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Article

The Effect of Adding Cinnamon, Rosemary, and Thyme Oils on the Chemical Properties of Minced Local Lamb Meat During Frozen Storage

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Abstract: This experiment was conducted in the laboratory of the Animal Production Department, College of Agriculture, University of Kirkuk, for a period of 60 days from 22/10/2025 to 21/12/2025. The aim was to study the effect of adding cinnamon, rosemary, and thyme oils on the chemical properties of minced local lamb meat during frozen storage. The thigh meat taken from local lambs was minced, the treatments were added, and the mixture was homogenized. The samples were distributed as follows: the control treatment without any addition, with meat stored for periods of 1, 30, and 60 days. Lambs fed on thyme powder 6g/kg of feed, lambs fed on rosemary powder 6g/kg of feed, lambs fed on cinnamon powder 6g/kg of feed, lambs fed on thyme powder 6g/kg of feed, and after slaughter, thyme oil was added at 0.06ml/kg of meat; lambs fed on rosemary powder 6g/kg of feed, and after slaughter, rosemary oil was added at 0.06ml/kg of meat; lambs fed on cinnamon powder 6g/kg of feed, and after slaughter, cinnamon oil was added at 0.06ml/kg of meat. With three replicates for each treatment, the transactions to which oils were added showed a decrease in moisture percentages. The first storage period recorded the highest percentage and a relative decrease in protein, while the second storage period was the best. There was an increase in ash and fat percentages for the treatments used in the study throughout the storage periods. From this, we can conclude that the treatments used had a clear effect on preserving the chemical composition of lamb meat, and that freezing storage played a role in maintaining the chemical qualities of the meat.

Keywords: Cinnamon, rosemary, thyme, lamb meat, freezing.

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Introduction

Meat spoilage during storage is a major concern for the meat industry [1]. Meat undergoes deterioration during processing and storage primarily due to lipid and protein oxidation, and enzymatic breakdown [2]. Various methods have been used to extend the shelf life of meat and improve its quality. The use of proper packaging and storage conditions can play a crucial role in protecting meat from spoilage caused by internal and external factors during storage [3]. Previous studies have shown that essential oils extracted from herbs and spices, when used as seasonings in meat products,

exhibit varying levels of antimicrobial activity against Salmonella, L. monocytogenes, E. coli, and S. aureus under laboratory conditions [4]. In this regard, we are witnessing today a clear change in consumer behavior, as they tend to be more concerned about potential health risks associated with artificial additives, which stimulates an industrial shift towards natural alternatives. To support this phenomenon, many studies have investigated plant-derived phenolic molecules and other compounds that can affect food preservation and have significant health benefits, demonstrating this shift to natural preservatives. In this context, essential oils derived from plants are explored for their functional properties, as they offer a potential alternative to artificial preservatives and are considered environmentally friendly. Essential oils are generally classified as safe and biologically non-hazardous by the global Food and Drug Administration [5], [6]. These natural additives have proven their ability and effectiveness in reducing oxidative rancidity effects, delaying the development of undesirable flavors, and improving the stability and color of meat pigments. Therefore, researchers' interest in studying the properties of these natural food additives has significantly increased [7]. Cinnamon is considered one of the important medicinal plants because it contains some substances with antimicrobial activity, such as essential oils, eugenol, and cinnamyl acetate, as well as tannins and mucilaginous substances [8]. The oil and extract of the cinnamon plant are also considered very important for their use in many pharmaceutical and medicinal products due to their broad effect against many types of bacteria and molds [9]. Rosemary (Rosmarinus officinalis) is considered a source of dietary polyphenols, as it contains antioxidant and antimicrobial potential for meat production. Rosemary products include leaves, essential oils, distilled leaves, and extracts, whose polyphenol content can vary significantly depending on unspecified variations, climatic conditions, and harvest time [10]-[12]. Thyme oil also has many medicinal benefits as it prevents inflammations, protects against heart diseases, prevents cancers, improves the body's defense mechanisms, and is used as an antioxidant and has importance in resisting fungi and germs [13].

This oil is also considered among the top ten essential oils as it is antibacterial, antifungal, antioxidant, and a natural food preservative [14].

