut shell extract. This may be due to the components of walnut shells and the compounds they contain, which inhibit and hinder the growth of bacteria and microbes.

The packaging may also have prevented microbes from reaching the insides of the samples by hindering their penetration into the meat and not providing appropriate conditions for bacterial growth and activity. This lowers their numbers through the deterioration of bacterial activity, loss of cellular enzymes, breakdown of the phospholipid bilayer, and damage to their genetic material. This leads to cell lysis, structural changes, and the production of irregularly shaped cells because of the resulting effect on membrane proteins. In addition, it inhibits ATP production, increases membrane permeability, and has lack of control over translocation across the cell ends because of changes in the ion transport channels present in the cell walls [29, 30]. Various studies have shown that the bark of walnut trees and the outer shells of walnut fruits possess antibacterial properties attributed to their polyphenol content [10].

Table 2. Effect of cooling storage duration and coating with walnut shell extract on number of microorganisms in chicken thighs

Storage Time	1 Day	4 Days	8 Days	12 Days	Average of treatments	Significance level
T1 (Control)	3.343 g	5.026 f	6.718 c	8.516 a	5.901 a	<.0001
T2	3.336 g	4.928 f	5.876 d	7.480 b	5.405 b	
T3	3.336 g	4.693 f	5.696 de	6.848 c	5.143 c	
T4	3.35. g	4.658 f	5.469 e	6.622 c	5.025 c	
Average storage period	3.341 d	4.826 c	5.940 b	7.367 a	Significance level of interference	<.0001
Significance level for storage period	**<.0001**				Mean standard error	0.226

*Values denote the mean ± standard error .

**ΔC: no significant changes between treatments at the P ≤ 0.05 significance level.

Significant changes between treatments at the P ≤ 0.05 significance level are indicated by different letters within the same row. T1 (control): uncoated leg of lamb; T2, T3, and T4: leg of lamb coated with dried walnut shell extract at 0.5, 1, and 1.5 g/coating mixture, respectively.

Table 3 shows the effect of cooling storage period at 4 °C on coliform numbers in chicken thighs. A significant increase ($p \leq 0.05$) in coliform counts was observed after 12 d storage for all treatments. Although, no significant differences were seen in the initial coliform numbers at the start of storage, the logarithms for bacterial count reached 3.197, 3.196, 3.195, and 3.196 cfu/g-1 in the control, T2, T3, and T4 groups, respectively. The control had the highest coliform numbers among all treatments. For the effect of the edible coating infused with walnut extract on coliform levels, the initial treatment

substantially surpassed ($p<0.05$) the others, although the fourth treatment exhibited the lowest significant value in coliform bacterial count. The logarithms in coliform counts after 12 days of refrigerated storage reached 5.015, 4.603, 4.155, and 4.042 cfu/g^{-1}, respectively. However, for storage and packaging interaction, the table shows no significant differences ($p<0.05$) in coliform numbers in the first storage period, while the first treatment recorded the highest significant value ($p < 0.05$) at 12 days storage. Meanwhile, T3 and T4 recorded the best interaction between the two factors for all storage periods.

These findings indicate that the coating support with walnut shell extract effectively inhibited the growth of coliform bacteria in coated chicken thighs. This effect is attributed to the components of walnut shells, including phenolics, tannins, and flavonoids, which tend to disrupt microbial activity by degrading the bacterial cell wall and enhancing its permeability. Moreover, the walnut shell extract and edible film matrix combination forms a strong double layer preventing bacterial growth on food surfaces and reducing external contamination by regulating and controlling the mechanism of oxygen and moisture exchange with the surrounding environment, thereby extending the shelf life of packaged meats while reducing the presence of microbes (30).

Table 3. Impact of storage and packaging on coliform counts in chicken thighs packed in edible film and enriched with walnut shell residue extract

Storage Period	1 Day	4 Days	8 Days	12 Days	Average of treatments	Significance level
T1 (Control)	3.197 h	3.717 e	4.147 c	5.015 a	4.019 a	<.0001
T2	3.196 h	3.468 g	3.742 e	4.603 b	3.752 b	
T3	3.196 h	3.455 g	3.694 ef	4.155 c	3.625 c	
T4	3.195 h	3.428 g	3.614 f	4.042 d	3.570 d	
Storage period	3.196 d	3.517 c	3.799 b	4.454 a	Significance level of interference	<.0001
Significance level for storage duration		**<.0001**			Mean standard error	0.075

*Values denote the mean ± standard error.
**ΔC: no significant changes between treatments at the $P \leq 0.05$ significance level.
***Significant changes between treatments at the $P \leq 0.05$ significance level are indicated by different letters within the same row. T1 (control): uncoated leg of lamb; T2, T3, and T4: leg of lamb coated with dried walnut shell extract at 0.5, 1, and 1.5 g/coating mixture, respectively.

