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Production of Value-Added Meat Patties by Addition of Pomegranate (*Punica granatum*) and Lemon (*Citrus limon*) Extracts

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Abstract

This study investigates the enhancement of quality and shelf stability in meat patties made from spent hen meat through the incorporation of natural extracts from pomegranate (Punica granatum) and lemon (Citrus limon). In response to growing consumer demand for natural ingredients, the research focuses on spoilage, texture, and flavor in meat products. Spent hen meat was selected due to its availability and potential for value addition. Meat cubes were treated with varying concentrations of the extracts and stored under refrigeration to facilitate the absorption of bioactive compounds. Results indicated that pomegranate and lemon extracts significantly improved sensory attributes, including flavor, tenderness, and juiciness, making the patties more appealing. Notably, pomegranate extracts reduced cooking loss, suggesting better moisture retention, whereas higher concentrations of lemon extract were associated with increased cooking loss. Both extracts demonstrated antimicrobial properties, potentially extending shelf life and enhancing nutritional profiles. This study underscores the potential of these extracts to improve the overall quality and safety of spent hen meat patties, aligning with consumer preferences for healthier, natural options. Future research should focus on identifying optimal extract concentrations to maximize benefits and ensure consumer acceptance.

Keywords: antioxidants, functional food, lemon extract, meat patties, nutritional profile, pomegranate extract, sensory properties, shelf life

Introduction

Predictions suggest that global meat production will nearly double by 2050. It is forecasted that from 2020 to 2049, beef, pork, and chicken meat production will increase by 0.7–1.9% annually, while poultry production growth is expected to be 1.6% during the same period. Poultry production is projected to rise in both developed and developing countries (Yin *et al*., 2024). The production of red meat accounts for 71% of greenhouse gas emissions from livestock, including carbon dioxide, methane, and nitrous oxide resulting from nitrogen application, agricultural soil use, and animal husbandry. Poultry contributes less than 10% of these emissions. With the world's growing population and the increasing demand for animal-based protein, particularly chicken due to its affordability, poultry consumption is expected to rise. Consumers are prioritizing their health and that of future generations, choosing meat from animals with a lower carbon footprint, free from contaminants and pollutants, and raised in a more sustainable manner (Forslund *et al*., 2023; Ivanovich *et al*., 2023). Therefore, synthetic compounds such as nitrites, nitrates, and different types of antioxidants have been used to maintain the quality and increase the shelf life of meat products. However, food safety authorities and consumers are increasingly concerned about the growing use of synthetic additives. In addition, studies have shown that some synthetic antioxidants can damage human health. Therefore, research on natural antioxidants has become increasingly important. Meat products are inherently sensitive to spoilage and relatively unstable by nature, as they are excellent substrates to support the growth of spoilage bacteria and pathogenic microorganisms (Asif *et al.*, 2024; Shiravani *et al.*, 2024). The maintenance of meat safety and quality is a significant challenge in the meat industry. It is important to develop and apply new methods to improve their safety and quality. The use of spent hen meat in food production is increasingly recognized for its potential benefits, especially in terms of sustainability and reducing waste in the poultry industry. Spent hens, which are older birds that are no longer productive for egg production, are a significant byproduct of poultry farming. Traditionally considered less suitable for direct consumption, these birds offer unique flavor profiles and textures that can be effectively enhanced through various culinary methods and processing techniques. For example, the incorporation of natural extracts can transform spent hen meat into value-added products. This not only addresses issues of food waste but also aligns with consumer preferences for healthier and more sustainable food options. Moreover, using hen meat in new food applications could contribute to improved nutritional profiles and overall product quality (Bodie *et al.*, 2024; Cava *et al.*, 2024).

The global demand for "green meat" (i.e., environmentally and health-friendly meat) is increasing due to heightened consumer awareness about health and the environmental impact of the meat industry. Consumers are also advocating for restrictions on growth-promoting factors in animal feeding. However, consumer taste preferences remain unchanged, and market forces are driving the need to address meat spoilage, disease mitigation, and other fresh meat requirements to ensure market access and cost-effective production of 'green meat' (Mohebalizadehgashti *et al.*, 2020). These demands can be met through the use of edible packaging and controlled-release coatings made from natural materials such as fruits and vegetables. Research will focus on utilizing the benefits of selected fruits and vegetables to create edible packaging, films, and coatings, as well as developing new technologies for preserving meat and meat products. The potent interactions between ingested fruit and vegetable antioxidants and the biochemical and health effects of nitrite, nitrate, iron, secondary lipid oxidation compounds, and chemically formed melanin need to be elaborated, as they will reflect not only on cancer risks but also on nitrosamine risk and color stability. Due to the complexity, the optimal antioxidant and antimicrobial activities should not be achieved via one or a few digestion-related pathways only. Nevertheless, fruits and vegetables can favorably enhance the color formation, retention, color uniformity, texture, and flavor of processed meats (Brynne *et al.*, 2020; Ford *et al.*, 2024).

During the last few decades, consumer focus on health and wellness has increased the demand for functional foods. Scientific evidence suggests that a diet rich in fruits and vegetables has preventive benefits, and antioxidants are recognized as compounds that protect cells from damage caused by oxidative stress. Consequently, consumer demand for natural antioxidants has increased, and the use of natural antioxidants to replace synthetic ones is rising. Animal products are particularly susceptible to oxidation, beginning when animals are transported and usually increasing exponentially a few days post-mortem. Natural antioxidants can be added to fresh meat, meat products, and animal diets to enhance color stability and inhibit lipid oxidation. Fruits, vegetables, plant extracts, juices, essential oils, herbs, spices, and marine algae can serve as natural antioxidant compounds (Ford *et al.*, 2024; Li *et al.*, 2024). The pomegranate is a tropical fruit used in food and traditional medicine due to its medicinal properties. Pomegranate juice is rich in antioxidant compounds such as tannins, flavonoids, and anthocyanins, and has been shown to have positive effects against chronic diseases. Lemons are known for their high levels of ascorbic acid (vitamin C) and flavonoids like hesperetin and naringenin, which act as antioxidants. A recent study compared two methods of lemon preparation and their potential benefits for reducing meat product oxidation. The bioactivity of pomegranate and lemon phenolics suggests their potential use as natural sources of phenolic compounds in functional meat product formulations (Figure 1). These functional ingredients could provide health benefits beyond basic nutrition. However, there is limited understanding of how to incorporate such extracts into meat formulations while maintaining consumer acceptability, which is an important aspect of developing this market opportunity (Begić *et al.*, 2024; Chauhan *et al.*, 2024).

This study aimed to investigate the utilization of pomegranate and lemon extracts as safe and effective functional ingredients in meat products. The present research examined the physicochemical and sensory properties, as well as the oxidative stability, of chicken patties formulated with two types of pomegranate extracts and lemon extracts. Selected patties were analyzed for pH, color stability, cooking loss, textural properties, free fatty acid content, Thiobarbituric acid reactive substances, antimicrobial activity, sensorial properties, and residual nitrite content.

