Evaluating the efficacy of an aqueous extract of pomegranate peels in maintaining the quality and stability of frozen goat meat during storage.

Mohammad Ali Al-Samarrai[1] , Yousif Ahmed Naef[2] and Ahmed Ramadhan Muhaimeed[3]

[1]Faculty of Agriculture, Samarra University, Iraq. Email: mohali822022@gmail.com ORCID: https://orcid.org/0208-6606-0007-0009

[2]Faculty of Agriculture, Diyala University, Iraq. Email: yousif.ahmed7755@gmail.com.

[3]Faculty of Agriculture, Tikrit University, Iraq. Email: ahmed.ramadhan@tu.edu.iq ORCID: https://orcid.org/0000-0001-6641-4917

Corresponding Author: Mohammad Ali Al-Samarrai, Email: mohali822022@gmail.com and Yousif Ahmed Naef. Email: yousif.ahmed7755@gmail.com.

Abstract

The purpose of this research was to ascertain whether or not the aqueous extract of pomegranate peels proved to be effective as a natural antioxidant in improving the physicochemical qualities of goat meat that had been maintained under frozen circumstances at a temperature of -18 degrees Celsius for a period of sixty days. The findings of the study revealed that there was a significant reduction ($P < 0.05$) in the lipid oxidation markers, which include the peroxide value, the TBA value, and the free fatty acids, as the extract concentration increased. In T4, the peroxide value was 1.69 meq/kg fat, which was a reduction from 4.09 meq/kg fat in T1. Over the same time period, the TBA value dropped from 1.43 mg MDA/kg fat in T1 to 0.59 mg MDA/kg fat in T4. At the conclusion of the storage period, which lasted for sixty days, the proportion of free fatty acids also decreased, going from 2.23 in T1 to 1.07 in T4. When the extract was applied to the samples, the water-holding capacity was increased, the cooking loss was decreased, and pH stability was found. These findings suggest that the protein structure and the integrity of the muscle tissue were preserved during the preservation process. One possible explanation for these effects is the high content phenolic compounds and flavonoids ,which possess strong antioxidant activity and may help protect meat components from oxidative deterioration during frozen storage ,Therefore ,the aqueous extract of pomegranate peels shows promising potential as a natural preservative for maintaining the physicochemical quality and improving the oxidative stability of frozen goat meat .

Keywords: Pomegranate peel extract, Freezing meat storage. meat products .Antioxidant.

Introduction

Goat meat is one of the red meats with high nutritional value and an important food source in many parts of the world due to its high quality and considerable protein content[1]. To meet the increasing demand for goat meat and reduce product losses, different preservation methods have been adopted. Freezing is one of the most important techniques used for shelf life extension and safety maintenance of the product[2]. Although freezing reduces microbial and enzymatic activities, it cannot prevent physicochemical changes in red meats during prolonged frozen storage. Lipid oxidation is one of the most significant changes that lead to undesirable secondary products such as peroxides, which cause rancid odors and reduce

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nutritional value[3].. Oxidation processes also affect the myoglobin pigment, resulting in a color change from red to brown, which is considered an indicator of reduced meat quality from the consumer's perspective[4].. In addition, the formation and recrystallization of ice crystals during freezing may damage muscle tissue structure, thereby increasing drip loss and decreasing water holding capacity, which negatively affects cooking quality and sensory acceptance. [5]. described that freezing may damage muscle tissue structure by forming ice crystals and its recrystallization during freezing. To address these challenges, attention has shifted toward the use of natural antioxidants as safer alternatives to synthetic antioxidants such as BHT and BHA due to potential health concerns associated with synthetic additives[6]. Pomegranate peels (*Punica granatum* L.) represent one of the most promising sources of phenolic compounds with antioxidant activity that exceeds that of many other fruits[7]. This study was therefore initiated to evaluate the efficacy of aqueous pomegranate peel extract as a natural preservative to minimize such undesirable Physicochemical changes in goat meat during its frozen storage.

Material and Methods

Location of the Study

The investigation was carried out at the labs of the College of Agriculture at the University of Samarra beginning on October 22, 2025, and continuing for a total of ninety one days To prepare pomegranate peel powder, pomegranate peels were obtained from ripe fruit purchased from local markets in Balad District. The peels were separated from the fruit, thoroughly washed, dried, and then ground using an electric grinder (CLA TRONIC, China, model number CT-1288). To obtain the aqueous extract, 1 kg of the powder was soaked in 1 liter of distilled water at a ratio of 1:8 (w/v) for 24 hours. The mixture was then filtered through a very fine sieve and subjected to centrifugation to obtain the aqueous extract of pomegranate peels according to the concentrations used in the experimental treatments shown in Table (1). Goat thigh meat samples were purchased from local markets in Balad District, Salah Al-Din Province. The samples were immersed in the specified extract concentrations shown in Table (1) for 24 hours under refrigeration, then removed, dried They were packed in polyethylene bags, vacuum-sealed, and stored frozen for periods of 30 and 60 days, with the required tests and measurements taken monthly.