Materials and Methods

This Source of Meat:

Four halves of local lamb carcasses were purchased from a researcher at the College of Agriculture. Three of the halves were treated by adding (thyme, rosemary, and cinnamon) in powdered form, while one half was used as a control without any additives. The required samples were taken, packed in special polyethylene bags that were air-evacuated, sterilized, and tightly sealed, then placed in a cooler until they reached the laboratory. They were stored in a freezer designated for storage until laboratory analyses were conducted.

Source of Oils:

The vegetable oils used in this study were purchased from a medicinal herb shop in the market of Kirkuk City, Iraq. The oils were of the type 'Emad' with a capacity of 30 ml per bottle. The oils were added to the meat samples using a precise sterilized syringe similar to an insulin syringe, where very small amounts were injected into the muscle tissue to ensure a homogeneous distribution of the oils within the samples.

Meat Sample Preparation:

After slaughter, the thigh muscle (Semimembranosus) was taken from the four halves of the carcasses and cut with a sharp knife; fat tissues were removed from it. Seven samples were taken, and each sample was divided into two parts. The first part was minced using an electric meat grinder with a 7 mm sieve diameter, and the second part was cut into small cube-shaped pieces. Then the meat samples were distributed according to the number of required treatments.

Negative control: meat without any addition, stored for 1, 30, and 60 days.

1. Meat of lambs fed with thyme powder 6 g/kg feed, with meat stored for 1, 30, and 60 days.
2. Meat of lambs fed with rosemary powder 6 g/kg feed, with meat stored for 1, 30, and 60 days.

3. Meat of lambs fed with cinnamon powder 6 g/kg feed, with meat stored for 1, 30, and 60 days.
4. Meat of lambs fed with thyme powder 6 g/kg feed, and after slaughter, thyme oil was added 0.06 ml/kg meat, with meat stored for 1, 30, and 60 days.
5. Meat of lambs fed with rosemary powder 6 g/kg feed, and after slaughter, rosemary oil was added 0.06 ml/kg meat, with meat stored for 1, 30, and 60 days.
6. Meat of lambs fed with powder 6 g/kg feed, and after slaughter, cinnamon oil 0.06 ml/kg meat was added, with storage of meat for 1, 30, and 60 days.

Moisture Content Determination:

The moisture content was determined according to [15] of the United States, where 5 g of the sample was placed in a pre-weighed porcelain crucible, and the crucible with the sample was placed in an electric oven at 105 °C for 24 hours. Afterwards, the crucibles were removed, weighed, and the percentage of moisture was calculated by subtracting the dry matter percentage from one hundred.

Protein Content Determination:

The protein content was estimated using the Semi-micro Kjeldahl method [15]. by taking 1 g of the sample and placing it in a digestion tube with the addition of 1 g of the catalyst CuSO4. Then 5 ml of concentrated sulfuric acid (98%) was added, and the digestion tubes were placed on a heater for the purpose of digesting the sample. After the mixture became clear, the samples were cooled, and then 25 ml of distilled water and 10 ml of sodium hydroxide were added. The resulting solution was distilled, and the ammonia gas was collected in 25 ml of 2% boric acid solution. The samples were titrated with hydrochloric acid (0.01 N), and the protein content was calculated using the following equation:

$$\% \text{ Protein} = \frac{\text{Volume of HCl acid} \times \text{normality (0.01)} \times 0.014 \times 6.25}{\text{Model weight (g)}} \times 100$$

Fat (Oil) Content Estimation:

Extraction was carried out according to [15] using a fat extraction device (Soxhlet), where 2 g of the sample were placed in the sample holder, and extraction was performed with diethyl ether at 30°C for 10 hours to protect the oils from damage due to high heat. After extraction, the fat was weighed and its percentage was calculated.

Oil weight

% Oil = (Weight of Oil / Weight of Sample) × 100

Ash Content Estimation:

After determining the weight of the dry matter as mentioned above, the porcelain crucibles containing the dry sample were placed in a muffle furnace at 550°C for six hours. After cooling, they were weighed, and the ash percentage was calculated [15].