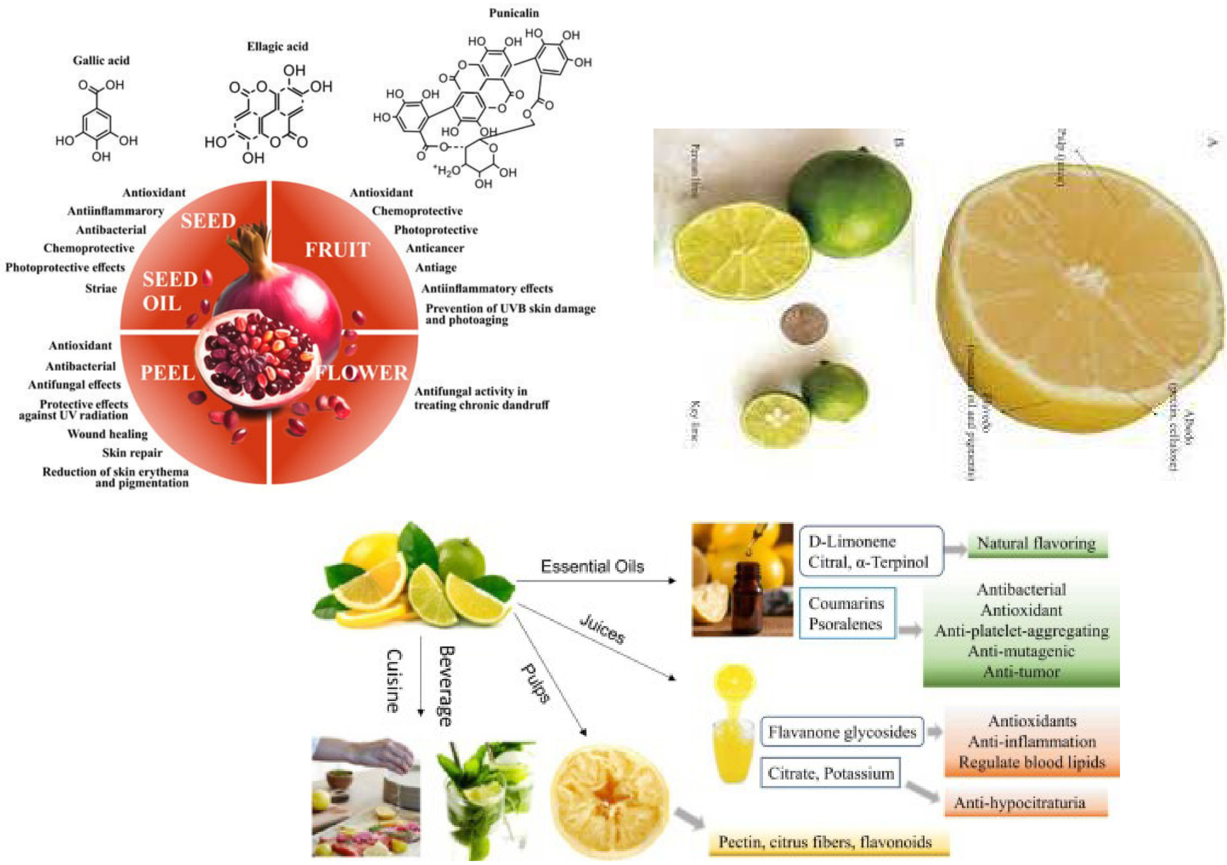

Figure 1. **Skin protection induced by *Punica granatum* and *Citrus limon*.**

Materials and Methods

Preparation of extracts

Fresh *Punica granatum* (Pomegranate) and *Citrus limon* (Lemon) leaves were sourced from a local market in Cairo, Egypt, and prepared as follows: The leaves were chopped and then blended for 1-2 minutes using an equal volume of distilled water. The blended pulp was filtered using muslin cloth to separate the solid parts from the liquid extract. The filtrates were collected and stored for use. These filtrates served as natural sources of antioxidants and antimicrobials during the production of chicken meat patties. Their inclusion aimed to enhance shelf life, improve safety, and maintain the quality of processed meat products by mitigating spoilage and oxidation. This preparation method ensures the extracts retain their bioactive compounds, which play a crucial role in preserving and enhancing the nutritional and sensory properties of the chicken patties.

Study design

To investigate the effect of *Punica granatum* (Pomegranate) and *Citrus limon* (Lemon) extracts, in different concentrations, and their combination, on the chemical composition, degradation indicators, and sensory properties of processed chicken meat patties, three independent experiments were conducted at different times to ensure reproducibility and consistency. Each experiment consisted of 3 samples for each analytical point to allow for statistical comparison.

I. **Treatments:**
   a. **Pomegranate Extracts:**
      i. 5% concentration.
      ii. 7% concentration.
   b. **Lemon Extracts:**
      i. 5% concentration.
      ii. 7% concentration.
   c. **Combined Treatment:**
      i. 5% Pomegranate + 5% Lemon extract.

II. **Parameters Assessed:**
   a. **Proximate Chemical Analysis:**
      Evaluate the moisture, protein, fat, and ash content to determine the impact of the extracts on the basic nutritional components of the chicken patties.
   b. **Degradation Parameters:**
      Analyze lipid oxidation, microbial growth, and pH changes to assess shelf-life stability and spoilage patterns.

III. **Sensory Attributes:**
Perform sensory evaluations (e.g., taste, texture, odor, color) to assess consumer acceptability and how the extracts influence sensory qualities like flavor, appearance, and overall appeal. This design allows for a comprehensive assessment of both the individual and combined effects of pomegranate and lemon extracts on improving the quality, extending shelf-life, and maintaining the sensory properties of chicken meat patties.

Preparation of spent hen meat patties ingredients

The preparation of spent hen meat patties followed a systematic approach to process the hens and utilize various functional ingredients. After acquiring ten white Leghorn hens, each weighing 4 kg, the carcasses were stored at 4ºC for 24 hours before separating the breast and thigh muscles. This cold storage helps maintain meat quality by minimizing microbial growth and preserving texture (Untari *et al.*, 2024; Wall *et al.*, 2024). The subsequent preparation involved trimming the muscle tissue to remove connective tissues and fat, ensuring a cleaner product. Cutting the muscle into 100 g cubes facilitates consistent mixing with the functional ingredients, which include common salt, starch, phosphate salt, and a seasoning mix sourced from local markets in Cairo. These ingredients are crucial for enhancing flavor, moisture retention, and overall texture in the final meat patty product (Untari *et al.*, 2024; Webster, 2000). Using phosphate salts, for example, is known to improve water-binding capacity and reduce cooking losses in meat products, which aligns with consumer expectations for juiciness and tenderness (Webster, 2000). Additionally, the incorporation of starch can contribute to the structural integrity of the patties, providing a better mouthfeel and preventing crumbling during cooking (Lindqvist *et al.*, 2002; Webster, 2000).

Immersion of spent chicken meat cubes in extract solutions

The spent chicken meat cubes were divided into six treatment groups, each immersed in different solutions for 24 hours at 4 °C in the refrigerator:

- Group 1: Immersed in 5% Pomegranate (Punica granatum) extract.
- Group 2: Immersed in 7% Pomegranate (Punica granatum) extract.
- Group 3: Immersed in 5% Lemon (Citrus limon) extract.
- Group 4: Immersed in 7% Lemon (Citrus limon) extract.
- Group 5: Immersed in a combination of 5% Pomegranate + 5% Lemon extracts.
- Group 6: Immersed in water only (no extracts).

Storage conditions

All groups were kept in the refrigerator at 4°C for 24 hours to allow the meat cubes to absorb the bioactive compounds from the extracts, enhancing their antioxidant and antimicrobial properties before being processed into patties. This pre-treatment with extracts is expected to improve the shelf life, sensory qualities, and safety of the spent hen meat patties by reducing spoilage and maintaining meat quality during storage.

Marination process

In this marination process, spent chicken meat cubes were marinated using extracts of *Punica granatum* (pomegranate) and *Citrus limon* (lemon) in different concentrations to assess the effects on flavor, texture, and microbial quality. The study included five groups of marinated meat, each with varying extract concentrations. All the meat groups, along with a control group (immersed in water), were refrigerated at 4°C for 24 hours. The use of natural extracts like pomegranate and lemon introduces antioxidant and antimicrobial properties, which help improve meat preservation while enhancing its flavor. *Punica granatum* is known for its phenolic compounds, while *Citrus limon* contributes citric acid and vitamin C, which help prevent microbial growth and lipid oxidation during storage. This process could potentially extend the shelf life and quality of the chicken meat.

Formulation, processing, and storage of spent hen meat patties

In preparing spent hen meat patties, marinated and untreated chicken meat (75%) is processed with added ingredients to enhance texture and flavor. The detailed steps are as follows: The spent chicken meat is minced using a grinder. For each group, the marinated or untreated minced meat is combined with 18% water, 1.5% salt, 0.3% polyphosphate (for moisture retention), 5% starch (to improve texture and binding), and 0.2% spices (for flavor). The mixture from each group is shaped into 80 g patties with a thickness of 1.5 cm using a patty mold. These patties are wrapped in plastic film. The patties are pre-frozen for 35 minutes at -40°C to rapidly solidify and maintain their structure. The frozen patties are then transferred to plastic bags and stored at -18°C for up to 3 months. Samples are taken at time zero (day 2 after preparation) and at monthly intervals for up to 3 months to assess the quality, microbial safety, and other parameters. This process ensures that the patties remain preserved while undergoing minimal quality degradation over time, making them suitable for longer-term frozen storage. Periodic sampling helps evaluate texture, flavor, and microbiological stability over the 3-month storage period.

Spent hen meat patties investigations measurement of the proximate chemical analysis

The proximate chemical analysis of spent hen meat patties involves determining key nutritional components, such as moisture, protein, fat, and ash content. These measurements help evaluate the quality and nutritional profile of the patties during storage. The following outlines how each component is typically measured:

1. **Moisture content:** This is measured to determine the water content of the patties. The patties are dried in an oven, and the loss in weight corresponds to the amount of water present.

2. **Protein content:** Determined using the Kjeldahl method (as outlined by the AOAC), this measures the nitrogen content in the patties, which is then converted to protein content based on a specific conversion factor.

3. **Fat content:** This is measured using solvent extraction methods, such as the Soxhlet method, which extracts fat from the patties using an organic solvent.

4. **Ash content**: Ash represents the total mineral content in the patties. This is measured by incinerating the patties at high temperatures (around 550°C) until all organic matter is burned off, leaving behind the ash.

These analyses are conducted following AOAC official methods, ensuring standardized and reliable results. The data from these measurements can be used to compare changes in nutritional quality over the storage period and across different treatment groups (treated and untreated).