Experimental Treatments

The experiment was divided into four experimental coefficients with three iterations, as shown in Table (1)

Table 1. shows the experimental treatments used in the study.

Treatment	Addition rate
1	0% aqueous extract of *Punica granatum*.
2	1% aqueous extract of *Punica granatum*.
3	2% aqueous extract of *Punica granatum*.
4	3% aqueous extract of *Punica granatum*.

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Physical Properties

pH Determination

The pH of minced meat samples was determined according to the method described by [8]. Ten grams of minced meat were homogenized with 100 ml distilled water using a Gerhardt homogenizer (Germany). The mixture was filtered through Whatman filter paper No.1, and the pH was measured after calibrating the pH meter at pH 4 and 7.

Water-Holding Capacity (WHC)

[9]. provided the methodology that was used to determine the water-holding capacity of the material. Over one minute, 50 g of each therapy was homogenized with 50 mL of distilled water. The mixture was centrifuged for 10 minutes at a speed of 5000 revolutions per minute at 4°C. The percentage of WHC was calculated using the following formula: Calculate the weight-to-capacity ratio (WHC) by subtracting the water supplied from the water after centrifugation and dividing the weight of the sample by 100.

Cooking Loss

The approach developed by [10]. was used in order to ascertain the amount of cooking loss. Two samples, each weighing five grams, were randomly sealed in polyethylene bags and then immersed in a water bath at a temperature of seventy degrees Celsius for a period of ninety minutes. Following the completion of the cooking process, the bags were opened, the liquid was extracted, and the samples were stored in the refrigerator at a temperature of 4 degrees Celsius for a period of twenty-four hours. Following the removal of surface moisture caused by filter paper, the samples were next subjected to weighing.

The percentage of cooking loss was determined as follows:

The percentage of cooking loss may be calculated by subtracting the weight before cooking from the weight after cooking for a total of 100.

Chemical Properties

Peroxide Value (PV)

A determination of the peroxide value was made in accordance with [11]. Through the use of a Soxhlet apparatus, two grams of fat that had been extracted were combined with thirty milliliters of a solution that was composed of three parts glacial acetic acid and two parts chloroform. After that, 0.5 milliliters of saturated potassium iodide, thirty milliliters of distilled water, and one milliliter of starch indicator at a concentration of one percent were added.

The mixture was titrated with sodium thiosulfate at a concentration of 0.01 N until the blue tint was no longer present.

For the peroxide value (meq/kg fat), the formula is as follows: ml sodium thiosulfate multiplied by 0.01 multiplied by 1000 divided by the sample weight.

Thiobarbituric Acid Value (TBA)

In accordance with [12]., the TBA value was measured in order to ascertain the level of lipid oxidation. For two minutes, one gram of the material was homogenized with 25 milliliters of a cold solution of twenty percent trichloroacetic acid that had been dissolved in two millimeters of phosphoric acid. It was then diluted to volume with distilled water after being transferred to a volumetric flask with a capacity of fifty milliliters. After half an hour of centrifugation at 3000 revolutions per minute, the mixture was filtered. A mixture of five milliliters of the filtrate and five milliliters of TBA reagent (0.005 M) was prepared. Utilizing a spectrophotometer, absorbance was determined at a wavelength of 530 nm.

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To get the TBA value (mg MDA/kg), multiply A530 by 5.2.

Free Fatty Acids (FFA)

In accordance with [11]. the free fatty acids were analyzed. Extraction of fat was accomplished by the use of the cold extraction technique. The mixture was then titrated with 0.1 N sodium hydroxide until a pink hue was seen. Ten grams of fat were combined with 25 ml of ether and 25 ml of ethanol (95%) and phenolphthalein indicator. Oleic acid was used to represent the proportion of FFA being present.

Statistical Analysis

Statistical Analysis System (SAS, 2012) software was used in order to analyze the data in order to assess the impact of various treatments in accordance with a Completely Randomized Design (CRD). For the purpose of comparing the differences between means, [13]was used.