Table 4 displays the impact of varying concentrations of alcoholic extract from walnut shells on psychrophilic bacteria in chicken thighs during the storage periods. A significant increase ($p < 0.05$) in psychrophilic bacteria was noted after 12 d of cold storage when evaluating the effect of storage alone. The logarithmic number of bacterial counts on the first day was 3.713 (control), 3.700 (T2), 3.682 (T3), and 3.705 (T4). After 12 days of cold storage, these values changed to 5.445, 5.232, 5.063, and 4.880 cfu\g-1, respectively. The results show that not wrapping the chicken thigh contributed to a significant increase ($p < 0.05$) of psychrophilic bacteria in the control group and for all addition ratios after the end

of cold storage, with the logarithmic bacteria numbers reaching 5.445 cfu/g -1. T4 exhibited the minimal increase in bacterial number following the cold storage period, at 4.880 cfu/g^{-1}. For the interaction between the two experimental factors and the numbers of psychrophilic bacteria, no significant difference ($p < 0.05$) was observed in all treatments on the first day of storage, while the highest significant superiority ($p<0.05$) was for the interaction of the control with 12 days storage.

The results indicate that the best interaction occurred with T3 and T4, whereas the third-best interaction was observed at 1, 4, and 8 storage days. The fourth treatment, which had the longest storage period of 12 d, showed the most significant improvement ($p < 0.05$) compared to the others. This could be due to the action mechanisms of the active compounds in the walnut shells in replacing divalent ions at the binding site on the bacterial cell wall which causes an interaction between the positive charges of the active compounds and the negative charges on the cell wall of Gram-negative bacteria.

It can be said that this reaction clearly affects the cell membrane, leading to its destruction and increased permeability, which in turn leads to leakage of cell contents and ultimately cell death. The active compounds in walnut shells possess antimicrobial activity, giving them a positive role in improving the quality and preservation of poultry meat during refrigerated storage. This is achieved by maintaining meat moisture and reducing juice loss, which creates an environment unsuitable for the growth and activity of microbes, including chemotrophic bacteria. This, in turn, helps preserve the quality of stored meat and extends its shelf life (13).

Table 4. Effect of storage and packaging factors on the number of psychrophilic bacteria in chicken thigh wrapped in edible film fortified with walnut shell residue extract

Treatments	1 Day	4 Days	8 Days	12 Days	Average of treatments	Significance level
	3.713 h	4.435 ef	5.100 c	5.445 a	4.673 a	<.0001
	3.700 h	4.365 gf	4.847 d	5.232 b	4.536 b	
	3.682 h	4.361 gf	4.797 d	5.063 c	4.476 c	
	3.705 h	4.291 g	4.499 e	4.880 d	4.343 d	
	3.700 d	4.363 c	4.811 b	5.155 a	Significance level of interference	<.0001
		<.0001			Mean standard error	0.082

* Values are mean ± standard error.
**ΔC: no significant changes between treatments at the P ≤ 0.05 significance level.
***Significant changes between treatments at the P ≤ 0.05 significance level are indicated by different letters within the same row. T1 (control): uncoated leg of lamb; T2, T3, and T4: leg of lamb coated with dried walnut shell extract at 0.5, 1, and 1.5 g/coating mixture, respectively.

Table 5 on the sensory evaluation of the chicken thigh cuts, shows that the lack of packaging led to a noticeable deterioration in the sensory characteristics of the thigh cuts, while packaging enhanced all previously described features. The improvement in T4 was most pronounced in terms of color, flavor, texture, juiciness, and overall acceptability,

scoring 9.420, 8.980, 8.740, 8.600, and 8.000, respectively. The table also shows that edible films enriched with walnut shell extract preserved the microbiological and sensory properties of the tested samples, owing to their isolation capabilities, and reduced the total number of microbes responsible for food spoilage.

Further, the ability of coatings to reduce moisture loss contributes to improved meat characteristics, such as texture and juiciness, which in turn enhances other properties. This suggests that coatings improve sensory parameters, particularly flavor, thereby increasing customer acceptance (4,25). Uncoated chicken thigh pieces showed a marked decrease in sensory attributes due to moisture evaporation, shrinkage, and depletion of flavoring fluids, making them susceptible to microbial contamination and oxidation. This subsequently results in the loss of positive characteristics and reduced customer approval (31).

Table 5. Effect of the different treatments on the sensory evaluation of chicken thigh wrapped in edible film fortified with walnut shell residue extract

Treatment	Color	Flavor	Texture	Juiciness	Acceptance
T1	6.120 d	5.500 c	5.920 d	5.920 c	5.740 c
T2	6.820 c	6.240 c	6.660 c	6.960 b	6.040 c
T3	8.080 b	7.520 b	7.520 b	7.400 b	7.000 b
T4	9.420 a	8.980 a	8.740 a	8.600 a	8.000 a
Prob	<.0001	<.0001	<.0001	<.0001	<.0001
Total mean	7.61	7.06	7.21	7.22	6.695
SEM	0.300	0.326	0.257	0.234	0.217

Conclusion

This study examined the impact of enhancing edible packaging with 0.5, 1.0, and 1.5% walnut shell powder aqueous and alcoholic extracts on the microbiological and sensory quality of chicken thighs after 12 days refrigeration. The findings indicated that extraction method and solvent type directly influenced the extract's ability to inhibit Gram-negative and Gram-positive bacteria. The effect was also influenced by the concentration of the extract, with the alcoholic extract demonstrating superior inhibition of the target bacteria over the aqueous extract, and the 100% concentration being more efficient than a 50% concentration.