Measurement of the deterioration criteria

The measurement of deterioration criteria in spent hen meat patties helps assess changes in quality and safety during frozen storage. The following parameters are typically evaluated.

pH measurement

The pH of meat is an indicator of freshness and quality. Changes in pH can affect the flavor, texture, and shelf life of the patties. pH is measured using a pH meter by homogenizing a meat sample in distilled water. A decrease in pH could indicate acid production from microbial activity, while an increase may suggest protein degradation.

Total volatile basic nitrogen (TVBN)

TVBN is a common indicator of spoilage in meat. It measures the levels of nitrogenous compounds such as ammonia and amines, which are produced by the breakdown of proteins during microbial spoilage. Higher TVBN levels correspond to greater spoilage. TVBN is determined using the Kjeldahl method or distillation procedures.

Thiobarbituric acid (TBA)

TBA is used to measure lipid oxidation, which leads to rancidity in meat products. The Thiobarbituric acid reactive substances (TBARS) assay is performed to detect malondialdehyde, a byproduct of fat oxidation. Higher TBA values indicate increased lipid oxidation, which can affect the flavor, odor, and overall quality of the patties.

These parameters are measured at zero time (initial measurement) and then monthly during frozen storage to track the patties' freshness and shelf-life stability. As storage progresses, an increase in TVBN and TBA values, along with shifts in pH, can indicate deterioration, signaling spoilage or reduced quality over time.

Sensory analysis

Sensory analysis involves assessing the quality and acceptability of food products based on the perceptions of trained panel members. In the case of the raw and cooked spent hen meat patties, the following protocol was used.

Raw patties evaluation

- **Panel Members**: A group of trained individuals from the Department of *(insert department name)* was selected to conduct the sensory evaluation.
- **Attributes Assessed**: The panelists evaluated the raw patties based on several key sensory attributes, including:
- **Appearance**: The visual appeal of the patties.
- **Color**: The color of the raw patties, an important indicator of freshness.

- **Aroma**: The smell of the patties, which can signal freshness or spoilage.
- **Consistency and Formation**: The texture and shape of the patties.
- **Margin**: The smoothness and definition of the patties' edges.
- **Overall Acceptability**: General impression of the product.

Each attribute was rated using a 9-point numerical scale, where higher scores represented more favorable characteristics.

Cooked patties evaluation

- **Cooking Method**: Five patties from each group were cooked in a hot air oven at 180°C until reaching a core temperature of 75°C, ensuring safe internal cooking.
- **Attributes Assessed**: After cooking, the patties were evaluated by the same panelists for.
- **Appearance**: Visual appeal after cooking.
- **Color**: The color after cooking, is an important indicator of doneness.
- **Flavor**: The overall taste, including any desirable or undesirable flavors.
- **Juiciness**: The perceived moisture content of the patties.
- **Overall Acceptability**: A general assessment of the patties' quality and taste.

Both the raw and cooked samples were rated using the same 9-point numerical scale to maintain consistency in evaluation. This approach helps in determining the effect of marination and storage on the sensory qualities of the patties, guiding product development and quality control decisions.

Measurement of cooking loss

To measure the cooking loss of chicken fillets:

After cooking the fillets in a hot air oven, they are removed and allowed to cool to room temperature.

The fillets are then reweighed to calculate the weight difference between the raw and cooked samples.

The percentage cooking loss is calculated using the following formula:

$$\text{Cooking Loss (\%)} = \left(\frac{\text{Weight before cooking} - \text{Weight after cooking}}{\text{Weight before cooking}}\right) \times 100$$

This method provides a quantitative assessment of the moisture and fat loss during cooking, which affects the texture and juiciness of the chicken fillets.

Statistical analysis

Statistical analysis for the investigation was performed using SPSS software. Data were expressed as mean ± standard error (SE). A two-way analysis of variance (ANOVA) was conducted to assess the interaction between different variables across groups. To identify significant differences between groups, the Least Significant Difference (LSD) test was applied. Statistical significance was considered at a P-value of less than 0.05, meaning that differences were deemed statistically significant if they fell within this threshold. This approach ensures a reliable interpretation of the data and the validity of the experimental results.

Results and Discussions

Proximate chemical analysis

Table 1 illustrates the impact of pomegranate (*Punica granatum*) and lemon (*Citrus limon*) extracts, both individually and in combination, on the moisture, protein, fat, and ash content of spent hen patties. Higher concentrations of lemon extract tend to increase protein content while reducing fat and ash content, leading to a healthier nutritional profile. The inclusion of these natural extracts significantly affects the proximate composition of the patties, with lemon extract concentrations showing the most pronounced effects. Notably, moisture content increases with higher lemon extract concentrations, particularly in the 7% lemon and combination groups, which helps retain water in the patties. Protein content reaches its peak at 19.17% with 7% lemon extract, suggesting that lemon may aid in preserving or enhancing protein levels during patty processing and storage. Fat content decreases as lemon extract concentration increases, highlighting its potential role in formulating lower-fat meat products. Ash content (indicating mineral content) decreases with higher lemon extract concentrations, especially in the combination group, suggesting a more refined or less mineral-dense profile. These compositional changes, driven by lemon's antioxidant and acidic properties, not only enhance the nutritional profile of the patties but may also contribute to better preservation and improved sensory qualities. The data in Table 1 underscore the significant effects of adding pomegranate (*Punica granatum*) and lemon (*Citrus limon*) extracts on the nutritional composition of spent hen patties. Research indicates that natural plant extracts, especially those rich in antioxidants, can influence the proximate composition of meat products. Lemon extract, which is high in ascorbic acid and citric acid, is known to help preserve moisture and protein content in meat, while also reducing fat content through its lipid-lowering properties. Studies confirm that the acidity and antioxidant properties of lemon can reduce lipid oxidation, leading to lower fat percentages in processed meats (Begić *et al*., 2024; Zimmermann & Gleichenhagen, 2011). Additionally, pomegranate extract, rich in polyphenols like ellagitannins, can positively impact protein retention and enhance the nutritional value of meat products by improving oxidative stability. The observed decrease in ash content with higher lemon extract concentrations may reflect the extract's role in reducing mineral content, potentially due to its action in binding and altering meat components during processing (Khalid *et al*., 2024; Sun *et al*., 2024).

These findings align with broader research on the use of plant-based extracts in meat preservation, which has shown that they can enhance not only the nutritional value but also the sensory properties of processed meat products.

Table 2 illustrates how the application of pomegranate and lemon extracts, either individually or in combination, impacts the pH values of frozen spent hen patties over three months of storage. As pH typically increases with protein degradation and microbial growth, the addition of these extracts helps mitigate this rise, contributing to better preservation. The pH values presented in Table 2 highlight the impact of pomegranate and lemon extracts on the acidity of spent hen patties during frozen storage. Over the 3 months, pH values increased slightly across all treatments, which is typical due to the gradual breakdown of proteins and the release of ammonia during storage. The control patties (without extracts) exhibited the highest initial pH (6.13) and experienced the largest increase, reaching 6.39 by the third month. This rise in pH could indicate the onset of spoilage-related chemical changes, such as protein breakdown and microbial activity. Both 5% and 7% concentrations showed lower initial pH values (5.73 and 5.48, respectively). This is likely due to the acidic nature of pomegranate's polyphenols, particularly ellagic acid. By the third month, pH values remained significantly lower in these groups compared to the control (6.21 for 5% and 6.13 for 7%), suggesting that pomegranate extract helped slow down the increase in pH and may have contributed to better preservation. The patties treated with lemon extract also showed lower pH values at the beginning of storage (6.01 for 5% and 6.00 for 7%). A lemon's citric acid content may explain its initial effect on lowering pH. By the third month, pH values for the lemon-treated groups were slightly higher than those for the pomegranate groups, but still lower than the control, indicating lemon extract's preservation effect. The patties treated with the combination of pomegranate and lemon extracts started with a pH of 5.87 and ended at 6.26 by the third month. The results show that combining both extracts led to a more controlled increase in pH, reflecting their complementary preservation properties, possibly due to the combined effects of polyphenols from pomegranate and citric acid from lemon.

In summary, pomegranate and lemon extracts—whether used individually or in combination—were effective in controlling the rise in pH, suggesting their role in improving the shelf life and quality of frozen meat products. These extracts have demonstrated efficacy in managing pH levels during the frozen storage of meat products, such as spent hen patties. The ability of pomegranate and lemon extracts to lower or slow the increase in pH is attributed to their natural acidic components—polyphenols like ellagic acid from pomegranate and citric acid from lemon. These compounds help inhibit microbial growth and protein degradation, which are common causes of pH rise during extended storage periods (Farhat *et al*., 2024; Kaderides *et al*., 2021). By stabilizing pH levels, the extracts contribute to enhanced preservation of frozen meat products by slowing spoilage processes. This preservation effect not only extends shelf life but also improves sensory qualities, such as

Table 1. Representing the proximate chemical analysis of spent hen patties treated with various concentrations of pomegranate and lemon extracts, as well as a mixture of both.