Results and Discussion

pH Value

A substantial drop ($P < 0.05$) was seen in the pH values of the meat that was treated with the extract during the frozen storage period, as shown by the data provided in Table (2). These results pertain to the impact of the aqueous extract of pomegranate peels on the pH value of frozen goat meat. A cumulative impact of the extract in stabilizing the reactive environment of the meat was shown by the fact that the higher concentration treatments (T3 and T4) recorded the lowest pH values when compared with the control treatment. The acidic character of pomegranate peels, as well as its antioxidant and antibacterial properties, are attributed, in part, to the chemical makeup of the peels, which is abundant in phenolic compounds such as flavonoids and tannins. During storage, these chemicals have a powerful capacity to restrict the development of microorganisms, minimize the breakdown of proteins, and limit the creation of volatile nitrogenous bases, which eventually results in a lowering or stability of pH [7]. [14] reported that the use of pomegranate peel extract, due to its high polyphenol content, helps reduce oxidative reactions and limits the formation of basic compounds such as volatile amines that increase pH values in stored meat. The findings of the present study and those reported by [14]are consistent with each other. In a similar vein, [15]. discovered that increasing the content of pomegranate peel extract resulted in a discernible decrease in the pH values of Karadi ram meat while it was being stored in the refrigerator.

Table 2 The impact that the application of an aqueous extract of pomegranate peel powder has on the pH value of goat meat that has been frozen.

Treatment	Period			Mean
	0	30	60	
T1	6.08^{a} ±0.04	6.05^{a} ±0.04	6.02^{a} ±0.04	6.05^{a}±0.04
T2	6.05^{a} ±0.03	5.98^{b} ±0.03	5.91^{b} ±0.03	5.98^{b}±0.03
T3	6.03^{a} ±0.03	5.90^{c} ±0.03	5.71^{c} ±0.03	5.88^{c}±0.03
T4	6.02^{a} ±0.02	5.82^{d} ±0.02	5.64^{d} ±0.02	5.83^{d}±0. 02

The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

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Water-Holding Capacity (WHC)

Before the application of storage conditions and treatment with pomegranate peel extract, the water-holding capacity values of goat meat at day zero (the beginning of the experiment) revealed no significant variations across all treatments. This indicates that the samples were uniform prior to the administration of these conditions. According to the findings shown in Table 3, it can be seen that the use of aqueous pomegranate peel extract resulted in a noteworthy enhancement ($P < 0.05$) in the water-holding capacity of frozen goat meat, namely in treatments T3 and T4, when compared to the control treatment (T1) over the storage periods of 0 days, 30 days, and 60 days. The control treatment showed a progressive decline in WHC, which went from 60.5% at day 0 to 55.8% and 52.3% at 30 and 60 days, respectively. This decrease occurred throughout the course of the study. The physicochemical changes that are brought about by freezing may provide an explanation for this previously anticipated decline. During the process of gradual freezing, huge ice crystals are generated both within and outside of the muscle cells. These ice crystals ultimately cause the cellular membranes to break when the muscle cells eventually thaw. As a consequence of this, cells lose their capability to reabsorb the water that has been released, which leads to an increase in the amount of water that is lost by drips and a decrease in the capacity to store water [16].In contrast, treatment T3 maintained the highest WHC levels, with 62.2% and 61.4% after 30 and 60 days, respectively. These values were recorded at the end of the study. It is possible that the protective roles played by the phenolic chemicals that are found in the peels, notably tannins, are responsible for the improvement that was seen in treatments that were supplemented with pomegranate peel extract. Consequently, the structural integrity of proteins that are important for water binding is preserved as a result of the actions of these chemicals, which function as antioxidants and scavenge free radicals while also reducing oxidative stress [7] Furthermore, these phenolic compounds interact with muscle proteins, primarily myosin, via the formation of hydrogen bonds and the formation of hydrophobic contacts and interactions with polar groups. As a result of this interaction, the connection of the protein network is improved, as is its ability to store water inside its structure. As a result, the damage caused by ice crystals is reduced, and the cell is preserved [17].. [18]. found that soaking sheep meat in pomegranate peel extract greatly enhanced the weight-to-height ratio (WHC) of the meat when it was being stored in the freezer. These findings are in agreement with their findings. A similar finding was made by [19]., who said that the incorporation of varying concentrations of aqueous pomegranate peel extract into chicken meat resulted in a considerable improvement in the meat's physical qualities, including its ability to retain water while being frozen.

Table 3. An aqueous extract of pomegranate peel powder was used to determine the effect that it had on the WHC value of frozen goat meat.