Moreover, the incorporation of 1.5% alcoholic walnut shell extract into chicken thigh casings significantly decreased bacterial proliferation and activity. This research demonstrated that applying 1.5% alcoholic extract of walnut shells to chicken thighs enhanced its sensory attributes and acceptability post-curing, resulting in superior ratings in color, flavor, texture, and overall acceptability. The control therapy did not attain these values. This research endorses Sustainable Development Goal 12 on responsible consumption and production practices.

Supplementary Materials
None.

Author Contributions
The published version of the work has been reviewed and approved by all authors.

Funding
This study did not receive any external funding.

Institutional Review Board Statement

The research was conducted according to the plan approved by the Iraqi Ministry of Higher Education and Scientific Research.

Informed Consent Statement
None.

Data Availability Statement
None.

Conflicts of Interest
The authors declare no conflict of interest in conducting this study.

Acknowledgments
The authors are grateful to the Food Sciences Department and the College Dean of the College of Agriculture at the University of Anbar, Iraq for their assistance.

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مقالة أصيلة

الأغشية الغذائية المضادة للميكروبات المصنوعة من مخلفات قشور الجوز: الاستخلاص، والتطبيق على الدجاج، وإطالة مدة الصلاحية

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الخلاصة بحثت الدراسة في آثار تدعيم الأغشية الصالحة للأكل بمستخلصات مائية وكحولية من مسحوق قشر الجوز بنسبة ٠.٥ و١.٠ و١.٥٪ على الجودة الميكروبية والحسية لقطع أفخاذ الدجاج بعد ١٢ يومًا من التخزين المبرد. أظهرت النتائج أن طريقة الاستخلاص ونوع المذيب كان لها تأثير واضح على قدرة المستخلص على تثبيط البكتيريا سالبة الجرام وموجبة الجرام. كما أثرت نسبة المستخلصات المضافة للغشاء على هذا التأثير. أكدت النتائج أن المستخلص الكحولي تمتع بقوة تثبيط أفضل من المستخلص المائي، بينما كان استخدام تركيز ١٠٠٪ من المستخلص الكحولي في تدعيم الأغشية أفضل من ٥٠٪ في تثبيط البكتيريا المستهدفة، فقد بلغ قطر clear zoon المتكونة حول الحفرة التي وُضع فيها ١٠٠٪ من المستخلص الكحولي ١٦.٤ و١٤.٩ و١٨.٩ و١٩.٥ ملم في الأطباق المزروعة ببكتيريا *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, and Bacillus subtilis* على التوالي. كذلك، أكدت النتائج أن إضافة ١.٥٪ من مستخلص كحولي إلى الأغشية أدى إلى انخفاض ملحوظ على نمو البكتيريا ونشاطها في قطعيات أفخاذ الدجاج المغلفة، فقد بلغ لوغاريتم Total coliform, and Psychrophilic bacteria بعد ١٢ يوم من التخزين المبرد ٦.٢٢ و٤.٠٤٢ و٤.٨٨٠ وحدة تكوين مستعمرة/جم-١. بينما ارتفعت الأعداد إلى ٨.٥١٦ و٥.٠١٥ و٥.٤٤٥ وحدة تكوين مستعمرة/جم-١ في المجموعة الضابطة. اشارت النتائج كذلك إلى أن تدعيم الأغشية بمستخلص كحولي من قشر الجوز بنسبة ١.٥٪ حَسَنَ الصفات الحسية والقبول العام لقطع أفخاذ الدجاج بعد التخزين، حيث بلغ اللون والنكهة والملمس والعصارة ٩.٤٢٠ و٨.٩٨٠ و٨.٧٤٠ و٨.٦٠٠ على التوالي. فيما بلغ التقبل العام ٨، أما المجموعة الضابطة، فقد انخفضت إلى ٦١٢٠، ٥٥٠٠، ٥٩٢٠، ٥٩٢٠، و٥٧٤٠.الكلمات المفتاحية: بقايا قشور الجوز، الاغشية الصالحة للأكل، التخزين المبرد، قطعيات أفخاذ الدجاج، الخصائص الحسية.

كلمات مفتاحية: بقايا المكسرات، الأغلفة الصالحة للأكل، التخزين المبرد، قطعيات فخذ الدجاج، الخصائص الحسية.

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