	Moisture (g%)	Protein (g%)	Fat (g%)	Ash (g%)
Control	$69.54^{c} \pm 0.06$	$15.53^{d} \pm 0.26$	$12.62^{a} \pm 0.19$	$2.28^{ab} \pm 0.05$
Pomegranate 5%	$69.77^{bc} \pm 0.18$	$17.73^{c} \pm 0.21$	$10.04^{b} \pm 0.02$	$2.44^{a} \pm 0.01$
Pomegranate 7%	$69.60^{bc} \pm 0.14$	$18.27^{b} \pm 0.09$	$9.64^{bc} \pm 0.31$	$2.46^{a} \pm 0.03$
Lemon 5%	$70.06^{ab} \pm 0.16$	$18.53^{ab} \pm 0.22$	$9.45^{cd} \pm 0.26$	$1.95^{bc} \pm 0.15$
Lemon 7%	$70.41^{a} \pm 0.13$	$19.17^{a} \pm 0.26$	$9.00^{d} \pm 0.01$	$1.42^{c} \pm 0.12$
Pomegranate 5% & Lemon 5%	$70.30^{a} \pm 0.12$	$18.74^{ab} \pm 0.24$	$9.07^{cd} \pm 0.08$	$1.63^{c} \pm 0.17$

$^{a–d}$Means with different superscripts within the same column are significantly different (P < 0.05 or P < 0.01). Values represent the mean ± SE.

Table 2. pH values of spent hen patties treated with Pomegranate (5 and 7%), Lemon (5 and 7%), and a mixture of Pomegranate (5%) and Lemon (5%) during frozen (–18 °C) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Control	$6.13^{a} \pm 0.03$	$6.24^{a} \pm 0.01$	$6.34^{a} \pm 0.01$	$6.39^{a} \pm 0.01$
Pomegranate 5%	$5.73^{d} \pm 0.06$	$5.91^{d} \pm 0.04$	$6.14^{d} \pm 0.01$	$6.21^{d} \pm 0.01$
Pomegranate 7%	$5.48^{e} \pm 0.01$	$5.73^{e} \pm 0.05$	$5.88^{e} \pm 0.02$	$6.13^{e} \pm 0.00$
Lemon 5%	$6.01^{b} \pm 0.04$	$6.08^{bc} \pm 0.00$	$6.19^{c} \pm 0.00$	$6.22^{cd} \pm 0.01$
Lemon 7%	$6.00^{b} \pm 0.02$	$6.06^{c} \pm 0.02$	$6.18^{c} \pm 0.00$	$6.24^{bc} \pm 0.02$
Pomegranate 5% & Lemon 5%	$5.87^{c} \pm 0.03$	$6.08^{bc} \pm 0.01$	$6.22^{b} \pm 0.01$	$6.26^{b} \pm 0.01$

[a–e]Different superscripts within the same column represent significant differences at $P < 0.05$ or $P < 0.01$. Values represent the mean ± SE.

taste and appearance, while maintaining the safety of the product (Li *et al.*, 2024). The natural acids, particularly polyphenols and citric acid, help reduce pH rise by inhibiting microbial activity and protein degradation that leads to spoilage in frozen storage (Untari *et al.*, 2024). Furthermore, lower pH levels act as a barrier to bacterial growth, ensuring that the product retains its integrity, flavor, and nutritional profile over time (Ford *et al.*, 2024). Thus, the application of natural extracts like pomegranate and lemon aligns with the growing consumer demand for cleaner, chemical-free preservation methods, offering both practical and health benefits in the food industry.

Table 3 highlights the changes in total volatile base nitrogen (TVB-N) values of spent hen patties treated with pomegranate and lemon extracts over a 3-month frozen storage period. TVB-N is an indicator of protein degradation and spoilage, as it measures the levels of nitrogenous compounds, such as ammonia, released during decomposition. The control patties showed a significant increase in TVB-N over time, rising from 2.62 mg% at 0-time to 12.08 mg% by the third month. This large increase reflects the typical spoilage process in untreated meat products. Patties treated with 5% and 7% pomegranate extract had initially higher TVB-N values (2.94 mg% and 3.25 mg%, respectively), but by the third month, these values increased to 14.08 mg% and 14.33 mg%, indicating spoilage but at a slightly higher rate compared to the control. Lemon-treated patties also showed an increase in TVB-N, from initial values of 3.89 mg% and 3.95 mg% to 14.18 mg% and 14.60 mg%, respectively. The lemon extract seemed to contribute more to controlling spoilage than pomegranate at lower concentrations but converged toward similar levels at higher concentrations. The patties treated with a combination of 5% pomegranate and 5% lemon started with 3.40 mg% TVB-N, increasing to 14.18 mg% by the third month. The combination of extracts did not show a substantial difference in controlling spoilage compared to using the extracts individually.

In summary, while both pomegranate and lemon extracts, either alone or in combination, contributed to delaying spoilage to some extent, the results indicate that these natural extracts were not highly effective in significantly reducing TVB-N values compared to the control group during extended frozen storage. Nevertheless, their use offers some benefits in slowing down the initial

Table 3. Total volatile base nitrogen (mg%) values of spent hen patties treated with Pomegranate (5% and 7%), Lemon (5% and 7%), and a mixture of Pomegranate (5%) and Lemon (5%) during frozen (-18 °C) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Control	$2.62^{d} \pm 0.14$	$3.86^{d} \pm 0.19$	$6.51^{b} \pm 0.20$	$12.08^{b} \pm 0.33$
Pomegranate 5%	$2.94^{cd} \pm 0.04$	$3.77^{cd} \pm 0.60$	$7.32^{ab} \pm 0.30$	$14.08^{a} \pm 0.96$
Pomegranate 7%	$3.25^{bc} \pm 0.16$	$4.63^{bc} \pm 0.31$	$7.58^{a} \pm 0.26$	$14.33^{a} \pm 0.88$
Lemon 5%	$3.89^{a} \pm 0.05$	$5.40^{ab} \pm 0.16$	$7.83^{a} \pm 0.43$	$14.18^{a} \pm 0.09$
Lemon 7%	$3.95^{a} \pm 0.03$	$5.81^{a} \pm 0.04$	$7.84^{a} \pm 0.12$	$14.60^{a} \pm 0.28$
Pomegranate 5% & Lemon 5%	$3.40^{b} \pm 0.21$	$5.16^{ab} \pm 0.01$	$7.51^{a} \pm 0.22$	$14.18^{a} \pm 0.60$

[a–d] Means with different superscripts within the same column significantly ($P < 0.05$ or $P < 0.01$) different Values represent the mean ± SE.

rate of spoilage, likely due to their antioxidant and antimicrobial properties (Brynne *et al.*, 2020; Forslund *et al.*, 2023; Lindqvist *et al.*, 2002). The findings regarding pomegranate and lemon extracts in delaying spoilage in spent hen patties align with existing research on the preservation effects of natural antioxidants. While these extracts demonstrated some effectiveness in slowing spoilage, they did not significantly reduce total volatile base nitrogen (TVB-N) values compared to the control group during extended frozen storage. Research has shown that pomegranate and lemon extracts possess antioxidant and antimicrobial properties, which can contribute to improving the shelf life of meat products. For example, pomegranate extracts, rich in polyphenols like ellagic acid, have been found to inhibit microbial growth and lipid oxidation, which are key factors in meat spoilage (Brynne *et al.*, 2020; Forslund *et al.*, 2023; Lindqvist *et al.*, 2002). Similarly, lemon extract's citric acid content is known to lower pH levels, which can help control microbial proliferation. While the use of these natural extracts offers benefits in terms of preserving meat quality and sensory attributes, they may not entirely prevent spoilage. Continued research is necessary to optimize concentrations and combinations of these extracts for better preservation efficacy (Begić *et al.*, 2024).