Treatment	Period			Mean
	0	30	60	
T1	$60.5^{a} \pm 1.31$	$55.8^{d} \pm 1.20$	$52.3^{d} \pm 1.20$	$56.2^{d} \pm 1.23$
T2	$60.2^{a} \pm 1.28$	$58.3^{c} \pm 1.13$	$55.6^{c} \pm 1.11$	$58.03^{c} \pm 1.17$
T3	$60.0^{a} \pm 1.24$	$62.2^{a} \pm 1.04$	$61.4^{a} \pm 1.00$	$61.2^{a} \pm 1.09$
T4	$59.8^{a} \pm 1.19$	$61.6^{b} \pm 1.03$	$60.5^{b} \pm 1.03$	$60.6^{b} \pm 1.08$

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The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

Cooking Loss

The data presented in Table (4) clearly indicate that the addition of aqueous pomegranate peel extract to frozen goat meat significantly reduced cooking loss ($P \leq 0.05$). In T1, the cooking loss increased gradually with storage time, from 28.0% at day 0 to 34.5% at day 60. This increase can be attributed to the progressive effect of freezing regarding structural damage to muscle fibers and cell membrane rupture by ice crystal formation and recrystallization. All these ultimately increase meat juice release and loss of soluble proteins during heat treatment. On the other hand, the extract supplemented treatments (T2, T3, and T4) showed a regular and significant decrease in cooking loss as the extract concentration increased. The lowest cooking loss values during storage were obtained with treatment T4.This reduction can be attributed to the phenolic compounds and tannins present in pomegranate peels, which enhance moisture retention and reduce the loss of water and proteins during cooking by protecting proteins and lipids from oxidative damage.

This result is similar to what was found by [20] who observed that quality was improved and cooking loss reduced in meat products by integrating pomegranate peel extract due to its antioxidant activity. [21]also found pomegranate peel extract for the same reason an efficient natural additive in fresh meat preservations by prolonging shelf life and minimizing oxidative losses during cooking.

Table 4.) Effect of using an aqueous extract of pomegranate peel powder on the WHC value of frozen goat meat.

Treatment	Period			Mean
	0	30	60	
T1	28.0^{a} ±0.9	31.8^{a} ±1.0	34.5^{a} ±1.0	31.4^{a} ±1.0
T2	27.8^{a} ±0.8	29.3^{b} ±0.9	30.2^{b} ±0.9	29.1^{b} ±0.9
T3	27.4^{a} ±0.8	26.5^{c} ±0.8	25.8^{c} ±0.8	26.6^{c} ±0.8
T4	27.1^{a} ±0.8	24.5^{d} ±0.7	23.4^{d} ±0.7	25.0^{d} ±0.7

The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

Peroxide Value (PV)

Table 5 shows that the peroxide value of frozen goat meat was significantly reduced ($P < 0.05$) when aqueous pomegranate peel extract was used. This reduction was compared to the control treatment (T1). In general, all treatments exhibited an increase in PV values as the storage period continued; however, the rate of increase was slower for higher extract concentrations. There was a marked increase in PV from 0.85 meq/kg fat on day 0 to 4.09 meq/kg fat on day 60 in the control (T1). At day 60, the increments were lesser for the samples that had been treated with extract (T2, T3, and

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T4). These samples reached 2.94, 2.12, and 1.69 meq/kg fat, respectively. [22]also found that the use of natural extracts could lower the peroxide value of meat and meat products. Further evidence of the gradual increase in PV during storage. Lipid oxidation is an accumulative process; it continues to increase over time even when the material is frozen, due to the continued formation of hydroperoxides as primary oxidation products. It may be assumed that lower PV values in the extract treated samples are due to the high phenolic compound content in pomegranate peels. Phenolic compounds are very strong antioxidants; they can trap free radicals and chelate transition metals that catalyze oxidation reactions [23].According to [24], who recently reported that polyphenol-rich extracts obtained from agro-byproducts efficiently inhibit hydroperoxide formation and enhance the shelf life of red meat, these results are similar to those of [24]

Table 5. With regard to the peroxide value (PV) of frozen goat meat, the following table presents the results of utilizing an aqueous extract of pomegranate peel powder.