Statistical Analysis

A factorial experiment (3x7) was applied using a completely randomized design (CRD) in analyzing the experimental data to study the effect of treatments and periods and their interaction on the studied traits. The significant differences between means were compared using [16] multiple range test. The SAS was used for the statistical analysis of the data according to the following mathematical model [17]:

Mathematical model:

$Yijk = M + Ti + Pj + TP(ij) + eijk$

Yijk = the jth observed value for the ith treatment

M = the overall mean of the trait

Ti = effect of treatments

Pj = effect of periods represented by three periods (1, 30, and 60)

TP(ij) = interaction between the effect of treatments and periods

eijk = random error, normally distributed with a mean equal to zero and variance equal to σ^2

Results and Discussion

Moisture Content Estimation

From Table No. (1), the effect of adding the treatments (thyme, rosemary, and cinnamon) and the storage periods by freezing (1, 30, 60 days) and their interaction on the moisture content in lamb meat is shown. It is evident that in studying the effect of the experimental treatments, the second treatment significantly outperformed the other treatments, recording the highest value among the treatments at 73.86%, while the seventh treatment recorded the lowest average moisture content at 72.58% at a significance level of (P≤0.05). As for studying the effect of the periods, the first period of the experiment recorded the highest significant value at 73.97%, while the third period, day 60, recorded the lowest significant value among the periods, with a moisture content of 72.38%. While the results showed that the interaction between treatments and storage periods in the table displayed significant differences, where the first treatment in the first period outperformed the other treatments with a moisture content of 74.61%, we notice a significant decrease in the same treatment during the 60th day of storage compared to the other treatments and periods, with a moisture content of 71.79%. This decrease in moisture content may be due to the evaporation of water from the surface of the meat and the breakdown of meat proteins by enzymes that act to break the bonds that link protein to water, thereby reducing the meat's ability to retain water and making it prone to evaporation [18]. This agrees with the study by Al-Ali et al. on the effect of storage period on different types of meat, including cows, buffalo, and sheep, stored for 1, 2, 3, and 4 months by freezing, which showed a significant decrease (P≤0.05) in moisture content [19]. Additionally, Abdullah et al. in a study where they added cinnamon extract at concentrations of 2% and 4% using spraying and dipping methods to minced meat taken from the thigh muscle of one-year-old Awassi lambs, observed a significant decrease (P≤0.05) in moisture content (71.85%) for the spray treatment at a 2% concentration compared to the control, which gave the highest moisture content (73.20%) [20]. This differs from what Al-Birkhedri indicated in his study, where a significant increase (P≤0.05) in moisture content was observed when adding cinnamon essential extract, reaching 66.43% and 66.73% for treatments T6 and T7, respectively, compared to the control, which recorded 65.95% for minced veal stored frozen for periods of 1, 30, and 60 days [21]. This also aligns with previous studies indicating a decrease in moisture content and an increase in dry matter as storage time progresses. It is consistent with the results of a previous study by Al-Salmani, where adding cinnamon and nano-turmeric extracts to minced beef led to a decrease in moisture content over the frozen storage period, with the first month recording 73.88% and then decreasing to 71.16% at the end of 3 months of storage [22]. Al-Birkhedri's study using aqueous and essential cinnamon extract added to minced veal resulted in a decrease in moisture content over storage time, recording 70% on the first day and then decreasing to 63.80% by the third period (60 days) [21].

Table 1. shows the effect of the treatments (thyme, rosemary, and cinnamon).

Treatment	Storage periods by freezing (day)			Average effect of Treatment
	1	30	60	
T1	0.044±74.61 a	0.017±74.54 B	0.01±71.79 i	0.463±73.64 d
T2	0.022±74.48 c	0.003±74.48 C	0.017±72.62 e	0.310± 73.86 a
T3	0.013±74.49 bc	0.009±74.46 C	0.017±72.54 g	0.323±73.83 b
T4	0.021±74.46 c	0.009±74.45 C	0.009±72.30 h	0.358±73.73 c
T5	0.009±74.47 c	0.003±74.46 C	0.015±72.33 h	0.355± 73.75 c
T6	0.015±72.68 d	0.009±72.67 D	0.013±72.55 g	0.022±72.63 e

T7	0.020±72.61 e	0.003±72.60 Ef	0.012±72.56 fg	0.010± 72.58 f
Average effect of periods	0.188±73.97 a	0.186±73.95 B	0.059±72.38 c	0.129±73.43

storage periods by freezing (1, 30, 60 days), and their interaction on the moisture content in lamb meat (mean ± standard error).Means carrying different letters differ significantly at P≤0.05 among them. T1 Negative control: meat without any additives, with storage of meat for 1, 30, and 60 days. T2 Lamb meat fed with thyme powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T3 Lamb meat fed with rosemary powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T4 Lamb meat fed with cinnamon powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T5 Lamb meat fed with thyme powder 6 g/kg feed, and after slaughter, thyme oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T6 Lamb meat fed with rosemary powder 6 g/kg feed, and after slaughter, rosemary oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T7 Lamb meat fed with cinnamon powder 6 g/kg feed, and after slaughter, cinnamon oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days.