Table 4 presents the Thiobarbituric acid (TBA) values of spent hen patties treated with pomegranate and lemon extracts during frozen storage at −18 °C for three months. The control patties exhibited a significant increase in TBA values, starting at 0.26 mg/kg at 0-time and rising to 0.88 mg/kg by the third month. This increase suggests lipid oxidation, which is a common spoilage indicator in frozen meat products. The 5% concentration of pomegranate extract started at 0.10 mg/kg and reached 0.36 mg/kg by the end of the storage period. The 7% concentration showed even lower values, starting at 0.08 mg/kg and increasing to 0.33 mg/kg. These results indicate that pomegranate extracts effectively reduced lipid oxidation, likely due to their high antioxidant capacity attributed to polyphenolic compounds like ellagic acid. For the 5% lemon extract, TBA values began at 0.15 mg/kg and increased to 0.45 mg/kg over three months. The 7% lemon extract showed a similar trend, starting at 0.13 mg/kg and rising to 0.42 mg/kg. Although lemon extracts provided some antioxidant activity, they were less effective than pomegranate extracts in limiting lipid oxidation. The initial TBA value for this combination was the lowest at 0.07 mg/kg, which increased to 0.29 mg/kg by the third month. This suggests that the combination of extracts may have a synergistic effect on reducing lipid oxidation compared to the individual extracts. Pomegranate and lemon extracts effectively lowered Thiobarbituric acid (TBA) values, indicating their ability to enhance the oxidative stability and overall quality of frozen meat products. The superior antioxidant properties of pomegranate extract, attributed to its high content of polyphenols, played a significant role in mitigating lipid oxidation more effectively than lemon extract (Forslund *et al.*, 2023). Pomegranate extracts are known for their potent antioxidant capacity, primarily due to compounds such as ellagic acid, which can inhibit lipid peroxidation and improve meat quality during storage. Lemon extracts also exhibit antioxidant activity due to their citric acid content; however, they may not be as effective as pomegranate extracts in reducing lipid oxidation. Research shows that while lemon extracts can help preserve meat quality, their effects are generally less pronounced than those of pomegranate (Webster, 2000). Using a combination of pomegranate and lemon extracts could offer a complementary approach to preserving meat products, potentially enhancing their shelf life and sensory qualities through synergistic antioxidant effects (Forslund *et al.*, 2023; Khalid *et al.*, 2024). In conclusion, both pomegranate and lemon extracts were effective in lowering TBA values, indicating their potential to enhance the oxidative stability and quality of frozen meat products. The pomegranate extract demonstrated superior antioxidant properties, helping to mitigate lipid oxidation more effectively than lemon extract.

Table 4. Thiobarbituric acid (mg/kg) values of spent hen patties treated with Pomegranate (5% and 7%), Lemon (5% and 7%), and a mixture of Pomegranate (5%) and Lemon (5%) during frozen (–18 °C) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Control	$0.26^{a} \pm 0.02$	$0.38^{a} \pm 0.04$	$0.75^{a} \pm 0.01$	$0.88^{a} \pm 0.01$
Pomegranate 5%	$0.10^{bcd} \pm 0.01$	$0.14^{c} \pm 0.01$	$0.27^{c} \pm 0.01$	$0.36^{c} \pm 0.01$
Pomegranate 7%	$0.08^{cd} \pm 0.02$	$0.13^{c} \pm 0.01$	$0.22^{d} \pm 0.00$	$0.33^{cd} \pm 0.01$
Lemon 5%	$0.15^{b} \pm 0.01$	$0.26^{b} \pm 0.01$	$0.34^{b} \pm 0.01$	$0.45^{b} \pm 0.02$
Lemon 7%	$0.13^{bc} \pm 0.01$	$0.23^{b} \pm 0.01$	$0.30^{bc} \pm 0.02$	$0.42^{b} \pm 0.02$
Pomegranate 5% & Lemon 5%	$0.07^{d} \pm 0.00$	$0.13^{c} \pm 0.01$	$0.19^{d} \pm 0.02$	$0.29^{d} \pm 0.01$

$^{a–d}$Means with different superscripts within the same column significantly (P < 0.05 or P < 0.01) different Values represent the mean ± SE.

The purpose of the study was to assess the sensory characteristics (such as appearance, color, odor, consistency, firmness, and edge quality) of raw spent hen patties that were treated with different concentrations of pomegranate and lemon extracts and then stored at -18°C for three months (see Table 5). The patties treated with pomegranate consistently received the highest scores, indicating better visual appeal compared to the control, which showed a significant decline over the storage period. The lemon-treated samples had moderate scores, slightly better than the control but less than the pomegranate-treated ones. The color scores for the control group notably decreased over time, while the pomegranate treatments maintained higher scores throughout the study. The mixtures of extracts showed improved color retention compared to the patties treated with lemon extract alone. The pomegranate-treated samples consistently had strong, pleasant odors at all-time points, while the control samples showed a marked decrease in odor quality. The lemon-treated samples also had favorable odors but not as pronounced as those treated with pomegranate. Both pomegranate and lemon treatments demonstrated better consistency, scoring higher than the control. The 7% concentration of pomegranate was particularly effective. The pomegranate-treated samples received higher scores, indicating a superior ability to maintain structural integrity compared to the control. The control patties showed the lowest scores in this category, indicating poorer quality. Both pomegranate and lemon treatments fared better, with mixtures showing the highest scores (Bariya *et al.*, 2020; Ford *et al.*, 2024).

The results indicate that incorporating pomegranate and lemon extracts into raw spent hen patties significantly improves sensory qualities during frozen storage. Pomegranate extract, in particular, was effective in preserving appearance, color, and odor, contributing to overall product quality. This analysis can guide food scientists and manufacturers in utilizing natural preservatives to enhance the sensory properties and shelf life of poultry products. Incorporating pomegranate and lemon extracts into raw spent hen patties shows significant promise in enhancing sensory qualities during frozen storage (Asif *et al.*, 2024). Pomegranate has been noted for its antioxidant properties, which can improve the stability of meat products during storage. Research indicates that its inclusion can enhance sensory attributes such as color, flavor, and aroma, contributing to overall product quality (Zimmermann & Gleichenhagen, 2011). Lemon extract is also recognized for its preservative qualities, particularly its ability to inhibit microbial growth and maintain freshness. Studies have shown that citrus extracts can positively affect the sensory characteristics of meat products, providing enhanced flavor and aroma (Al Jumayi *et al.*, 2022; Allam *et al.*, 2024). The combination of pomegranate and lemon extracts can yield synergistic effects, further improving the sensory profile. Research suggests that mixtures of natural extracts often outperform individual components in preserving color and flavor during storage (Allam, 2023). These findings can serve as valuable guidelines for food scientists and manufacturers looking to utilize natural preservatives effectively. By enhancing the sensory properties and extending the shelf life of poultry products, such practices align with consumer demand for cleaner, more natural food options. The sensory analysis data presented in Table 6 illustrates the effects of different treatments on the sensory qualities of cooked spent hen patties during frozen storage at -18 °C over a period of three months (Table 6). Pomegranate extracts (5% and 7%) and the mixture of Pomegranate (5%) and Lemon (5%) consistently received the highest scores throughout the storage period, indicating excellent appearance retention. The Control group showed a significant decline in appearance from 6.33 to 3.67 over three months. Similar trends were observed in color, where Pomegranate (5%) and Pomegranate (7%) maintained higher scores (8.67 and 8.33, respectively), whereas the Control group dropped from 6.00 to 3.33.

Flavor ratings were also highest for the Pomegranate and Lemon treatments, with the Control group significantly lower, showing a decline from 4.67 to 2.33. Tenderness scores were maintained well in treatments with Pomegranate and Lemon. The Control group had the lowest scores, decreasing from 4.67 to 2.33. Juiciness was notably higher in the treated groups, especially with Pomegranate (7%), which started at 9.00 and remained at 8.00 after three months, contrasting with the Control group's decline from 4.33 to 2.67. The overall acceptability ratings favored the treatments, with Pomegranate (5%) & Lemon (5%) achieving the highest mean scores (9.00 at 0-time and 8.00 at 3 months). The Control group displayed a significant drop from 4.67 to 3.00. The incorporation of pomegranate and lemon extracts into cooked spent hen patties has been shown to significantly enhance their sensory attributes during frozen storage. These extracts not only improve the appearance, color, flavor, tenderness, and juiciness of the patties but also contribute to their overall acceptability. This suggests that they could serve as effective natural preservatives, potentially extending product shelf life while meeting consumer preferences for natural ingredients (Abdallah *et al.*, 2019; Al Jumayi *et al.*, 2022; Allam, 2023). Research supports the use of pomegranate extracts in meat products to improve quality and safety. Also, studies have indicated that pomegranate extract can enhance oxidative stability and flavor profiles in meat, as noted by Abdallah *et al.* (2019). Additionally, the antioxidant properties of these extracts are beneficial in preserving the quality of perishable foods, making them appealing choices for food manufacturers looking to innovate with clean-label