Treatment	Period			Mean
	0	30	60	
T1	0.85^{a} ±0.03	2.40^{a} ±0.08	4.09^{a} ±0.12	2.45^{a} ±0.10
T2	0.83^{a} ±0.04	1.85^{b} ±0.06	2.94^{b} ±0.10	1.87^{b} ±0.06
T3	0.81^{a} ±0.03	1.42^{c} ±0.05	2.12^{c} ±0.08	1.45^{c} ±0.05
T4	0.78^{a} ±0.03	1.15^{d} ±0.04	1.69^{d} ±0.06	1.20^{d} ±0.04

The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

Thiobarbituric Acid Value (TBA)

Table 6 proved that aqueous pomegranate peel extract worked as a good natural source of antioxidants in frozen goat meat. The same trend was recorded for its ability to inhibit lipid oxidation in frozen goat meat. Lipid oxidation was determined using the thiobarbituric acid value (TBA) which is an indicator of the amount of malondialdehyde (MDA) formed through the degradation of unsaturated fatty acids; it is an important indicator of oxidative deterioration in meat [25]. The highest TBA values ($P \leq 0.05$) were observed in the control treatment (T1) throughout the storage period; these values increased from 0.27 mg MDA/kg at day 0 to 1.43 mg MDA/kg at day 60. This increase reflects the uninterrupted lipid oxidation process in frozen storage until the development of secondary products, which are undesired flavor compounds and off-odors [26]. All treatments with pomegranate peel extract (T2, T3, and T4) significantly reduced TBA values compared with the control, showing that all of them had the ability to delay or inhibit the oxidative reactions. The average TBA values for treatments T2, T3, and T4 were 0.62, 0.52, and 0.40

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mg MDA/kg, respectively. These results are similar to those of [27], who found that TBA values were significantly lower during storage in treatments with pomegranate peel extract than in the control treatment.

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Table 6. With regard to the Thiobarbituric Acid Value (TBA) of frozen goat meat, the following table presents the results of utilizing an aqueous extract of pomegranate peel powder.

Treatment	Period			Mean
	0	30	60	
T1	0.27^{a} ±0.01	0.91^{a} ±0.04	1.43^{a} ±0.07	0.87^{a} ±0.03
T2	0.25^{a} ±0.01	0.65^{b} ±0.03	0.95^{b} ±0.05	0.62^{b} ±0.03
T3	0.24^{a} ±0.01	0.53^{c} ±0.02	0.78^{c} ±0.04	0.52^{c} ±0.02
T4	0.22^{a} ±0.01	0.40^{d} ±0.02	0.59^{d} ±0.03	0.40^{d} ±0.02

The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

Free Fatty Acids (FFA)

Data presented in Table (7) show a significant increase ($P < 0.05$) in free fatty acid (FFA) levels in all treatments over the sixty-day frozen storage period. However, FFA values were highest in the control treatment (T1) compared to the other treatments; at increasing extract concentrations, there was a steady decrease in FFA generation by the pomegranate peel extracts (T2, T3, and T4 It rose from 0.45 on day 0 to 2.23% on day 60 in the control treatment. At the end of the storage period, the lowest value was recorded in treatment T4 at 1.07%. Pomegranate peels have high phenolic compound and flavonoid concentrations that scavenge free radicals and break the chain events responsible for lipid oxidation [25]. This inhibitory effect may be related to the high concentration of these compounds in pomegranate peels. In a related development, [28] found that plant extracts high in polyphenols inhibit the formation of free fatty acids in refrigerated or frozen meat. They achieved this by reducing overall oxidative stress while at the same time preserving membrane phospholipids. These results are in line with the results they presented.

Table 7. With regard to the Free Fatty Acids (FFA) of frozen goat meat, the following table presents the results of utilizing an aqueous extract of pomegranate peel powder.

Treatment	Period			Mean
	0	30	60	
T1	0.45^{a} ±0.02	1.21^{a} ±0.06	2.23^{a} ±0.09	1.30^{a} ±0.09
T2	0.44^{a} ±0.02	0.91^{b} ±0.05	1.61^{b} ±0.07	0.99^{b} ±0.07
T3	0.42^{a} ±0.01	0.82^{c} ±0.04	1.29^{c} ±0.06	0.84^{c} ±0.06
T4	0.41^{a} ±0.01	0.70^{d} ±0.02	1.07^{d} ±0.05	0.73^{d} ±0.05

The means of each group followed by a different letter indicate significant differences between them at the probability level ($P \leq 0.05$) according to Duncan's multiple range test

Conclusion

The results of this study add to the body of evidence supporting the use of liquid pomegranate peel extract to improve some physical and chemical properties of frozen goat meat. It was necessary to improve the qualities that would help stop lipid

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oxidation, lower the production of free fatty acids, keep the pH level stable while the product was being stored, and make it better at holding water while also lowering the amount of water lost during cooking. It was mostly found that the health benefits came from the high amounts of phenolic chemicals and antioxidants that were found in pomegranate leaves. With this information, we can say that the water-based extract of pomegranate leaves might be a great natural source of an antioxidant that can be used to make meat products better in terms of their general quality, shelf life, and resistance to oxidation.

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