Protein Percentage Estimation

From Table No. (2), the effect of adding treatments (thyme, rosemary, and cinnamon) and freezing storage periods (1, 30, 60 days) and their interaction on the protein content in lamb meat is shown. It appears that in studying the effect of the experimental treatments, the first and third treatments were significantly superior to the other treatments, recording the highest value among the treatments, which reached 18.32% for both treatments, while the seventh treatment recorded the lowest protein average at 18.08% at a significance level (P≤0.05). As for studying the effect of storage periods, the second period of the experiment recorded the highest significant value of 18.28%, while the third period, day 60, recorded the lowest significant value among the periods, with a protein content of 18.2%. While the results of the interaction between treatments and storage periods in the table showed significant differences, the second treatment in the second period outperformed the other treatments, with a protein percentage of 18.38%, whereas the seventh treatment in the first period (day 1) of storage recorded the lowest significant difference among the other treatments and periods, with a protein percentage of 18.07%. The gradual decrease in protein percentage with the progression of storage time can be explained by changes in the structural composition of the protein due to the formation of ice crystals during freezing, which leads to partial disintegration of muscle fibers and the loss of some soluble nitrogen compounds with the meat juice upon thawing. These results are consistent with what indicated, stating that the protein content in meat is affected by storage conditions and storage duration [23].

On the other hand, the results differ from what mentioned in his study on the effect of adding cinnamon powder and its extracts to minced veal stored by freezing, where the protein percentage increased using cinnamon and rose during the third storage period [21]. It also differs from what obtained in results using different ratios of cinnamon and thyme oils and their effects on locally frozen veal, as the results indicated an increase in protein percentage with the use of treatments and its rise in the third storage period (40 days) [24].

Table 2. shows the effect of the treatments (thyme, rosemary, and cinnamon), storage periods by freezing (1, 30, 60 days), and their interaction on the protien content in lamb meat (mean ± standard error).

Treatment	**Storage periods by freezing (day)**			**Average effect of Treatment**
	1	**30**	**60**	
T1	0.025±18.37 ab	0.007±18.37 ab	0.017±18.23 gf	18.32±0.025 A
T2	0.013±18.35 a-d	0.009±18.38 a	0.009±18.21 g	18.31±0.025 ab

T3	0.012±18.33 cd	0.003±18.36 abc	0.009±18.27 e	18.32±0.015 A
T4	0.012±18.32 d	0.003±18.32 d	0.003±18.25 ef	18.29±0.013 B
T5	0.012±18.34 bcd	0.012±18.35 a-d	±18.260.009 e	18.31±0.014 ab
T6	18.1±0.012 hi	18.12±0.006 h	18.09±0.009 hi	18.1±0.006 C
T7	0.001±18.07 i	0.007±18.09 hi	0.003±18.09 hi	18.08±0.005 D
Average effect of periods	18.27±0.026 b	18.28±0.025 a	18.2±0.017 c	18.25±0.014

storage periods by freezing (1, 30, 60 days), and their interaction on the moisture content in lamb meat (mean ± standard error).Means carrying different letters differ significantly at P≤0.05 among them. T1 Negative control: meat without any additives, with storage of meat for 1, 30, and 60 days. T2 Lamb meat fed with thyme powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T3 Lamb meat fed with rosemary powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T4 Lamb meat fed with cinnamon powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T5 Lamb meat fed with thyme powder 6 g/kg feed, and after slaughter, thyme oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T6 Lamb meat fed with rosemary powder 6 g/kg feed, and after slaughter, rosemary oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T7 Lamb meat fed with cinnamon powder 6 g/kg feed, and after slaughter, cinnamon oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days.