Table 5. Sensory analysis of raw spent hen patties treated with pomegranate (5% and 7%), lemon (5% and 7%), and a mixture of pomegranate (5%) and lemon (5%) during frozen (–18 °c) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Appearance				
Control	$6.67^{b} \pm 0.33$	$5.33^{c} \pm 0.67$	$4.67^{c} \pm 0.33$	$4.00^{c} \pm 0.00$
Pomegranate 5%	$8.67^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Pomegranate 7%	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 5%	$7.33^{b} \pm 0.33$	$7.00^{ab} \pm 0.00$	$6.33^{b} \pm 0.33$	$6.00^{b} \pm 0.58$
Lemon 7%	$7.00^{b} \pm 0.00$	$6.67^{b} \pm 0.33$	$6.00^{b} \pm 0.00$	$5.67^{b} \pm 0.33$
Pomegranate 5% & Lemon 5%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Color				
Control	$5.67^{c} \pm 0.33$	$4.33^{c} \pm 0.33$	$3.67^{c} \pm 0.33$	$2.67^{d} \pm 0.33$
Pomegranate 5%	$8.33^{a} \pm 0.33$	$7.67^{ab} \pm 0.33$	$7.33^{ab} \pm 0.33$	$7.00^{ab} \pm 0.58$
Pomegranate 7%	$8.00^{ab} \pm 0.00$	$7.67^{ab} \pm 0.33$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 5%	$7.33^{b} \pm 0.33$	$7.00^{b} \pm 0.00$	$6.33^{b} \pm 0.33$	$5.67^{c} \pm 0.33$
Lemon 7%	$7.33^{b} \pm 0.33$	$7.00^{b} \pm 0.00$	$6.33^{b} \pm 0.33$	$6.00^{bc} \pm 0.00$
Pomegranate 5% & Lemon 5%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$
Odor				
Control	$4.33^{b} \pm 0.33$	$3.67^{b} \pm 0.33$	$3.00^{b} \pm 0.58$	$2.67^{b} \pm 0.33$
Pomegranate 5%	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Pomegranate 7%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$	$7.67^{a} \pm 0.33$
Lemon 5%	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.33^{a} \pm 0.33$	$7.00^{a} \pm 0.58$
Lemon 7%	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.00$	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$
Consistency				
Control	$4.33^{c} \pm 0.33$	$3.33^{c} \pm 0.33$	$3.00^{d} \pm 0.00$	$2.33^{c} \pm 0.33$
Pomegranate 5%	$8.33^{ab} \pm 0.33$	$8.00^{a} \pm 0.20$	$7.67^{ab} \pm 0.33$	$7.33^{ab} \pm 0.33$
Pomegranate 7%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$
Lemon 5%	$8.00^{ab} \pm 0.33$	$7.33^{b} \pm 0.33$	$7.00^{bc} \pm 0.00$	$6.67^{b} \pm 0.33$
Lemon 7%	$7.67^{b} \pm 0.33$	$7.00^{b} \pm 0.00$	$6.67^{c} \pm 0.33$	$6.33^{b} \pm 0.33$
Pomegranate 5% & Lemon 5%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$
Forming				
Control	$7.67^{bc} \pm 0.33$	$7.00^{ab} \pm 0.00$	$6.33^{c} \pm 0.33$	$6.00^{b} \pm 0.58$
Pomegranate 5%	$8.33^{ab} \pm 0.33$	$8.00^{a} \pm 0.58$	$7.67^{ab} \pm 0.33$	$7.33^{a} \pm 0.33$
Pomegranate 7%	$8.33^{ab} \pm 0.33$	$7.67^{ab} \pm 0.33$	$7.67^{ab} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 5%	$7.33^{c} \pm 0.33$	$7.00^{ab} \pm 0.58$	$6.67^{bc} \pm 0.33$	$6.67^{ab} \pm 0.33$
Lemon 7%	$7.00^{c} \pm 0.00$	$6.67^{b} \pm 0.33$	$6.00^{c} \pm 0.58$	$6.00^{b} \pm 0.00$
Pomegranate 5% & Lemon 5%	$8.67^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$
Fringe				
Control	$7.00^{c} \pm 0.00$	$6.67^{b} \pm 0.33$	$5.67^{b} \pm 0.33$	$5.33^{b} \pm 0.33$
Pomegranate 5%	$8.00^{b} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Pomegranate 7%	$8.00^{b} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 5%	$6.67^{c} \pm 0.33$	$6.33^{b} \pm 0.33$	$6.33^{b} \pm 0.33$	$6.00^{b} \pm 0.58$
Lemon 7%	$6.67^{c} \pm 0.33$	$6.00^{b} \pm 0.00$	$6.00^{b} \pm 0.00$	$5.67^{b} \pm 0.33$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.00$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.33^{a} \pm 0.33$
Overall-acceptability				
Control	$5.00^{c} \pm 0.58$	$4.00^{d} \pm 0.58$	$3.67^{d} \pm 0.67$	$3.33^{d} \pm 0.33$
Pomegranate 5%	$8.33^{ab} \pm 0.33$	$7.67^{ab} \pm 0.33$	$7.33^{ab} \pm 0.33$	$7.00^{ab} \pm 0.00$
Pomegranate 7%	$8.00^{ab} \pm 0.58$	$8.00^{ab} \pm 0.58$	$7.67^{ab} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 5%	$7.67^{ab} \pm 0.33$	$7.00^{bc} \pm 0.00$	$6.67^{bc} \pm 0.33$	$6.33^{b} \pm 0.33$
Lemon 7%	$7.00^{b} \pm 0.58$	$6.00^{c} \pm 0.00$	$5.67^{c} \pm 0.33$	$5.33^{c} \pm 0.33$

a–d Means with different superscripts within the same column significantly (P < 0.05) different Values represent the mean ± SE.

Table 6. Sensory analysis of cooked spent hen patties treated with Pomegranate (5 and 7%), Lemon (5 and 7%), and a mixture of Pomegranate (5%) and Lemon (5%) during frozen (–18 °C) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Appearance				
Control	$6.33^{c} \pm 0.33$	$5.00^{c} \pm 0.58$	$4.33^{c} \pm 0.33$	$3.67^{c} \pm 0.33$
Pomegranate 5%	$9.00^{a} \pm 0.00$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$	$7.67^{a} \pm 0.33$
Pomegranate 7%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$	$7.67^{a} \pm 0.33$
Lemon 5%	$7.67^{b} \pm 0.33$	$7.33^{ab} \pm 0.33$	$6.67^{ab} \pm 0.33$	$6.33^{b} \pm 0.33$
Lemon 7%	$7.33^{b} \pm 0.33$	$7.00^{b} \pm 0.00$	$6.33^{b} \pm 0.33$	$6.00^{b} \pm 0.00$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.00$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$	$7.67^{a} \pm 0.33$
Color				
Control	$6.00^{c} \pm 0.00$	$4.67^{b} \pm 0.33$	$4.00^{c} \pm 0.00$	$3.33^{c} \pm 0.33$
Pomegranate 5%	$8.67^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Pomegranate 7%	$8.33^{ab} \pm 0.33$	$8.00^{a} \pm 0.00$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$
Lemon 5%	$7.67^{b} \pm 0.33$	$7.33^{a} \pm 0.33$	$6.67^{b} \pm 0.33$	$6.00^{b} \pm 0.00$
Lemon 7%	$7.67^{b} \pm 0.33$	$7.33^{a} \pm 0.33$	$6.67^{b} \pm 0.33$	$6.00^{b} \pm 0.00$
Pomegranate 5% & Lemon 5%	$8.33^{ab} \pm 0.33$	$8.00^{a} \pm 0.00$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$
Flavor				
Control	$4.67^{b} \pm 0.33$	$3.33^{b} \pm 0.33$	$2.67^{b} \pm 0.33$	$2.33^{b} \pm 0.33$
Pomegranate 5%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$	$7.67^{a} \pm 0.33$
Pomegranate 7%	$8.67^{a} \pm 0.33$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$
Lemon 5%	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$7.67^{a} \pm 0.33$	$7.33^{a} \pm 0.33$
Lemon 7%	$8.67^{a} \pm 0.33$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.58$
Pomegranate 5% & Lemon 5%	$8.67^{a} \pm 0.33$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.33^{a} \pm 0.33$
Tenderness				
Control	$4.67^{c} \pm 0.33$	$3.67^{c} \pm 0.33$	$3.33^{d} \pm 0.33$	$2.33^{d} \pm 0.33$
Pomegranate 5%	$8.67^{ab} \pm 0.33$	$8.33^{ab} \pm 0.33$	$8.00^{ab} \pm 0.00$	$7.67^{ab} \pm 0.33$
Pomegranate 7%	$9.00^{a} \pm 0.00$	$8.67^{a} \pm 0.33$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$
Lemon 5%	$8.33^{ab} \pm 0.33$	$7.67^{ab} \pm 0.33$	$7.33^{bc} \pm 0.33$	$7.00^{bc} \pm 0.00$
Lemon 7%	$8.00^{b} \pm 0.00$	$7.33^{b} \pm 0.33$	$7.00^{c} \pm 0.00$	$6.67^{c} \pm 0.33$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.00$	$8.67^{a} \pm 0.33$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$
Juiciness				
Control	$4.33^{c} \pm 0.33$	$3.33^{e} \pm 0.33$	$3.00^{d} \pm 0.00$	$2.67^{d} \pm 0.33$
Pomegranate 5%	$8.33^{a} \pm 0.33$	$8.00^{bc} \pm 0.00$	$7.67^{ab} \pm 0.33$	$7.33^{ab} \pm 0.33$
Pomegranate 7%	$9.00^{a} \pm 0.33$	$8.67^{ab} \pm 0.33$	$8.00^{a} \pm 0.58$	$8.00^{a} \pm 0.58$
Lemon 5%	$7.67^{b} \pm 0.33$	$7.33^{cd} \pm 0.33$	$6.67^{bc} \pm 0.33$	$6.33^{bc} \pm 0.33$
Lemon 7%	$7.33^{b} \pm 0.33$	$6.67^{d} \pm 0.33$	$6.33^{c} \pm 0.33$	$6.00^{c} \pm 0.00$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.33$	$9.00^{a} \pm 0.00$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$
Overall-acceptability				
Control	$4.67^{c} \pm 0.33$	$3.67^{d} \pm 0.33$	$3.33^{d} \pm 0.33$	$3.00^{d} \pm 0.00$
Pomegranate 5%	$8.67^{a} \pm 0.33$	$8.00^{ab} \pm 0.00$	$7.67^{ab} \pm 0.33$	$7.33^{ab} \pm 0.33$
Pomegranate 7%	$8.67^{a} \pm 0.33$	$8.33^{ab} \pm 0.33$	$8.00^{ab} \pm 0.00$	$7.67^{ab} \pm 0.33$
Lemon 5%	$8.33^{ab} \pm 0.33$	$7.67^{b} \pm 0.33$	$7.33^{b} \pm 0.33$	$7.00^{b} \pm 0.00$
Lemon 7%	$7.67^{b} \pm 0.33$	$6.67^{c} \pm 0.33$	$6.00^{c} \pm 0.00$	$5.67^{c} \pm 0.33$
Pomegranate 5% & Lemon 5%	$9.00^{a} \pm 0.00$	$8.67^{a} \pm 0.33$	$8.33^{a} \pm 0.33$	$8.00^{a} \pm 0.00$