Fat Content Estimation

From Table No. (3), the effect of adding treatments (thyme, rosemary, and cinnamon) and freezing storage periods (1, 30, 60 days) and their interaction on the fat content in lamb meat is shown. It appears that, in the case of studying the effect of experimental treatments, treatment seven recorded a significant superiority, reaching 8.1%, followed by treatment six at 8.03% at a significance level of (P≤0.05). Meanwhile, treatment one recorded the lowest significant difference among the treatments, reaching 5.28% at a significance level of (P≤0.05). In the case of studying the effect of periods, the first and second periods of the experiment recorded the highest significant values, reaching 6.29% and 6.28%, respectively, while the third period (day 60) recorded the lowest significant value among the periods, with the fat content reaching 6.13%. Meanwhile, the results of the interaction between the effect of treatments and storage periods in the table showed significant differences. Treatment seven during the first and second periods outperformed the other treatments, with a fat content of 8.13% for both periods, while treatment one during the third period (day 60) of storage recorded the lowest significant difference among the treatments and periods, with a fat content of 5.06%. The addition of natural oils, including thyme oil, rosemary oil, and cinnamon, to minced lamb meat stored by freezing resulted in a significant increase (P≤0.05) in fat content for all treatments compared to the control treatment. This increase in fat content in the treatments with added natural substances is attributed to the ability of these oils to protect fats from oxidation and degradation by preventing the formation of free radicals and reactive oxygen species [25]. This is consistent with the study by Al-Salmani, where the addition of nano-extracts of cinnamon and turmeric to minced beef during the freezing storage period led to a significant increase (P≤0.05) in fat content compared to the control treatment [22]. As for the effect of the storage period, it was found that there is a significant effect (P≤0.05) on fat percentage. The first period recorded the highest fat percentage on day (1), reaching 6.29%, then it started to decrease as the storage period progressed, reaching its lowest level in the third period (60 days), which was 6.13%. This differs from what was found by Al-Salmani [22]. When nano cinnamon and turmeric extracts were added to frozen beef, a significant effect on fat percentage was observed. The lowest percentage was

recorded during the first month, reaching 5.95%, then it began to increase as storage progressed until it reached its highest level in the third period (3 months), which was 7.37%. This also differs from Al-Bir Khadri, who found that when aqueous and oil extracts of cinnamon were added to minced veal stored by freezing, the lowest percentage was during the first storage period (1 day) at 6.13%, then it began to increase until it reached its highest percentage during the third storage period (60 days), which was 8.11% [21].

Table 3. shows the effect of the treatments (thyme, rosemary, and cinnamon), storage periods by freezing (1, 30, 60 days), and their interaction on the fat content in lamb meat (mean ± standard error).

Treatment	Storage periods by freezing (day)			Average effect of Treatment
	1	30	60	
T1	0.027±5.41 ij	0.003±5.37 jk	0.026±5.06 L	0.057±5.28 G
T2	0.020±5.54 gh	0.010±5.54 gh	0.007±5.34 k	0.035±5.47 F
T3	0.015±5.56 gh	0.009±5.56 gh	0.015±5.43 i	0.023±5.52 E
T4	0.015±5.63 de	0.009±5.61 ef	0.015±5.52 h	0.018±5.59 D
T5	0.012±5.66 d	0.009±5.65 ed	0.009±5.57 fg	0.015±5.63 C
T6	0.022±8.08 b	0.003±8.08 b	0.015±7.93 c	0.025±8.03 B
T7	0.006±8.13 a	0.003±8.13 a	0.015±8.04 b	0.015±8.1 A
Average effect of periods	0.257±6.29 a	0.258±6.28 a	0.265±6.13 b	0.148±6.23

storage periods by freezing (1, 30, 60 days), and their interaction on the moisture content in lamb meat (mean ± standard error).Means carrying different letters differ significantly at P≤0.05 among them. T1 Negative control: meat without any additives, with storage of meat for 1, 30, and 60 days. T2 Lamb meat fed with thyme powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T3 Lamb meat fed with rosemary powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T4 Lamb meat fed with cinnamon powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T5 Lamb meat fed with thyme powder 6 g/kg feed, and after slaughter, thyme oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T6 Lamb meat fed with rosemary powder 6 g/kg feed, and after slaughter, rosemary oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T7 Lamb meat fed with cinnamon powder 6 g/kg feed, and after slaughter, cinnamon oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days.