$^{a–e}$Means with different superscripts within the same row for each parameter are significantly ($P < 0.05$) different. Values represent the mean of 3 independent replicates± SE.

products. Using natural preservatives like pomegranate and lemon extracts not only enhances the product's sensory qualities but also aligns with consumer preferences for clean-label ingredients. The antioxidant properties of these extracts help preserve food quality, potentially extending shelf life while maintaining taste and freshness (Amalraj *et al.*, 2022). The incorporation of pomegranate and lemon extracts effectively enhances the sensory attributes of cooked spent hen patties during frozen storage, demonstrating potential as natural preservatives. These findings suggest that food scientists and manufacturers can utilize such extracts to improve product quality and shelf life, appealing to consumer preferences for natural ingredients (Amalraj *et al.*, 2022). Table (7) highlights the importance of selecting appropriate natural preservatives to optimize product quality and minimize cooking loss. The control group exhibited the lowest cooking loss percentages throughout the storage period, while patties treated with lemon extract (both 5% and 7%) showed the highest cooking loss, indicating greater moisture loss. The treatment with 5% and 7% pomegranate extracts resulted in moderate cooking loss, which was significantly lower than that observed with lemon extracts. The mixture of 5% pomegranate and 5% lemon extracts displayed a cooking loss percentage that was significantly higher than the control but lower than that of the lemon-only treatments. Means with different superscripts within the same column (a-e) are significantly different ($P < 0.05$). Values represent mean ± SE. These findings suggest that while pomegranate extract can help reduce cooking losses, lemon extract might contribute to higher moisture loss, potentially affecting the overall quality and acceptability of the patties during storage.

The data highlights the importance of selecting appropriate natural preservatives to optimize product quality and minimize cooking loss (Amalraj *et al.*, 2022). Research has shown that natural extracts like pomegranate and lemon can have varying effects on meat products. For instance, pomegranate extract is noted for its antioxidant properties and ability to enhance the shelf life and sensory qualities of meat products by reducing cooking losses (Amaral *et al.*, 2019). Conversely, lemon extract, rich in citric acid, has been associated with increased moisture loss due to its acidic nature, which can affect texture and juiciness (Amaral *et al.*, 2019). These findings suggest that while pomegranate extract can help reduce cooking losses, lemon extract might contribute to higher moisture loss, potentially affecting the overall quality and acceptability of the patties during storage. Ultimately, selecting the right combination of natural preservatives is crucial for enhancing the quality and shelf stability of meat products while catering to consumer preferences for natural ingredients. Research has demonstrated that various natural extracts can offer significant benefits in this regard (Beatriz Nunes *et al.*, 2023; Brynne *et al.*, 2020; Chunzhi *et al.*, 2018). Pomegranate extract has been recognized for its potent antioxidant properties, which can reduce oxidation and cooking losses in meat, thereby improving sensory attributes and extending shelf life (Chunzhi *et al.*, 2018). On the other hand, while lemon extract can provide antimicrobial effects and improve flavor, it may also lead to increased moisture loss due to its acidic nature, potentially affecting the texture and juiciness of the product (El Sheikha *et al.*, 2022). Therefore, a balanced approach in choosing natural preservatives, considering both their benefits and limitations, is essential for optimizing meat product quality. This strategic selection not only enhances the product's acceptability but also aligns with consumer trends toward healthier and more natural food options.

Conclusions

This study investigates the potential of enhancing the quality and shelf stability of meat patties made from spent hen meat through the incorporation of

Table 7. Cooking loss percentage of spent hen patties treated with Pomegranate (5 and 7%), Lemon (5 and 7%), and a mixture of Pomegranate (5%) and Lemon (5%) during frozen (–18 °C) storage for 3 months.

Treatments	Storage period (months)			
	0-time	1st month	2nd month	3rd month
Control	13.85^{c} ± 0.67	17.25^{d} ± 0.21	20.11^{e} ± 0.35	27.96^{d} ± 0.41
Pomegranate 5%	14.18^{bc} ± 0.67	19.47^{c} ± 0.30	23.75^{d} ± 0.57	31.53^{c} ± 0.37
Pomegranate 7%	15.51^{bc} ± 0.34	22.47^{b} ± 0.91	25.08^{cd} ± 0.30	33.86^{b} ± 0.52
Lemon 5%	20.67^{a} ± 0.72	26.14^{a} ± 0.49	27.08^{b} ± 0.30	36.26^{a} ± 0.31
Lemon 7%	22.34^{a} ± 1.05	27.35^{a} ± 0.60	28.68^{a} ± 0.49	37.04^{a} ± 0.27
Pomegranate 5% & Lemon 5%	16.18^{b} ± 0.26	23.14^{b} ± 0.69	25.75^{bc} ± 0.53	34.53^{b} ± 0.27

[a–e]Means with different superscripts within the same column significantly ($P < 0.05$) different Values represent the mean ± SE.

natural extracts from pomegranate (Punica granatum) and lemon (Citrus limon). Given the growing consumer preference for natural ingredients, this research aims to address issues related to spoilage, texture, and flavor in meat products. Spent hen meat was selected due to its availability and potential for value addition. The meat cubes were treated with varying concentrations of pomegranate and lemon extracts and stored under refrigeration to allow for the absorption of bioactive compounds. The effects of these extracts on the sensory attributes, cooking loss, and overall acceptability of the patties were evaluated. The addition of pomegranate and lemon extracts significantly improved the sensory qualities of the patties, including flavor, tenderness, and juiciness. The organoleptic properties were enhanced, making the product more appealing to consumers. Results indicated a reduction in cooking loss for patties treated with pomegranate extracts, suggesting that these extracts help retain moisture during cooking. Conversely, higher concentrations of lemon extract were associated with increased cooking loss, which may affect the overall quality and acceptability of the product. The natural antioxidants present in both extracts exhibited antimicrobial properties that potentially extend the shelf life of the patties. This is particularly relevant in the context of food safety and quality preservation. Incorporating these extracts not only enhances flavor and texture but also boosts the nutritional profile of the meat patties, adding functional benefits associated with antioxidants.

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Conflict of Interest

The authors declare no conflict of interest.

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References

Abdallah, N., Ahlan, A.R., Abdullah, O.A. (2019). The role of quality factors on learning management systems adoption from instructors' perspectives. The Online Journal of Distance Education and e-Learning, 7(2), 133.