Ash Content Estimation

From Table No. (4), the effect of adding treatments (thyme, rosemary, and cinnamon) and freezing storage periods (1, 30, 60 days) and their interaction on the ash content in lamb meat is shown. In the case of studying the effect of experimental treatments, the sixth and seventh treatments significantly outperformed the other treatments, recording the highest ash content among the treatments at 1.15% for both treatments, while the first treatment recorded the lowest average ash content, which was 1.12%, at a significance level of (P≤0.05). As for studying the effect of the periods, the third period of the experiment recorded the highest significant value compared to the first and second periods, which reached 1.16%.

Meanwhile, the results of the interaction between the effect of treatments and storage periods in the table showed significant differences, where the first treatment in the third period (day 60) outperformed the other treatments, with ash content reaching 1.17%, while the same treatment in the first storage period showed a significant decrease compared to the other treatments and periods, with ash content at 1.08%. The significant increase in ash content with extended storage duration is due to the decrease in moisture content in the meat. The study also indicated that the chemical composition of meat is affected by preservation and storage processes, which is reflected in the distribution of chemical components [23]. These results differ from the study by Al-Kanani [24], which showed the average effects of adding cinnamon oil, thyme oil, and their mixture to minced veal stored by freezing. Significant differences were recorded between the addition treatments and the control treatment. The control treatment recorded the highest ash content at 0.92%, while the treatment with the lowest addition recorded 0.88%. Natural additives from cinnamon oil, thyme oil, and the mixture added to minced veal stored by freezing recorded significant differences ($P \leq 0.05$) in ash content compared to the control treatment. Al-Birkhdari also noted that adding aqueous and ethanolic extracts of cinnamon to minced and frozen veal resulted in a significant decrease ($P \leq 0.05$) in ash content compared to the control treatment [21]. This was confirmed by Al-Salmani [22], whose study showed the presence of significant differences in the ash content for treatments to which nano-cinnamon extracts at different concentrations were added to minced beef during the freezing storage period compared to the control treatment.

As for the study on the effect of storage periods, the results were consistent with the study by Al-Kanani [24], which found a significant increase ($P \leq 0.05$) in ash content as the storage period progressed. The first period recorded the lowest ash content at 0.87%, then it started to increase with the advancement of the storage period until it reached its highest level during the third period, which was 40 days, reaching 0.93%. This is natural because, as the storage period advances, moisture decreases and dry matter, which includes ash, increases.

Table 4. shows the effect of the treatments (thyme, rosemary, and cinnamon), storage periods by freezing (1, 30, 60 days), and their interaction on the ash content in lamb meat (mean ± standard error).

Treatment	Storage periods by freezing (day)			Average effect of Treatment
	1	30	60	
T1	0.009±1.08 e	0.009±1.09 Ed	0.006±1.17 a	0.013± 1.12 c
T2	0.003±1.113 c	0.003±1.12 C	0.01±1.15 ab	0.007 ±1.13 b
T3	0.003±1.10 cd	0.003±1.11 Cd	0.009±1.16 ab	0.008 ±1.12 cb
T4	0.000±1.11 cd	0.006±1.11 cd	0.007±1.16 ab	0.008 ±1.13 cb
T5	0.006±1.11 cd	0.003±1.12 c	0.006±1.15 b	0.006 ±1.13 cb
T6	0.009±1.14 b	0.003±1.14 b	0.000±1.16 ab	0.004 ±1.15 a
T7	0.003±1.15 b	0.006±1.15 b	0.000±1.16 ab	0.002 ±1.15 a
Average effect of periods	0.048±1.11 b	0.044±1.12 b	0.021±1.16 a	0.033±1.13

storage periods by freezing (1, 30, 60 days), and their interaction on the moisture content in lamb meat (mean ± standard error).Means carrying different letters differ significantly at P≤0.05 among them. T1 Negative control: meat without any additives, with storage of meat for 1, 30, and 60 days. T2 Lamb meat fed with thyme powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T3 Lamb meat fed with rosemary powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T4 Lamb meat fed with cinnamon powder 6 g/kg feed, with storage of meat for 1, 30, and 60 days. T5 Lamb meat fed with thyme powder 6 g/kg feed, and after slaughter, thyme oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T6 Lamb meat fed with rosemary powder 6 g/kg feed, and after slaughter, rosemary oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days. T7 Lamb meat fed with cinnamon powder 6 g/kg feed, and after slaughter, cinnamon oil was added 0.06 ml/kg meat, with storage of meat for 1, 30, and 60 days.

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