Al Jumayi, H.A., Allam, A.Y., El-Beltagy, A.E.-D., Algarni, E.H., Mahmoud, S.F., El Halim Kandil, A.A. (2022). Bioactive compound, antioxidant, and radical scavenging activity of some plant aqueous extracts for enhancing shelf life of cold-stored rabbit meat. Antioxidants, 11(6), 1056. https://doi.org/10.3390/antiox11061056

Allam, A.Y. (2023). Effect of addition loquat (eribotrya japonica) seed powder extract as a natural bioactive compound on the quality characteristics of goat meat nuggets during refrigerated storage–Part I. Journal of Food and Dairy Sciences, 14(3), 51–62. https://doi.org/10.21608/jfds.2023.192707.1099

Allam, A.Y., Elsadek, M.F., Al-Numair, K.S., Badr, A.A.A., Singh, S., Elkabary, M.R. (2024). Antioxidant and antibacterial effect of lemon verbena leaves'(Lippia citriodora) extract as a natural preservative on refrigerated meat patties during storage. Italian Journal of Food Science, 36(3), 95. https://doi.org/10.15586/ijfs.v36i3.2514

Amalraj, A., Kuttappan, S., AC, K.V., Matharu, A. (2022). Herbs, Spices and Their Roles in Nutraceuticals and Functional Foods. Elsevier. pp. 95–109. https://doi.org/10.1016/B978-0-323-90794-1.00016-8

Amaral, D.S.d., Cardelle-Cobas, A., Dias, C.d.C.Q., Lima, D.A.S., Pereira, S.d.F., Arcanjo, N.M.d.O., Dalmas, P.S., Madruga, M.S., Pintado, M.M.E. (2019). Low fat goat meat sausage with chitosan-glucose Maillard reaction product: impact on quality and shelf life. Food Science and Technology, 40, 132–139. https://doi.org/10.1590/fst.34018

Asif, A., Ibrahim, F., Ansari, A. (2024). A Systematic Review: Effectiveness of Herbs and Spices as Natural Preservatives to Enhance Meat Shelf-Life: Herbs and Spices as Natural Preservatives. Journal of Health and Rehabilitation Research, 4(3), 1–7. https://doi.org/10.61919/jhrr.v4i3.1419

Bariya, A., Patel, A., Joshi, A. (2020). Application of natural antioxidants from vegetables, plant and fruits origin into meat and meat products-A review. Journal of Meat Science and Technology| January-March, 8(1), 12–22.

Beatriz Nunes, S., Cadavez, V., Caleja, C., Pereira, E., Calhelha, R.C., Añibarro-Ortega, M., Finimundy, T., Kostić, M., Soković, M., Teixeira, J.A. (2023). Phytochemical composition and bioactive potential of Melissa officinalis L., Salvia officinalis L. and Mentha spicata L. extracts. Foods, 12(5), 947. https://doi.org/10.3390/foods12050947

Begić, M., Huremović, J., Selović, A., Karadža, A. (2024). The effect of ascorbic acid and lemon juice on the extraction of metals from green tea, health risk assessment. Toxin Reviews, 43(1), 118–126. https://doi.org/10.1080/15569543.2023.2298930

Bodie, A.R., Wythe, L.A., Dittoe, D.K., Rothrock Jr, M.J., O'Bryan, C.A., Ricke, S.C. (2024). Alternative additives for organic and natural ready-to-eat meats to control spoilage and maintain shelf life: current perspectives in the united states. Foods, 13(3), 464. https://doi.org/10.3390/foods13030464

Brynne, A., Katz-Rosene, R., Martin, S.J. (2020). The structural constraints on green meat. Green Meat?: Sustaining Eaters, Animals, and the Planet, 185–205. https://doi.org/10.1515/9780228002710-012

Cava, R., Ladero, L., Riaguas, E., Vidal-Aragón, M.C. (2024). Assessing the Impact of Pomegranate Peel Extract Active

Packaging and High Hydrostatic Pressure Processing on Color and Oxidative Stability in Sliced Nitrate/Nitrite-Reduced Iberian Dry-Cured Loins. Foods, 13(3), 360. https://doi.org/10.3390/foods13030360

Chauhan, N., Khulbe, P., Sen, P., Gupta, M. (2024). Potentials of berries and pomegranate in management of the neurodegenerative disorders. in: Nutraceutical Fruits and Foods for Neurodegenerative Disorders, Elsevier, pp. 277–300. https://doi.org/10.1016/B978-0-443-18951-7.00017-7

Chunzhi, C., Anton, A., Duarte, C.M., Agusti, S. (2018). Macroalgae as Blue Carbon Reservoirs and Bioindicators of Metal Pollution in the Saudi Arabian Red Sea: A Comparative Study of Coral Reef and Seagrass Meadow Habitats. Available at SSRN 4860701.

El Sheikha, A.F., Allam, A.Y., ElObeid, T., Basiouny, E.A., Abdelaal, A.A., Amarowicz, R., Oz, E., Proestos, C., Karrar, E., Oz, F. (2022). Impact of a carboxymethyl cellulose coating incorporated with an ethanolic propolis extract on the quality criteria of chicken breast meat. Antioxidants, 11(6), 1191. https://doi.org/10.3390/antiox11061191

Farhat, G., Cheng, L., Al-Dujaili, E.A., Zubko, M. (2024). Antimicrobial potential of pomegranate and lemon extracts alone or in combination with antibiotics against pathogens. International Journal of Molecular Sciences, 25(13), 6943. https://doi.org/10.3390/ijms25136943

Ford, H., Zhang, Y., Gould, J., Danner, L., Bastian, S.E., Yang, Q. (2024). Comparing motivations and barriers to reduce meat and adopt protein alternatives amongst meat-eaters in Australia, China and the UK. Food Quality and Preference, 118, 105208. https://doi.org/10.1016/j.foodqual.2024.105208

Forslund, A., Tibi, A., Schmitt, B., Marajo-Petitzon, E., Debaeke, P., Durand, J.-L., Faverdin, P., Guyomard, H. (2023). Can healthy diets be achieved worldwide in (2050) without farmland expansion? Global Food Security, 39, 100711. https://doi.org/10.1016/j.gfs.2023.100711

Ivanovich, C.C., Sun, T., Gordon, D.R., Ocko, I.B. (2023). Future warming from global food consumption. Nature Climate Change, 13(3), 297–302. https://doi.org/10.1038/s41558-023-01605-8

Kaderides, K., Kyriakoudi, A., Mourtzinos, I., Goula, A.M. (2021). Potential of pomegranate peel extract as a natural additive in foods. Trends in Food Science & Technology, 115, 380–390. https://doi.org/10.1016/j.tifs.2021.06.050

Khalid, S.A., Ghanem, A.F., Abd-El-Malek, A., Ammar, M.A., El-Khateib, T., El-Sherbiny, I.M. (2024). Free-standing carboxymethyl cellulose film incorporating nanoformulated pomegranate extract for meat packaging. Carbohydrate Polymers, 332, 121915. https://doi.org/10.1016/j.carbpol.2024.121915

Li, H., Hu, S., Tong, H. (2024). Carbon footprint of household meat consumption in China: A life-cycle-based perspective. Applied Geography, 169, 103325. https://doi.org/10.1016/j.apgeog.2024.103325

Lindqvist, C., Schütz, K., Jensen, P. (2002). Red jungle fowl have more contrafreeloading than white leghorn layers: Effect of food deprivation and consequences for information gain. Behaviour, 139(9), 1195–1209. https://doi.org/10.1163/15685390260437335

Mohebalizadehgashti, F., Zolfagharinia, H., Amin, S.H. (2020). Designing a green meat supply chain network: A multi-objective approach. International Journal of Production Economics, 219, 312–327. https://doi.org/10.1016/j.ijpe.2019.07.007

Shiravani, Z., Aliakbarlu, J., Moradi, M. (2024). Application of bacterial nanocellulose film loaded with sodium nitrite, sumac, and black carrot extracts to reduce sodium nitrite, extend shelf life, and inhibit Clostridium perfringens in cooked beef ham. International Journal of Biological Macromolecules, 135841. https://doi.org/10.1016/j.ijbiomac.2024.135841

Sun, M.-J., Chiang, Y.-C., Hou, C.-Y., Ciou, J.-Y. (2024). Effect of Combining Moisture-assisted Drying on Lemon (Citrus limon (L.) Brum.): Physicochemical Properties, Antioxidant Capacities, and Sensory Evaluations. Food and Bioprocess Technology, 1–11. https://doi.org/10.1007/s11947-024-03484-z

Untari, H., Wibawa, H., Susilaningrum, S., Ariyadi, B., Dono, N., Kurniawati, A., Hanim, C. (2024). Effects of mineral premix feed supplement on immunity of laying white leghorn. IOP Conference Series: Earth and Environmental Science. IOP Publishing. pp. 012072. https://doi.org/10.1088/1755-1315/1341/1/012072

Wall, D.C., Malheiros, R.D., Anderson, K., Anthony, N. (2024). Comparing performance, morphological, physical, and chemical properties of eggs produced by 1940 Leghorn or a commercial 2016 Leghorn fed representative diets from 1940 to 2016. Journal of Applied Poultry Research, 33(4), 100463. https://doi.org/10.1016/j.japr.2024.100463

Webster, A. (2000). Behavior of white leghorn laying hens after withdrawal of feed. Poultry Science, 79(2), 192–200. https://doi.org/10.1093/ps/79.2.192

Yin, K., Zhao, X., Liu, Y., Zhu, J., Fei, X. (2024). Aging Increases Global Annual Food Greenhouse Gas Emissions up to 300 Million Tonnes by 2100. Environmental Science & Technology, 58(13), 5784–5795. https://doi.org/10.1021/acs.est.3c06268

Zimmermann, B.F., Gleichenhagen, M. (2011). The effect of ascorbic acid, citric acid and low pH on the extraction of green tea: How to get most out of it. Food chemistry, 124(4), 1543–1548. https://doi.org/10.1016/j.foodchem.2010.08.009